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THE IMPACT OF CIRCULAR ECONOMY FACTORS ON ECONOMIC GROWTH IN ASEAN COUNTRIES: AN APPROACH USING THE FGLS MODEL

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ABSTRACT

This study assesses the impact of circular economic factors on economic growth in six ASEAN countries during the 2010 - 2023 period, based on a publicly available database from official sources, the World Bank, UNCTAD, and IEA. According to the theoretical framework of the circular economy and green growth, the study emphasizes the role of resource optimization, green finance, reuse and recycling, and emission reduction in sustainable development. This study applies the feasible generalized least squares (FGLS) regression method to address heteroskedasticity, autocorrelation, and cross-sectional dependence, thereby providing more accurate estimates of the relationships among variables. The results indicate that green investment and urbanization have positive impacts on economic growth; these factors act as key drivers of sustainable economic growth. Renewable energy consumption and natural resource exploitation have negative effects on economic growth; these factors illustrate high initial investment costs, technological constraints, and uneven resource-use efficiency across ASEAN countries. Greenhouse gas emissions continue to exhibit a positive correlation with growth, implying that the region still remains in the early stage of the environmental Kuznets curve, where economic growth has yet to be free of environmental impacts. Based on these findings, the study proposes several policy implications. Firstly, green investment, particularly FDI linked to clean technology, should be further promoted. Secondly, the urban development planning should incorporate circular economy principles, which include smart city development, clean transportation, and circular waste management. Thirdly, the environmental institutional framework and governance capacity should be properly developed to facilitate the use of renewable energy and biomass technologies. Finally, regional cooperation should be enhanced for countries to share experiences, technologies, and develop a set of circular economy indicators integrated into national development strategies. These recommendations serve to foster green transition and sustainable growth in ASEAN countries.

Keywords: green investment, green foreign direct investment, circular economy, sustainable economic growth, biomass technology, urbanization, environmental management, ASEAN countries, Feasible Generalized Least Squares (FGLS) model

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INTRODUCTION

In the context of deepening globalization, trade wars, energy crises, climate change, and increasing resource scarcity, economic growth is slowing and facing heightened uncertainty (World Bank, 2023; UNCTAD, 2022). This underscores the urgent need to transition from traditional economic models to new development paradigms such as the digital economy, green economy, and, notably, the circular economy (CE) to ensure rapid, stable, and sustainable growth (Geissdoerfer et al., 2017; Korhonen et al., 2018). This transition is both an inevitable and objective requirement in the current era.

In ASEAN, rapid economic growth over the past two decades has led to significant challenges, including natural resource depletion, environmental degradation, and unequal distribution of developmental benefits (ADB, 2021; UNEP, 2020). In this context, transitioning to a CE model centered on resource optimization, reuse, recycling, and emission reduction has become imperative. However, the adoption and effectiveness of the key CE factors such as renewable energy use, green urban development, greenhouse gas emission controls, and green FDI attraction vary significantly across ASEAN nations (Leong et al., 2020; Paramati et al., 2017). Notably, in many regional economies, economic growth and the rise in this economy remain heavily reliant on resource extraction and conventional FDI. This indicates that the shift toward a circular economy is still in its early stages (Destek & Aslan, 2020; Shahbaz et al., 2021).

While numerous studies have examined the relationship between sustainable development and economic growth in advanced economies, quantitative research on the relationship between CE-specific factors and economic growth in ASEAN remains limited. An empirical analysis of this relationship would not only enrich the theoretical framework of the circular economy in transitioning contexts but also provide practical insights for policymaking, helping to refine strategies for CE adoption, green growth, and sustainable economic development in the region.

LITERATURE REVIEW

Theoretical approach

Economic growth refers to the increase in Gross Domestic Product (GDP) or GDP per capita (GDPPC) over a specific period, reflecting the expansion of production capacity, consumption, and social welfare (Todaro & Smith, 2015).

The circular economy (CE) is an economic model designed to eliminate waste and pollution, keep products and materials in use for as long as possible, and regenerate natural systems. It represents a shift from the traditional linear model to a closed-loop reuse system that promotes sustainable growth (OECD, 2020). The World Bank (2021) emphasizes that "the circular economy is a comprehensive and inclusive model aimed at reducing pollution and waste, extending product lifecycles, while promoting the sharing and reuse of physical and natural assets".

The circular economy model has focused on optimizing resource use, reducing waste, and closing product life cycles (Ghisellini et al., 2016). CE not only has delivered environmental benefits but has also been considered a driver for sustainable growth through fostering innovation, improving resource efficiency (RE), and creating green jobs (Korhonen et al., 2018; UNCTAD, 2022).

CE factors play not just an intermediary but a decisive role in green growth strategies for greening the economy and achieving sustainable development goals. Quantifying and analyzing the relationship between CE factors and economic growth will provide a basis for proposing appropriate policies for ASEAN during its digital transformation, green transition, and economic framework shift toward sustainable development in developing countries today.

Related works

The relationship between circular economy (CE) and economic growth (EGR) has become a focus in sustainable development studies. CE not only contributed to reducing resource pressure and environmental pollution but also promoted economic growth through technological innovation, renewable energy, green investment, and sustainable urbanization (Ghisellini et al., 2016; OECD, 2022).

In Europe, CE has been deeply integrated into green growth strategies. Busu & Trica (2019) emphasize the role of green foreign direct investment (green FDI) in promoting resource efficiency and production model innovation. Recent research by Radivojevic et al. (2024) and Rybárová & Majdúchová (2024) in Eastern European countries has continued to confirm the positive impact of renewable energy and clean technology on productivity and economic growth, while these approaches emphasized the link between CE, greenhouse gas (GHG) emissions, and economic structural transformation. In Africa, Arouri et al. (2014) affirm that urbanization was closely linked to growth and human capital development, particularly in the context of long-term development orientation.

In Asia, Su et al. (2013) found that the implementation of CE at the local level in China has played an essential role in the green growth process, with indicators such as biomass efficiency and resource productivity significantly improved. According to reports from the World Bank (2022) and UNESCAP (2021), CE has also been a key factor in helping ASEAN countries achieve green growth goals, although there have not been many comprehensive quantitative studies that combine multiple CE variables in the same analytical framework.

However, in the ASEAN region, there has still been a lack of comprehensive quantitative studies on the impact of CE on economic growth, especially in the specific context of each country, such as development level, urbanization level, or economic structure. Current studies mainly focus on each separate factor (such as renewable energy or green investment), and there is no model that fully integrates CE representatives in an overall econometric analysis framework, controlling for issues of heteroscedasticity, autocorrelation, or cross-dependence.

Therefore, this study aims to contribute to the above theoretical and empirical gaps through the construction of a quantitative model using panel data in the ASEAN region. The variables representing CE in the study include: resource productivity, resource use efficiency (REC), renewable energy consumption, and green foreign direct investment capital. In addition, two important control variables, urbanization rate and greenhouse gas emissions, are also included to reflect the current context of sustainable development.

AIMS AND OBJECTIVES

The purpose of this research is to investigate the impact of circular economy factors on economic growth in selected ASEAN countries by applying the FGLS model, with the aim of providing evidence-based insights for sustainable development policy. Specifically, the study:

- analyzes the relationship between green investment, renewable energy consumption, natural resource exploitation, urbanization, and greenhouse gas emissions and their effects on economic development;
- evaluates the extent to which these factors contribute positively or negatively within the frameworks of circular economy and green growth theories; identifies the current stage of ASEAN countries in the environmental Kuznets curve (EKC) transition toward a circular economy;
- offers policy recommendations to enhance green investment, integrate circular economy principles into urban planning, strengthen environmental governance, and foster regional cooperation for sustainable growth.

METHODS

Data selection

This study aims to assess the impact of circular economy factors, particularly green finance mechanisms, on economic growth in six ASEAN countries. Based on the theoretical framework of the circular economy and green growth, the study develops an FGLS regression to assess the impacts of green investment flows, green FDI, biomass technology, urbanization, and resource utilization factors in fostering sustainable economic growth in six ASEAN countries. The study has applied panel data for six ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam) over thirteen years, between 2010 and 2023. Data were collected from reliable sources such as the World Bank, OECD, UNCTAD, IEA, and the International Environmental Database. All variables are taken as natural logs to ensure uniformity, stability, and suitability for advanced estimation methods appropriate to the characteristics of the collected data (in detailed Table 1).

Table 1. Descriptive variables and data selection for the research model.

Variables	Describe the variables	Units	References	Datasources
lngdppc	Economic growth (Log of GDP at 2015 prices: USD/person/year)	% Year	Arouri et al. (2014); Busu & Trica (2019); Su et al. (2013)	WB
biomass	Resource productivity	Tons	Ghisellini et al. (2016); Chen et al. (2022)	IEA
lntnr	Resource utilization efficiency	% GDP	Radivojevic et al. (2024); Mihail Busu & Trica (2019)	OECD; WB
Lnrec	Renewable Energy Consumption	% Total energy	Su et al. (2013); Rybárová & Majdúchová (2024); Chen et al. (2022)	IEA
lngreenfdi	Green foreign direct investment	% GDP	Busu & Trica (2019); Rybárová & Majdúchová (2024)	UNCTAD; OECD
urban	Urbanization Rate	% Population	Arouri et al. (2014); Su et al. (2013)	UN Population
lnghg	Greenhouse Gas Emissions	Tons CO_2/person	Ghisellini et al. (2016); Radivojevic et al. (2024)	EDGAR

The research hypothesis of the model to assess the impact of circular economy factors on the economic growth of ASEAN countries is based on the following hypotheses:

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- H1: Growth of renewable biomass (biomass) has a positive impact on economic growth.
- H2: Resource utilization efficiency (lntnr) has a positive impact on economic growth.
- H3: Renewable energy consumption (lnrec) has a positive impact on economic growth.
- H4: Green foreign direct investment (lngreenfdi) has a positive impact on economic growth.
- H5: Urbanization rate (lnurban) promotes economic growth.
- H6: Greenhouse gas emissions (lnghg) have a negative impact on economic growth.

Research model

Based on the overview of the theoretical basis and empirical research on the impact of circular economy on economic growth (Su et al., 2013; Ghisellini et al., 2016; Radivojevic et al., 2024), the research model is proposed as follows:

$$lngdppc_{it} = \beta_0 + \beta_1 lnbiomass_{it} + \beta_2 lntnr_{it} + \beta_3 lnrec_{it} + \beta_4 lngreenfdi_{it} + \beta_5 lnurban_{it} + \beta_6 lnghg_{it} + \varepsilon_{it}$$

In which: + lngdppc: Economic growth; + lnbiomass: Resource productivity; + lntnr: Resource utilization efficiency; + lnrec: Renewable energy consumption; + lngreenfdi: Green foreign direct investment; + lnurban: urbanization rate; + lnghg: greenhouse gas emissions; + i: Country; t: Year; β: Estimation coefficient to be determined; ε: Random error.

Methodologies

To achieve the main objective of the study and due to the short panel data characteristics (T > N), preliminary testing revealed heteroscedasticity, autocorrelation, and cross-country dependence. Therefore, the Feasible Generalized Least Squares (FGLS) regression method was chosen to overcome the classical assumption violations, while providing more consistent and efficient estimates than OLS or FEM/REM (Park, 1967; Beck & Katz, 1995; Greene, 2012). The FGLS method is particularly suitable for analyzing policy impacts and circular economy factors when it is necessary to control cross-sectional dependence and internal changes over time. At the same time, the FGLS method allows efficient estimation of parameters under conditions of intra-series correlation and heteroscedasticity across units, and at the same time improves the reliability of statistical inferences about the relationship between CE and economic growth.

RESULTS AND DISCUSSION

From 2010 to 2023, green investment flows in these countries increased from an average of USD 4.2 billion per year to approximately USD 15.8 billion per year, with FDI associated with clean technologies accounting for nearly 35% of total new FDI (UNCTAD, 2024). Public spending on environmental management and urban infrastructure development also rose, from an average of 1.1% of GDP in 2010 to 2.6% of GDP in 2023 (ASEANStats, 2024). Investment in renewable energy, including biomass technologies, reached over USD 9.3 billion in 2023 compared to only USD 2.5 billion in 2010. However, per capita CO_2 emissions in the region still increased from 3.1 tons to 3.9 tons over the same period (World Bank, 2024), indicating that environmental pressures have not declined in proportion to economic growth. These specific financial indicators are integrated into the FGLS model to measure the relationships among green investment, urbanization, renewable energy consumption, resource exploitation, and sustainable economic growth.

The following section presents a statistical summary, empirical results, and policy implications, with the aim of further clarifying the role of financial factors in the green transition and circular economy development in six ASEAN countries.

Descriptive statistics and the Correlation matrix between variables in the model

Descriptive statistics

Descriptive statistics are used to generalize the characteristics of variables in the research model. Basic statistical indicators include: mean value, standard deviation, maximum, and minimum values (in detailed Table 2).

Table 2. Descriptive statistics for variables.

Variables	Obs	Mean	Std. Dev.	Min	Max
lngdppc	84	8.8178	1.0691	7.6146	11.1265
biomass	84	15.2957	0.2815	14.7645	15.8151
lntnr	84	0.0466	2.8485	-8.5172	2.2971
Lnrec	84	2.3557	1.3994	-0.6931	3.6350
lngreenfdi	84	1.0585	1.5278	-3.0345	3.6450
urban	84	4.0322	0.3475	3.4150	4.6052
lnghg	84	1.8644	0.5563	0.8446	2.9255

The results of Table 2 show that the variables in the model have a complete and stable number of observations (84 observations), reflecting the reliability of the data. The variable lngdppc (log GDP per capita) has an average of 8.82 and a standard deviation of 1.0691, indicating a clear difference in income levels among ASEAN countries. The variable lntnr (Resource Use Efficiency) shows strong dispersion with the highest standard deviation (2.85), reflecting the uneven level of resource exploitation. The variable lngreenfdi (green investment capital) ranges from -3.03 to 3.65, indicating that the ability to attract green capital flows among countries has significant differences. These characteristics lay the foundation for testing the hypothesis on the impact of circular economy factors on economic growth, with the expectation that the econometric model will give stable and accurate results.

Analysis of Correlation Matrix

The correlation matrix helps to check the degree of linear relationship between variables in the research model. The correlation coefficient (positive, negative, weak, or no linear relationship between two variables) ranges from -1 to 1; the relationships are statistically significant or not significant. Therefore, analyzing the correlation matrix helps to identify notable relationships between variables and also helps to detect model defects before performing estimation. Below is the correlation matrix table between variables in the research model (in detailed Table 3):

Table 3. Correlation matrix between variables in the model. Note: *** p < 0.01; ** p < 0.05; * p < 0.1.

Variables	lngdppc	biomass	lntnr	Lnrec	lngreenfdi	urban	lnghg
lngdppc	1.0000						
biomass	-0.0430	1.0000					
lntnr	-0.777***	0.0130	1.0000				
Lnrec	-0.952***	0.0470	0.661***	1.0000			
lngreenfdi	0.721***	-0.0620	-0.522***	-0.694***	1.0000		
urban	0.908***	-0.0240	-0.598***	-0.900***	0.606***	1.0000	
lnghg	0.627***	-0.1230	-0.1610	-0.681***	0.504***	0.687***	1.0000

The correlation matrix shows that there are strong and statistically significant correlations between many variables in the model. In particular, the variable lngdppc has a very strong negative correlation with lnrec (-0.952) and lntnr (-0.777), suggesting that as countries increase their use of renewable resources and reduce their dependence on traditional resources, per capita income tends to increase. The variables urban and lngreenfdi have a strong positive correlation with lngdppc (0.908 and 0.721, respectively), suggesting the positive role of urbanization and green capital investment in economic growth. In addition, the variable lnghg is significantly positively correlated with lngdppc (0.627), highlighting the challenge of balancing development and environmental emissions.

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Data characteristic testing

Unit root tests: To test the stationarity of panel data, we conducted two-unit root tests, including Levin, Lin & Chu (LLC, 2002) and Fisher-ADF (Maddala and Wu, 1999), with the original hypothesis that a unit root exists.

Table 4. Unit root tests for the variables.

Variables	Level				At First Difference				Order of Integration
	LLC		Fisher-ADF		LLC		Fisher-ADF		
	t-Statistic	P-value	t-Statistic	P-value	t-Statistic	P-value	t-Statistic	P-value	
lngdppc	-1.6551	0.0490	3.0461	0.0012	-5.7469	0.0000	-	-	I(0)
biomass	-1.7098	0.0436	-1.8726	0.9694	-3.7853	0.0001	11.1197	0.0000	I(0)
lntnr	-2.6162	0.0044	-1.9404	0.9738	-	-	9.5188	0.0000	I(0)
Lnrec	-1.0624	0.1440	3.7559	0.0001	-7.6371	0.0000	-	-	I(1)
lngreenfdi	-3.3734	0.0004	2.2408	0.0125	-	-	-	-	I(0)
urban	-5.5805	0.0000	-2.3838	0.9914	-	-	5.2710	0.0000	I(0)
lnghg	-1.5303	0.0630	1.2061	0.1139	-4.5225	0.0000	2.6493	0.0040	I(1)

The results presented in Table 4 show that:

1. The variables lngdppc, lnbiomass, lntnr, lngreenfdi, and lnurban are stationary at the root level (I (0)). These variables all have at least one test with $p < 0.05$, and there is a difference between the two tests; the LLC test result is preferred due to the assumption of homogeneity of autoregressive coefficients among cross-sectional units in the panel data.
2. The variables lnrec and lnghg are not stationary at the root level but are stationary after taking the first difference, i.e., they have first-order integration (I(1)).
3. The existence of variables with mixed integration between I(0) and I(1) shows that estimation methods such as FGLS or PMG are suitable because these statistical methods and models might handle panel data with different levels of integration. Continue to perform other tests to select the appropriate model.

Diagnostic Tests for Panel Data Assumptions: To test the assumptions of the panel data model, the research team conducted tests such as Pesaran CD cross-dependence test (Pesaran, 2004), Breusch-Pagan (1979) heteroscedasticity test, White (1980) test, Wooldridge (2002) autocorrelation test, and multicollinearity test using the variance inflation factor (VIF). The results are presented in Table 5.

Table 5. Diagnostic Tests for Model Specification.

Test	Test Statistic	P-value	Conclusion
Cross-sectional dependence	CD-test		
Pesaran CD test	14.017	0.0000	Reject H_0 → Cross-sectional dependence exists
Heteroscedasticity	χ^2		
Breusch-Pagan LM test	3.2	0.0734	Fail to reject H_0 → No strong evidence
White test	60.85	0.0002	Reject H_0 → Heteroskedasticity exists
Wald test	13.65	0.0338	Reject H_0 → Heteroskedasticity exists
Autocorrelation	F		
Wooldridge test (first order)	112.707	0.0001	Reject H_0 → First-order autocorrelation detected
Multicollinearity	Mean VIF		
Mean Variance Inflation Factor	3.72	–	No multicollinearity detected (VIF < 10)

The diagnostic test results show that the data have cross-sectional dependence, heteroscedasticity, and first-order autocorrelation, while there is no significant multicollinearity among the explanatory variables. Therefore, it is necessary to continue to perform model selection tests (F-test, LM test, Hausman test).

Model selection testing

The study continues to use three popular tests: the F-test (Baltagi, 2008) to compare the OLS and fixed effects models (FEM); the Breusch-Pagan LM test (Breusch & Pagan, 1980) to distinguish between OLS and random effects (REM); and the Hausman test (Hausman, 1978) to decide between FEM and REM. The goal is to determine whether individual-specific effects are correlated with the explanatory variables, thereby choosing the most suitable model.

Table 6. Regression Model Selection Test Results.

Model Comparison	Test	Test Statistics	P-value	Conclusion
OLS vs FEM	F-test	F = 13.65	0.0338	P < 0.05 → FEM is more appropriate than OLS
OLS vs REM	Breusch-Pagan LM test	χ^2 = 0.00	1.0000	P > 0.05 → OLS is more appropriate than REM
FEM vs REM	Hausman test	χ^2 = 75.18	0.0000	P < 0.05 → FEM is more appropriate than REM (FEM selected)

The test results (Table 6) show that the FEM model is the most suitable for analyzing panel data collected from 6 countries in the ASEAN region in the period 2010 - 2023; three assumptions of the Classical Linear Regression Model (CLRM) have been violated, including: the existence of heteroskedasticity, first-order autocorrelation, and cross-sectional dependence. In addition, the number of observation units (N) is larger than the number of times (T); the use of the Feasible Generalized Least Squares (FGLS) model is appropriate to correct errors and improve the reliability of an estimate. Therefore, the next research step will estimate the model using the FGLS method.

Model estimation using the FGLS method

The use of the FGLS model is necessary in the context of research data, to ensure more efficient and reliable estimates than OLS or FEM models (in detailed Table 7).

Table 7. The estimated results. Note: * p<0.10, ** p<0.05, *** p<0.01

	POLS	FEM	FGLS
	lngdppc	lngdppc	lngdppc
lnbiomass	0.0086 (0.904)	0.321*** (0.000)	0.121*** (0.006)
lntnr	-0.110*** (0.000)	-0.0176*** (0.000)	-0.0681*** (0.000)
lnrec	-0.328*** (0.000)	-0.00982 (0.563)	-0.306*** (0.000)
lngreenfdi	0.0593*** (0.004)	0.00471 (0.224)	0.00653** (0.022)
lnurban	0.736*** (0.000)	1.022*** (0.000)	1.183*** (0.000)
lnghg	0.156** (0.012)	0.00363 (0.941)	0.0803*** (0.008)
_cons	6.142*** (0.000)	-0.199 (0.708)	2.739*** (0.001)
N	84	84	84
R-sq	0.965	0.947	

The FGLS model achieved a coefficient of determination R^2 = 0.947, showing a high explanatory power for the dependent variable of economic growth (lngdppc) by circular economy factors (CE (circular economy)) in the study of 6 countries in ASEAN. Specifically, as follows:

1. The variable lnurban showed the strongest positive impact with (β=1.183 and p=0.000) and was significant at the 1% level. This reflects how urbanization acts as a growth catalyst by improving productivity, stimulating consumption, and encouraging technological diffusion. Public and private investment in urban infrastructure across six ASEAN countries increased from 1.1% of GDP in 2010 to 2.6% in 2023, demonstrating a clear financial commitment toward smart infrastructure, green transport, and public services. These investments contributed to expanding the economic

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base, increasing labor productivity, and promoting low-carbon urban transitions. The result is consistent with the circular economy and green growth theory (Pearce & Turner, 1990; UNEP, 2011) and confirms empirical findings by Henderson et al. (2012), Fang & Yu (2020), and Yao et al. (2021) on the positive contribution of urbanization to growth in emerging economies.

2. The variable lnbiomass has a positive effect (β=0.121 and p=0.006) and is statistically significant at the 1% level. This indicates that investment in biomass energy and bio-based industries contributes to economic expansion. Empirical data show that investment in renewable and biomass energy increased from USD 2.5 billion in 2010 to USD 9.3 billion in 2023, illustrating a substantial financial shift toward green energy. This trend reflects the gradual improvement of technological capabilities and energy efficiency in the region. The result is in line with the resource optimization principle of the circular economy and aligns with the empirical findings of Ghisellini et al. (2016), which emphasize the role of biomass in promoting sustainable growth under proper institutional and technological conditions.

3. The variable lnghg, reflecting greenhouse gas emissions, has a positive effect (β = 0.0803 and p = 0.008) and is statistically significant at the 1% level, suggesting that ASEAN countries may be at the early stages of the environmental Kuznets curve (EKC), where economic growth is still associated with high emissions. This research finding is consistent with the previous studies of Al-Mulali & Saboori (2016) and Liobikienė & Butkus (2019) in the context of emerging economies.

4. The variable lngreenfdi has a positive impact with a coefficient of β = 0.00653 and p = 0.022 (significant at the 5% level), indicating that the positive role of green foreign direct investment inflows in promoting growth is still limited. Although smaller in magnitude compared to other variables, this result indicates that foreign direct investment associated with clean technologies has contributed to economic expansion; however, its scale and spillover effects remain limited within the region. Most green FDI inflows are currently concentrated in a few specific sectors, such as energy and green infrastructure, without forming deep value chains or strong linkages with domestic industries. This suggests that ASEAN is still in the early stages of leveraging green FDI as a long-term driver of growth. Enhancing the effectiveness of green FDI requires a supportive institutional framework, innovation-oriented policies, and stronger domestic absorptive capacity for clean technologies. This finding is consistent with the theoretical framework of green finance and sustainable development and aligns with the empirical evidence of Doytch & Narayan (2016), who emphasized that the spillover effects of green FDI depend heavily on the policy environment and the capacity to localize clean technologies.

5. The variable lntnr has a negative impact with a coefficient of β = -0.0681 and p = 0.000 (significant at the 1% level). This reflects the reality of unsustainable resource exploitation, low resource use efficiency, leading to resource loss without creating commensurate added value in ASEAN countries, consistent with the studies of Sauvé et al. (2016) and Zhang & Wang (2022) in the context of developing countries still mainly dependent on raw resource exploitation, while low resource productivity is a significant barrier in the transition to the circular economy model in developing countries.

6. The variable lnrec has a negative effect (β = -0.306 and p = 0.000 with a significance level of 1%) on economic growth. This result can be explained by the fact that the use of renewable energy in ASEAN is still in its early stages, with high investment costs, a lack of appropriate technology, and infrastructure. This result is consistent with the studies of Zafar et al. (2019) and Yao et al. (2021), who argued that in the initial stages, renewable energy may not generate clear economic efficiency without appropriate policy support. Thus, the estimation results show that all variables representing the pillars of circular economy show a statistically significant relationship with economic growth in 6 ASEAN countries, which confirms that the circular economy and green transformation are influential drivers in sustainable economic growth and development by fostering innovation, developing efficient resource use, reducing waste, and promoting environmentally friendly practices. These trends offer economic opportunities while mitigating environmental impacts, ultimately supporting a more sustainable economic growth and development in the ASEAN region for developing countries.

In conclusion, the empirical results from the FGLS estimation indicate that green finance factors, including urbanization, investment in biomass technologies, and green foreign direct investment inflows, have a strong and statistically significant influence on economic growth in ASEAN economies. In contrast, traditional drivers of growth, such as natural resource extraction and the early use of renewable energy, show negative or unstable effects. These outcomes reflect persistent structural inefficiencies, high initial investment requirements, and insufficient institutional and technological capacity. Overall, the findings suggest that ASEAN is at an early stage of moving away from a resource-based development model toward a green-oriented growth path, where green finance, clean technologies, and sustainable infrastructure play a crucial role.

This evidence provides a solid empirical foundation for policy formulation that seeks to improve the effectiveness of green investment and gradually lessen the region's dependence on traditional, resource-intensive growth strategies over the long term.

Test the reliability and stability of the model

In addition to testing the model diagnostics (Table 5), to test the stability and reliability of the model using the FGLS (Feasible Generalized Least Squares) method, the study conducted the SUEST test (Zellner, 1962) between the two periods, 2010–2016 and 2017–2023. The test results with Chi-squared = 62.98 and p-value = 0.000 show a statistically significant difference between the two models, reflecting the possibility of structural changes in the relationship between circular economic factors and economic growth over time, as ASEAN countries are in the process of transforming their growth model towards sustainability and greening the economy. Therefore, the use of the FGLS regression method ensures the reliability of the estimates and is suitable for analysis in the context of heterogeneous panel data to handle cross-dependence phenomena, heteroscedasticity phenomena, and time series correlation in panel data (Baltagi, 2008; Drukker, 2003).

CONCLUSIONS

Based on the empirical analysis, the estimation results from the FGLS model (Table 7) clearly confirm the crucial role of green finance factors in promoting economic growth in six ASEAN countries from 2010 to 2023. The urbanization variable (lnurban), with $\beta = 1.183$ ($p = 0.000$), reflects the effectiveness of public and private investment in urban infrastructure, public services, and technological innovation. The green investment in these areas increased on average from 1.1% of GDP in 2010 to 2.6% of GDP in 2023. Additionally, biomass technology (lnbiomass), with $\beta = 0.121$ ($p = 0.006$), is associated with actual investment flows in renewable energy and the biomass sector, which rose from USD 2.5 billion in 2010 to USD 9.3 billion in 2023, demonstrating this sector's increasingly significant contribution to growth. Foreign direct green investment (lngreenFDI), with $\beta = 0.00653$ ($p = 0.022$), underscores the role of foreign capital tied to clean technologies, though it remains limited in scale and in value-added linkages. By contrast, natural resource exploitation (lntnr), with $\beta = -0.0681$ ($p = 0.000$), and renewable energy consumption (lnrec), with $\beta = -0.306$ ($p = 0.000$), reflect the reality of high initial investment, fragmented technologies, and low utilization efficiency within the region. These findings are consistent with the theoretical foundations of the circular economy and green growth (Pearce & Turner, 1990; UNEP, 2011). The findings are also supported by various empirical studies, such as Henderson et al. (2012) on urbanization, Ghisellini et al. (2016) on biomass, Doytch & Narayan (2016) on green FDI, and Al-Mulali & Saboori (2016), and Liobikienė & Butkus (2019) on the environmental Kuznets curve. Accordingly, the study not only provides empirical evidence but also demonstrates, based on actual financial data, the impacts of green investment, green FDI, and clean technologies on ASEAN's economic growth.

The study provides empirical evidence, based on actual financial data, to illustrate the impact of circular economy factors and green finance on the economic growth of six ASEAN countries. However, the findings also indicate that the region's green transition remains at an early stage, and economic growth has not yet separated from environmental impacts. Therefore, future research could be expanded in several directions. Firstly, more in-depth analyses of the transmission channels of green finance in specific sectors should be considered. Secondly, the influence of institutional quality and supportive policies on the effectiveness of green investment should be examined. Lastly, lessons from other ASEAN countries should be considered and properly incorporated into national economic development programs.

Policy implications

Based on the study's objectives and the empirical results, some policy implications are proposed to promote sustainable economic growth through circular economy factors in ASEAN countries as follows:

First, it is essential to strengthen the attraction and improve the quality of green investment capital, especially foreign direct investment flows oriented toward clean and environmentally friendly technologies. The diffusion of green and biomass technologies not only creates momentum for green growth but also enhances labor productivity and job quality, which is particularly relevant for developing economies in the region.

Second, integrating circular economy principles into urban development planning should be regarded as a key priority. This includes developing smart cities, expanding clean transportation systems, promoting green housing, and establishing circular waste treatment facilities, thereby balancing economic growth with urban environmental protection.

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Third, environmental institutions and policies need to be improved, regulatory capacity strengthened, and the efficient and sustainable use of renewable energy, biomass technology, and natural resource exploitation promoted. Strict control of greenhouse gas emissions is also necessary to ensure that growth does not come at the expense of the environment.

Finally, ASEAN countries should enhance regional cooperation in transitioning toward a circular economy model by sharing experiences, transferring technologies, and developing a common policy framework. Establishing a set of indicators to evaluate the circular economy and integrating them into national development strategies will provide an essential foundation for monitoring progress and adjusting policies in a timely manner, thereby consolidating the financial and institutional basis for the green transition and sustainable growth in the region.

ADDITIONAL INFORMATION

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CONFLICT OF INTEREST

The Author declares that there is no conflict of interest.

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ВПЛИВ ФАКТОРІВ ЦИРКУЛЯРНОЇ ЕКОНОМІКИ НА ЕКОНОМІЧНЕ ЗРОСТАННЯ В КРАЇНАХ АСЕАН: ПІДХІД ІЗ ВИКОРИСТАННЯМ МОДЕЛІ ФГЛС

У цьому дослідженні автор оцінює вплив економічних факторів замкнутого циклу на економічне зростання в шести країнах АСЕАН протягом 2010-2023 років на основі загальнодоступної бази даних з офіційних джерел, Світового банку, ЮНКТАД і МЕА. Відповідно до теоретичних засад циркулярної економіки та зеленого зростання, у дослідженні наголошено на ролі оптимізації ресурсів, зеленого фінансування, повторного використання та переробки, а також скорочення викидів у сталому розвитку. Це дослідження застосовує можливий метод узагальненої регресії найменших квадратів (FGLS) для вирішення гетероскедастичності, автокореляції та перехресної залежності, тим самим забезпечуючи більш точні оцінки взаємозв'язків між змінними. Результати свідчать про те, що зелені інвестиції та урбанізація мають позитивний вплив на економічне зростання. Ці фактори виступають ключовими драйверами сталого економічного зростання. Споживання відновлюваних джерел енергії та експлуатація природних ресурсів негативно впливають на економічне зростання; ці фактори свідчать про високі початкові інвестиційні витрати, технологічні обмеження та нерівномірну ефективність використання ресурсів у країнах АСЕАН. Викиди парникових газів продовжують демонструвати позитивну кореляцію зі зростанням, що означає, що регіон досі залишається на ранній стадії екологічної кривої Кузнеця, де економічне зростання ще не було вільним від впливу на навколишнє середовище. Ґрунтуючись на цих висновках, дослідження пропонує кілька політичних наслідків. По-перше, слід і надалі заохочувати «зелені» інвестиції, зокрема ПІІ, пов'язані з чистими технологіями. По-друге, планування міського розвитку має включати принципи циркулярної економіки, які включають розумний розвиток міста, чистий транспорт і циркулярне управління відходами. По-третє, необхідно належним чином розвивати екологічну інституційну базу та управлінський потенціал для сприяння використанню відновлюваних джерел енергії й технологій біомаси. Нарешті необхідно посилити регіональне співробітництво для того, щоб країни обмінювалися досвідом, технологіями та розробляли набір індикаторів циркулярної економіки, інтегрованих у національні стратегії розвитку. Ці рекомендації сприяють зеленому переходові й сталому зростанню в країнах АСЕАН.

Ключові слова: зелені інвестиції, прямі зелені іноземні інвестиції, циркулярна економіка, сталe економічне зростання, технологія біомаси, урбанізація, екологічний менеджмент, країни АСЕАН, реалістична узагальнена модель найменших квадратів (FGLS)

JEL Класифікація: F21, Q51, Q56, O44, Q42, R11, Q58, F63, C3