DEVELOPING THE CIRCULAR ECONOMY PROMOTES SUSTAINABLE GROWTH IN THE CONTEXT OF THE FOURTH INDUSTRIAL REVOLUTION

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Abstract: ***Economic development requires natural resources, especially energy sources for input needs of economic activities. In total, dependence on fossil energy sources creates environmental challenges such as rising sea levels, rising global temperatures, negatively affecting human health and growth efficiency. The research results indicated that although fossil energy sources bring positive benefits to growth in the short term, but, the economy should shift to renewable energy consumption, promoting circular supply chains based on the rational use of natural resources to ensure higher growth in the long term. Therefore, developing the circular economy promotes sustainable growth is necessary in the current context.***

• Keywords: *circular economy, fossil energy, renewable energy, sustainability.*

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1. Introduction

Developing circular economy in general and circular supply chains in particular has attracted the attention of some scholars recently through scientific publications on Scopus and Web of Science in recent years, which suggests more in-depth studies on developing circular supply chains for sustainable cities (Anser et al., 2024; Perera et al., 2024; Xu et al., 2025; Montag, 2023). In fact, the world is facing many environmental challenges, especially the increasing environmental pollution that has led to a number of consequences such as rising sea levels, increasing global temperatures, increasing environmental pollution and thus affecting human health and life, increasing business costs and costs for the economy. Faced with this context, countries must harmonize economic development and environmental protection, in which building a green growth strategy and sustainable growth is a necessary goal to both maintain economic growth and achieve long-term growth goals. Therefore, the study focuses on analyzing a case study in Vietnam to clarify the role of circular supply chains for sustainable development.

In that context, promoting a circular economy is one of the solutions to achieve economic growth in the short and long term. A circular economy is an economic model in which design, production and service activities are organized appropriately to minimize negative impacts on the environment. A circular economy aims to reuse, repair, refurbish, recycle and remanufacture products and materials based on basic principles such as preserving and developing nature, using renewable resources, optimizing resource use, reducing waste and pollution and increasing renewable energy consumption.

Vietnam implemented economic reform in 1986 and implemented a strategy of opening up economic activities to the global economy. Vietnam has achieved many successes in socio-economic development with an average income of about 7%/year and Vietnam has achieved an average income per capita of nearly 5,000 USD/person/year in 2025. It can be said that Vietnam is one of the fast-growing countries in Asia with an open economy associated with high FDI attraction and open international trade. However, Vietnam is also facing the problem of environmental pollution that degrades the living environment and increases costs for people and the economy such as costs related to health, longevity, production costs, and costs related to environmental pollution. This raises the urgency of building and developing the economy associated with maintaining environmental protection in Vietnam.

In order to clarify the relationship between sustainable development and economic factors, the objective of this study is to assess the impact of energy use on economic growth in the context of promoting circular supply chains in Vietnam. The research results clarify whether increased energy

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consumption promotes economic growth or not, especially in the context of promoting circular supply chainsin specific and circular economy in particular. Specifically, every year thousands of studies related to circular economy are published in Scopus or the Web of Science, reflecting the level of interest of scholars and researchers in circular economy development and sustainable development goals (Perera et al., 2024).

2. Resource recovery and circular supply chains

As discussed above, the strategy of promoting and developing a circular economy creates a foundation for sustainable growth, maintaining high growth while ensuring a clean environment. In recent times, the world has witnessed rapid economic development with per capita income increasing every year, but the level of pollution has also increased, affecting the global biosphere and increasing challenges to human life. Therefore, developing a circular economy to maintain sustainable growth is necessary. Most studies emphasized the role of developing circular supply chains to promote circular economy and bring benefits to the economy, especially sustainable development in businesses, localities and cities. In the context of increasing environmental pollution, promoting sustainable development becomes necessary and essential.

Given that energy is an essential factor for economic growth and sustainable development, in which energy supply and consumption play a key role in economies. Wei et al. (2025) argued that energy competition makes energy more sustainable and accessible to all. Indeed, global energy consumption has skyrocketed, and driven by rapid industrialization, urbanization, and economic development, especially in the United States, the EU, and China. Conducting a study to assess the spatial-temporal variation and the linkage between global primary energy consumption and economic growth during the period 1965–2000, the study results showed that global energy consumption is heterogeneous and heterogeneous with impressive growth. Regional inequality has decreased and remained stable at high levels over time. The study also found that most countries have an imbalance between non-fossil energy consumption and GDP. Large energy consumers struggle to meet renewable energy consumption targets, following a fossil-to-renewable energy transition path while maintaining economic growth.

Anser et al. (2024) studied the BRICS countries including Brazil, India, China, South Africa and Russia in the context of their increasing importance in the global economy as emerging countries. Specifically, BRICS accounts for a significant proportion of the world's population, GDP and energy consumption. These countries have promoted industrialization, resource use and technological innovation and have contributed greatly to global economic growth. However, BRICS countries also face significant challenges related to balancing economic development with environmental sustainability and efficient resource management. Furthermore, BRICS countries are important players in the global energy market as Brazil and Russia are major energy resource exporters and India, China and South Africa are major energy consumers. This energy consumption has a direct impact on economic growth and environmental sustainability. In addition, BRICS countries showed varying degrees of success in integrating technological advances into the energy sector, especially in how technological innovation affects economic growth and energy use in the context of developing sustainable development strategies in economies.

Perera et al. (2024) argued that many countries develop nuclear energy as their main energy source while the world's second-lowest carbon energy source and only meets 10% of global energy demand. The study examined the relationship between renewable, non-renewable energy sources and growth to clarify how renewable and non-renewable energy consumption interact and influence economic growth. The study results provided evidence of a unidirectional causal relationship running from renewable energy consumption to economic growth and non-renewable energy consumption to economic growth in transition economies. Therefore, implementing global energy efficiency standards, reducing fossil fuel use, and adopting regulatory measures are feasible policies to limit negative environmental impacts and promote economic development.

The rapid growth of the global economy has led to environmental problems such as pollution, resource depletion, creating global economic and political barriers to social existence and development. Li et al. (2024) argued that sustainable development has become an accepted and chosen norm globally, including in China. The Chinese government has implemented new economic strategies to effectively use natural resources. China is known as the fastest growing country in the world, and its participation in international trade is a driving force for growth. In particular, its export-oriented policies have helped China become a global manufacturing hub. However, China still faces vulnerabilities related to environmental degradation, including significant

dependence on coal and fossil fuels, so the efficient exploitation of natural resources is urgent to promote industrial development and infrastructure projects.

3. Urban resource challenge

3.1. Material intensity of cities

Typically, material intensity of cities corresponds to the mass of materials used to construct a building or a structure per unit of floor area. It is measured to assess the resource use and environmental performance of buildings and the larger urban environment. It is understood that material intensity is a fundamental characteristic for material flow management, assessing demolition waste. Celik et al. (2023) indicated that material intensity has a negative impact on the environmental factors, demonstrating the existence of a feasible sustainable consumption and production among the nations. Therefore, reducing material intensity across economic sectors in advanced economies is a good recommendations for maintaining the sustainable development.

3.2. Linear supply chains in urban contexts

Linear supply chains in urban contexts reflect the linear relationship of supply chains in urban areas. Xu et al. (2025) indicated that the frequent occurrence of exogenous events such as natural disasters, extreme weather, and the impact on national governments, therefore the study suggests that supply chain digitization has the potential to promote urban resilience, enhancing cities' ability to withstand and recover from risks. The supply chain promotion effect on urban resilience is stronger in cities with higher development, densely populated areas, or central areas. It is evident that the economy has significantly changed from linear supply chain to circular supply chain as suggested in Figure 1 below:

Figure 1. Trends of supply chain

Source: Authors' compilation

4. Circular supply chains and Resource recovery pathways in urban systems

4.1. Fundarmentals of circular supply chains

Circular supply chain incorporates circular thinking in the supply chain, and has attracted the attention of scholars and countries to optimize supply chain operations. Montag (2023) argues that an efficient supply chain is based on optimizing input and output resources, thereby saving natural resources, the environment, and thereby reducing environmental impact, sustainable development.

4.2. Resource recovery pathways in urban systems

Resource recovery in cities involves extracting valuable resources from waste streams and reusing them, thereby promoting a circular economy and shifting the economy to a resource-light economy. By treating waste as a resource, urban areas can reduce their environmental impact, reduce emissions and thus create greater benefits for the economy. Therefore, a country with resource recovery solutions is a driving force for the economy to optimize the use of resources and create economic efficiency (Meier et al., 1975).

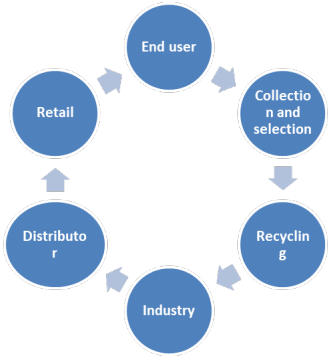
5. Urban infrastructure for resource recovery and case study

5.1. Decentralized recovery facilities

Decentralized recovery facilities in urban areas involve the treatment of wastewater or solid waste instead of transporting them to large centers for treatment, also known as decentralized waste treatment. This approach offers several benefits such as reduced capital costs, infrastructure costs, increased flexibility for resource recovery, and better environmental performance. Indeed, decentralized systems treat on-site and in small clusters, and are suitable for areas with appropriate waste volumes (Qiao et al., 2024).

5.2. Reverse logistics and collection networks

Figure 2. Reverse logistics



Source: Authors' compilation

Reverse logistics is the process of managing goods after they have reached the end consumer. It includes moving products back into the supply chain such as returning, repairing, recycling or discarding. Therefore, it can be understood as the process that includes the physical movement of goods, the organization and administration of managing this process. Or it can be said that reverse logistics aims to move products back into the supply chain and help the economy operate more optimally based

on the perspective of sustainable development and promoting circular supply chain management. Figure 2 indicated that reverse logistics include a circular of industry, distributor, retail, end user, collection and selection, and recycling.

5.3. Digital tools and data for circular flows

Digital tools and data play an important role in promoting circularity through mechanisms for tracking, monitoring and analyzing the efficiency of resources and products in their lifecycles. Specifically, these tools help reuse resources and optimize production processes, ultimately improving supply chains. Another possibility, Celik et al. (2023) indicated that material productivity and material intensity as drives of environmental sustainability, thus promoting the circular economy in the long run and thereby making the economy more efficient.

5.4. A case study

We collected data in Vietnam from 2000 to present. The collected data include: Fossil energy consumption, economic growth, international trade and foreign direct investment. The data source is collected from various sources in local and international.

The proposed regression equation is as follows:

$$GDP = \beta_0 + \beta_1 FOSSIL + \beta_2 FDI + \beta_3 TRADE + \mu$$

In this model, FOSSIL is a variable representing fossil energy consumption, FDI is a variable measuring foreign direct investment attraction, TRADE is a variable measuring the level of international trade, GDP is a variable measuring per capita income, reflecting the level of income improvement or economic growth.

Figure 3 indicates fossil fuel energy consumption and suggests that fossil fuel energy consumption is the main source of energy to meet Vietnam's energy needs in recent times. In 2000, the contribution rate of fossil energy sources was less than 40% compared to energy consumption demand, and correspondingly over 60% of renewable energy sources were capable of meeting energy consumption demand in Vietnam. However, the contribution rate of renewable energy sources has continuously decreased and correspondingly the contribution rate of fossil energy sources to total energy demand has been increasing. This explains why Vietnam's economic development always requires an increase in energy sources. Although Vietnam has invested in renewable energy sources, but the increase is slow due to high investment costs and long payback periods, so fossil energy sources, typically coal and oil, are still the main sources of energy for the country.

Figure 4 describes Vietnam's per capita income in the recent period and shows that Vietnam's per capita income has been continuously improved since 2000. Per capita income was below 500 USD/person/year in 2000, increased to about 1000 USD/person/year in 2006 and 2000 USD/person/year in 2011. By 2024, Vietnam's per capita GDP has increased to 4700 USD/person/year and the country is rapidly entering the upper middle-income group in the near future. This reflects the economy achieving a high growth rate throughout the past period (National Statistics Office, 2025).

Figure 3. Fossil fuel energy consumption (% of total)

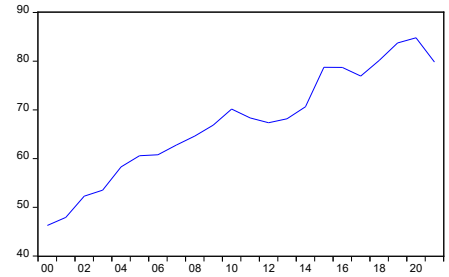
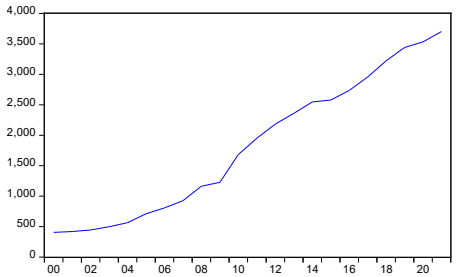


Figure 4. Per capita income (GDP)



5.5. Regression results

Table 1. LS regression results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FOSSIL	89.24872	10.89077	8.194897	0.0000
FDI	-122.3013	52.58266	-2.325887	0.0319
TRADE	6.257375	6.316033	0.990713	0.3350
C	-4464.085	568.5271	-7.852019	0.0000

Source: Authors' analysis

Table 2. RLS regression results

Variable	Coefficient	Std. Error	z-Statistic	Prob.
FOSSIL	84.74053	12.56141	6.746102	0.0000
FDI	-147.8626	60.64882	-2.438012	0.0148
TRADE	8.639892	7.284910	1.185999	0.2356
C	-4336.408	655.7389	-6.613010	0.0000

Source: Authors' analysis

Table 3. GLM regression results

Variable	Coefficient	Std. Error	z-Statistic	Prob.
FOSSIL	89.24872	10.89077	8.194897	0.0000
FDI	-122.3013	52.58266	-2.325887	0.0200
TRADE	6.257375	6.316033	0.990713	0.3218
C	-4464.085	568.5271	-7.852019	0.0000

Source: Authors' analysis

The regression results in Table 1, Table 2 and Table 3 show that:

The regression coefficient of FOSSIL is positive and statistically significant, this result shows that there is a positive impact of fossil energy consumption on Vietnam's economic growth. Or it can be said that fossil energy consumption brings a positive effect to economic development. In fact, Vietnam's economy is classified as a country with a fast growth rate and therefore requires a large demand for energy consumption. In order to meet that demand, Vietnam still has to depend on fossil energy sources while renewable energy sources cannot contribute significantly to the country's energy consumption demand.

The regression coefficient of FDI is negative and statistically significant, this result shows that there is no positive impact of attracting foreign direct investment and economic growth. This result affirms Vietnam's recent policies, especially policies related to trade liberalization and openness to attract foreign direct investment. However, the effectiveness of attracting FDI will be stronger if Vietnam selectively attracts FDI, especially prioritizing FDI projects with more technology, low energy consumption and green FDI. Indeed, FDI capital is a source of long-term capital for the economy and this capital has the ability to expand investment in technical infrastructure, fixed assets of enterprises and the country, thus having the ability to improve large-scale production activities in the country. The effectiveness of attracting FDI is higher if this capital has the ability to improve labor productivity, skills, and quality of human resources through the learning process.

The regression coefficient of TRADE is positive but not statistically significant, this result shows that international trade does not always bring positive benefits to the economy. International trade is capable of meeting domestic consumption needs when the domestic market cannot produce consumer goods at competitive prices, so international trade may not improve domestic production capacity and economic development, and international trade may bring risks due to trade wars and external shocks spilling over into the economy. Therefore, only when international trade is associated with improving domestic business performance will it bring positive effects to the economy.

6. Conclusion

Economic development has created more environmental challenges, especially increasing environmental pollution, some consequences such as rising sea levels, increasing global temperatures, increasing environmental pollution and affecting human health, life and economic benefits. The research results showed that fossil energy has a positive impact on growth, affirming that fossil energy consumption still brings positive effects to the economy, especially in the short term. However, an economy that depends too much on fossil energy consumption can reduce the efficiency of economic growth in the future. Therefore, the study also recommends that the government should have solutions to prioritize the efficient use of energy sources, reduce dependence on natural resources and transform the growth model based on a more efficient technology platform.

It can be seen that Vietnam needs to harmonize the use of fossil energy sources to meet the requirements of the country's economic development, but at the same time encourage the expansion of renewable energy sources to create long-term sustainable economic development benefits. In the short term, fossil fuels are cheap, making production costs cheaper, but they also create additional environmental burdens, thereby reducing economic growth efficiency. Second, Vietnam needs to take measures to promote circular supply chains, especially an economy that shifts towards saving on the use of natural resources to minimize environmental impacts and promote sustainable development.

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