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Original scientific paper

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CIRCULAR ECONOMY AND SUSTAINABLE GROWTH - EVIDENCE FROM NORTH MACEDONIA

Abstract: *Sustainable economic growth has become a central priority for countries striving to balance economic development with environmental protection and social well-being. The concept of the circular economy (CE), which emphasizes resource efficiency, waste reduction and innovation is increasingly recognized as a pathway to achieving long-term sustainability. Estimating an extended Cobb–Douglas production function that incorporates traditional growth drivers (capital, labour) alongside sustainability-related variables (resource productivity, renewable energy,), the paper tests the hypothesis whether the higher resource productivity and renewable energy use, contributes positively to GDP growth while reducing environmental pressures (decreasing CO₂ emissions). The estimation is made with ARDL model and use annual time-series data for North Macedonia (NM) covering the period from 2000 – 2023.*

The research findings reveal that economic growth in North Macedonia is driven by the traditional factors, especially labour. Also, a 1% increase in resource productivity is associated with a 0.75% increase in GDP is a strong*

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and direct validation of the circular economy concept. It shows that North Macedonia can achieve economic growth not just by extracting and using more resources, but by using them more efficiently. This finding directly supports the idea of "decoupling" economic growth from environmental degradation.

Key words: circular economy, economic growth, resource productivity, renewable energy, CO₂ emissions, North Macedonia

JEL classification: Q0, Q56, O440, E23

INTRODUCTION

In response to growing environmental degradation, resource scarcity and climate change, the CE has emerged as a transformative model for achieving sustainable economic growth. Unlike the traditional linear model of "take-make-dispose" the CE emphasizes resource efficiency, waste minimization and the continual reuse of materials. This model is particularly relevant for developing economies like North Macedonia, where the need to balance economic development with environmental sustainability is increasingly urgent.

North Macedonia has recently taken significant steps toward embracing CE principles. In 2024, the country adopted the OECD Roadmap towards a Circular Economy, aligning with the European Union's Green Agenda and the Sofia Declaration for the Western Balkans. This roadmap outlines over 40 policy recommendations across five priority sectors—SMEs, construction, biomass and food, textiles and mining aimed at improving resource productivity, promoting renewable energy and reducing environmental impact. These policy efforts reflect a growing recognition that CE strategies can serve as a catalyst for long-term sustainable growth. However, the transition remains slow due to weak policy coordination, limited financial support and a continued reliance on fossil fuels. (Daniloska, Boshkovska 2025).

This study investigates the impact of CE indicators on economic growth in North Macedonia from 2000 to 2023. Using an extended Cobb-Douglas production function and the Autoregressive Distributed Lag (ARDL) model, the analysis incorporates GDP as the dependent variable and capital, gross capital formation, labour, resource productivity, renewable energy use and CO₂ emissions as explanatory variables. The goal is to estimate both short and long-run effects of CE practices on economic performance.

By integrating recent policy developments and empirical evidence, this paper aims to provide a comprehensive understanding of how CE influence growth based on estimation on selected variables and will suggest recommendation for successful transition toward sustainable growth in North Macedonia.

1. THE IMPORTANCE OF CE IN THE TRANSFORMATION TOWARD SUSTAINABLE GROWTH IN NORTH MACEDONIA

The CE has emerged as a transformative framework for achieving sustainable growth, particularly in economies facing structural limitations and environmental pressures. In North Macedonia, where productivity remains low and economic growth is largely driven by labour and capital intensification (Djambaska et al., 2022), the CE offers a strategic pathway to decouple growth from resource depletion and environmental degradation. By promoting resource efficiency, waste minimization and regenerative production models, CE can enhance long-term competitiveness and resilience.

North Macedonia's economic structure, dominated by traditional sectors such as agriculture, retail and low-tech manufacturing limits its capacity for innovation and high-value output. The integration of CE principles into these sectors, especially through small and medium-sized enterprises (SMEs), is critical. As Hadzi Naumova-Mihajlovska et al. (2022) emphasize, government policies targeting green economy development in SMEs are essential for fostering environmental sustainability and economic modernization.

The literature underscores the importance of CE in driving sustainable development. Angelova et al. (2022) link CE with ESG (Environmental, Social, and Governance) frameworks, arguing that circular practices reinforce sustainability by reducing emissions, conserving resources and promoting social inclusion. Globally, CE is recognized as a key mechanism for achieving climate goals and mitigating biodiversity loss (Khanna et al., 2022). Moreover, CE contributes to employment generation and innovation, particularly in labour-intensive sectors (Shaheera & Imala, 2024).

Despite policy alignment with EU sustainability directives, North Macedonia's CE transition is hindered by low enterprise productivity, limited green investment and weak institutional capacity. The World Bank's Enterprise Surveys reveal negative productivity growth across key sectors, highlighting the urgency for structural reform (Djambaska et al., 2022). Strengthening gov-

ernance, stimulating green innovation and enhancing human capital are vital for embedding CE into the national development agenda.

Together, these studies reveal that while North Macedonia has begun aligning with CE principles, significant gaps remain in policy integration, institutional capacity and enterprise-level adoption. The literature consistently calls for coordinated reforms, stakeholder engagement and investment in human capital to unlock CE's full potential for sustainable growth.

Existing literature highlights that CE practices, particularly circular material use (CMU) play a pivotal role in enhancing resource productivity across EU member states. Islam and Afolabi (2025) demonstrate that higher CMU significantly increases a country's likelihood of belonging to a high-resource productivity cluster, underscoring its impact on economic efficiency and sustainability. Similarly, Nowak-Marchewka et al. (2025) emphasize that national strategies aligned with EU CE policies contribute to improved waste management, energy efficiency and long-term competitiveness in countries like Poland, Netherlands and Romania.

While there has been extensive research on the role of resource productivity and CE practices in EU member states, there is still a lack of empirical evidence for small, transition economies like North Macedonia. Most existing studies focus on advanced economies where institutional frameworks and circular infrastructures are already well-developed, leaving a gap in understanding how resource productivity affects growth sustainability in candidate countries with weaker systems. This paper addresses these gaps by providing a country-specific econometric analysis of North Macedonia, thereby contributing to both the academic literature and policy dialogue on sustainable convergence with the EU.

2. CE AND SUSTAINABLE GROWTH IN NORTH MACEDONIA: EVIDENCE FROM ARDL ESTIMATION

This paper uses an extended Cobb–Douglas production function to estimate the impact of CE determinants on sustainable economic growth in North Macedonia. The model expands beyond traditional inputs of capital and labour by incorporating resource productivity, renewable energy and CO₂ emissions as additional explanatory variables. This extension allows the analysis to capture both economic and environmental dimensions of growth. The functional form is expressed in log-linear terms as:

$$\ln\text{GDPT}=\beta_0+\beta_1\ln\text{Kt}+\beta_2\ln\text{Lt}+\beta_3\ln\text{RPt}+\beta_4\ln\text{REnt}+\beta_5\ln\text{CO2t}+\epsilon$$

The changes in the GDP, as a depended variable, it is assumed to be explained with the capital, labour, resource productivity, renewable energy and CO2 as independent variable of the model. The independent variables were selected based on established economic growth theory and their relevance to CE frameworks, while also reflecting the availability of consistent annual data for North Macedonia. This combination ensures the variables provide both theoretical validity and practical suitability, making them the best fit for the extended Cobb–Douglas model. Therefore, the explanation of the independent variables is:

- Capital (GFC) – expressed as the gross capital formation (GFC) as a% of GDP, measures a country’s investment in fixed assets like buildings and machinery. It is a key indicator of investment in the economy. An increase in physical capital stock leads to increased productivity and economic expansion. Hence, it is expected positive influence on economic growth (+).
- Labour (EMP) – represents the level of employment, which is the number of people who are working. According to Okun’s Law, there is a strong relationship between employment and economic growth. An increase in employment increases the amount of labour in the production process, which in turn increases economic output (+).
- Resource productivity (RES) - refers to the efficiency with which a country uses its natural resources to generate economic output. An increase in resource productivity means that an economy can produce more goods and services with the same or fewer natural resources, leading to more sustainable and efficient economic activity. This is a key component of green growth theories (+).
- Renewable energy (RENEN) - represents the consumption of energy from renewable sources such as solar, wind and hydropower. The use of renewable energy is linked to sustainable economic growth as it reduces a country’s reliance on limited fossil fuels and minimizes environmental pollution (+).
- Carbon dioxide emissions (CO2) - measures the level of carbon dioxide emissions, which is a common indicator of environmental degradation. The relationship between CO2 emissions and economic growth is complex. The Environmental Kuznets Curve (EKC) hypothesis suggests that environmental degradation initially rises with economic develop-

ment and then declines. Therefore, the influence can be either positive or negative depending on the stage of economic development (+/-).

Table 1 Variables in the model

Variable	Proxy / Measure	Source
GDP	Gross Domestic Product (constant US\$)	World Bank WDI
K (Capital)	Gross Capital Formation (% of GDP)	World Bank WDI
L (Labour)	Employment / Number of employees	World Bank WDI
RP (Resource Productivity)	GDP per unit of Domestic Material Consumption	Eurostat / State Statistical Office of North Macedonia
REN (Renewable Energy)	Share of renewable energy in total final energy consumption (%)	Eurostat / IEA
CO₂	Carbon dioxide emissions (metric tons per capita)	World Bank / IEA

Note: All variables are transformed into natural logarithms for estimation.

Source: <https://databank.worldbank.org/reports.aspx?source=worldwide-governance-indicators>; <https://ec.europa.eu/eurostat/data/database>; <https://www.iea.org/data-and-statistics>;

Annual data from the World Bank, Eurostat, the International Energy Agency (IEA), and the State Statistical Office of North Macedonia from 2000 to 2023 were collected. All series were transformed into natural logarithms, enabling the interpretation of coefficients as elasticities.

The analysis applies the Autoregressive Distributed Lag (ARDL) approach, which is particularly suited for small sample sizes and mixed integration orders of variables. Prior to estimation, unit root tests (ADF, PP, KPSS) were conducted to determine the stationarity properties of the data. The ARDL bounds testing procedure was then applied to assess the existence of long-run relationships among the variables.

The ARDL framework provides both short-run dynamics and long-run equilibrium estimates, making it ideal for assessing the sustainability of growth. An error correction mechanism (ECM) was included to capture the speed of adjustment toward equilibrium. Diagnostic tests for serial correlation, heteroskedasticity, normality and model stability were performed to ensure robustness of results.

This methodological framework ensures that the study not only quantifies the contributions of traditional factors but also evaluates the role of CE practices in shaping long-run sustainable growth in North Macedonia.

Table 2 ARDL Estimation Results (Dependent Variable: LNGDP)

Variable	Coefficient	Std. Error	t-Statistic	p-Value
LNGDP(-1)	0.2593	0.0817	3.1734	0.0247**
LNGCF (Capital)	-0.3785	0.1126	-3.3621	0.0201**
LNEMP (Labor)	1.2781	0.2769	4.6160	0.0058***
LNCO₂	0.1349	0.0810	1.6651	0.1568
LNRENEN (Renewable energy)	-0.2601	0.0574	-4.5313	0.0062***
LNRES (Resource productivity)	0.7537	0.0911	8.2752	0.0004***
C (Constant)	-7.4531	2.9439	-2.5317	0.0524*

$R^2 = 0.999$; $Adj. R^2 = 0.998$; F -statistic = 792.72 ($p = 0.0000$).

Source: own estimations using E-views statistical packages

The empirical findings (table 2) partly confirm theoretical expectations, while also revealing notable deviations. Estimated coefficient of the GDP evident positive and statistically significant effects (0.26), that suggest that around 26% of previous year’s GDP carries over to current year. This confirms growth inertia in the economy, meaning that past performance strongly influences at current output.

In alliance with the growth theory, labour emerges as a strong positive contributor to GDP, with an elasticity greater than one (1.278, $p = 0.0058$). So, a 1% increase in employment contributes to about 1.28% increase in GDP. This confirms the strong role of human capital and labour input as a driver of growth and economic performance in North Macedonia. Also, the model confirms the positive and a highly significant influence of resource productivity on growth (0.7537, $p = 0.0004$), aligns with CE theory. This confirms that efficiency in material use directly enhances competitiveness and sustainability, highlighting resource productivity as a key policy lever for achieving both economic and environmental goals.

By contrast, the results for capital formation, renewable energy, and CO₂ emissions diverge from theoretical predictions. Capital, expected to positively affect GDP, shows a significant negative impact, suggesting inefficiencies and potential misallocation of investments into less productive or resource-intensive sectors. Renewable energy also displays a negative relationship with growth, contrary to its theoretical role as a driver of sustainable development. This likely reflects the short-run costs of transitioning to renewables and the country’s structural dependence on fossil fuels. Finally, CO₂ emissions, expected to reduce growth through environmental degradation, appear positive

but statistically insignificant, indicating that growth remains only partially decoupled from emissions.

Table 3 Short – run coefficient (Bound test)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP(-1)*	-0.740638	0.080831	-9.162847	0.0003
LNGCF**	-0.378549	0.103464	-3.658766	0.0146
LNEMP**	1.278087	0.224997	5.680475	0.0024
LNCO2**	0.134885	0.082148	1.641976	0.1615
LNRENEN**	-0.260059	0.065023	-3.999529	0.0103
LNRES**	0.753662	0.086781	8.684685	0.0003
C	-7.453127	2.271358	-3.281353	0.0219

Source: own estimations using E-views statistical packages

The short-run coefficients represent the immediate impact of a change in an independent variable on the dependent variable. The coefficient from the Bound test (table 3) shows that GCF, EMPL and RES are statistically significant. Therefore, short-run coefficients that are statistically significant: labour coefficient of 1.278087 (Prob. 0.0024) indicates that a 1% increase in the change of employment leads to a 1.28 % increase in the change of GDP in the short term, resource productivity 0.753662 (Prob. 0.0003), where 1% increase of the resource productivity leads to a 0.75 % increase in GDP in short term (table 3).

Table 4 Long-Run Cointegration Results

Variable *	Coefficient	Std. Error	t-Statistic	Prob.
LNGCF	-0.511112	0.111596	-4.580026	0.0025
LNEMP	1.725657	0.213947	8.065823	0.0001
LNCO2	0.182121	0.107570	1.693038	0.1343
LNRENEN	-0.351129	0.077123	-4.552843	0.0026
LNRES	1.017585	0.035357	28.78056	0.0000

*Notes: ***, *, * denote significance at the 1%, 5%, and 10% levels, respectively.

The results confirm a stable long-run equilibrium relationship between GDP, capital, labour, CO₂ emissions, renewable energy, and resource productivity.

Source: own estimations using E-views statistical packages

Based on the cointegrating results (Table 4) in the long run, GCF, EMP RENEN and RES all have a statistically significant relationship with the dependent variable. A positive long-run relationship was found for employment and non-renewable energy consumption, while, a negative one was found for capital formation and renewable energy consumption. However, the effect of carbon emissions was not statistically significant.

The Breusch-Pagan-Godfrey test is used to check for heteroskedasticity. The results are F-statistic - 3.876592 with a probability of 0.0793 and R^2 is 9.876824 with a probability of 0.1299. Since the p-values for both the F-statistic and the R^2 are greater than the conventional significance level of 0.05, we fail to reject the null hypothesis of homoskedasticity. This means that the model's residuals do not show evidence of heteroskedasticity. The use of Huber-White-Hinkley (HC1) heteroskedasticity consistent standard errors in regression further ensures the reliability of t-statistics and probabilities, even if heteroskedasticity were present. The Ramsey RESET test evident the F-statistic that is 6.627767 with a p-value of 0.0617. Results suggest that there is no statistically significant evidence of a model specification error. This Ramsey RESET test confirms that the linear functional form of the model is appropriate for the data and that there no major omitted variables or non-linear relationships that need to be addressed.

3. POLICY RECOMMENDATION

The empirical results of the extended Cobb–Douglas model highlighted the critical role of labour and resource productivity in driving sustainable economic growth in North Macedonia. To capitalize on these findings, policymakers should prioritize strategies that enhance human capital and promote efficient resource use.

Strengthen labour market policies - Given the strong elasticity of employment (1.278), investments in education, vocational training, and labour mobility should be intensified. These measures will not only boost productivity but also ensure inclusive growth by integrating more citizens into the formal economy.

North Macedonia's commitment to human capital development is firmly established in the Strategy for Human Capital Development 2022-2030, which outlines a long-term vision for improving education, workforce skills and labour market inclusion. The strategy prioritizes modernizing vocational education and training (VET), promoting lifelong learning and enhancing

labour mobility especially for youth, women and vulnerable groups. These goals are reinforced by the Employment and Social Policy Reform Programme (ESRP) and the Economic Reform Programme (ERP) 2023-2026, which emphasize targeted training, adult education and activation measures. Strengthen labour market policies and investment in vocational training directly supports these national priorities, aligning with the broader objective of building a competitive, inclusive and workforce ready for future. (Roadmap North Macedonia, 2024)

Promote resource efficiency - Resource productivity shows a robust positive impact on GDP (0.7537), affirming its centrality to CE success. Policies should support eco-innovation, industrial symbiosis and waste-to-resource initiatives. Tax benefits or subsidies for firms adopting resource-efficient technologies can accelerate this transition. The OECD's Roadmap towards Circular Economy of North Macedonia (OECD, 2024) identifies resource efficiency as a cornerstone of sustainable growth. The recommendation to stimulate eco-innovation and industrial symbiosis directly supports this roadmap, which promotes circular business models and better material use across sectors like construction, textiles and food.

Reform capital allocation - The negative impact of capital formation suggests inefficiencies in investment targeting. A national investment audit should be conducted to redirect funds toward high-productivity and low-carbon sectors. Public-private partnerships in green infrastructure and digital transformation can enhance capital effectiveness. This aligns with OECD concerns about misallocated resources and the need for better investment targeting. Investment audit and redirection toward green infrastructure fills a critical gap in current policy execution.

Accelerate renewable energy transition – Use of renewable energy currently shows a negative growth correlation, likely due to transitional costs. To reverse this, the government should implement phased subsidy schemes, grid modernization and local capacity-building to reduce dependency on fossil fuels and improve renewable integration. North Macedonia has committed to the Green Agenda for the Western Balkans and EU climate goals, including expanding renewable energy. However, the recommendation address transitional costs and grid modernization reflects the OECD's observation that infrastructure limitations and financial constraints are slowing progress.

Decouple growth from emissions - the weak link between GDP and CO₂ emissions highlights the need for stronger decarbonization policies. Introducing carbon pricing, enhancing emissions monitoring and supporting

low-emission technologies will help align economic growth with environmental sustainability (Daniloska et.al 2025). Emphasizing the carbon pricing and emissions monitoring echoes the roadmap's call for stronger environmental governance. While CO₂ emissions are acknowledged in national strategies, this recommendation adds urgency and specificity to the decoupling challenge that remains unresolved.

By aligning policy with these findings, North Macedonia can foster a resilient, inclusive and green economy that meets both present and future sustainable development goals.

CONCLUSION

This study aims to analyse the relationship between CE determinants and economic growth in North Macedonia using an extended Cobb–Douglas production function and the ARDL methodology. The findings provide important insights into how traditional and sustainability-related factors shape the country's growth trajectory. The results highlight labour and resource productivity as the strongest positive contributors to GDP. Labour elasticity exceeds unity, indicating that employment expansion has a substantial effect on growth, while resource productivity has a robust and highly significant impact. This confirms the theoretical argument that greater efficiency in resource use directly supports competitiveness and sustainable expansion. For North Macedonia, policies that enhance skills, human capital and resource efficiency will be critical to aligning growth with EU sustainability objectives. Conversely, gross capital formation exerts a negative effect on growth. This suggests inefficiencies in investment allocation, with capital directed toward sectors that do not generate sufficient productivity gains. Similarly, the share of renewable energy shows a negative impact on GDP. While counterintuitive, this may reflect the high transition costs of renewable deployment and structural reliance on fossil fuels. These findings point to the need for better integration of renewables and more strategic, productivity-oriented investment. The effect of CO₂ emissions is positive but insignificant, implying that growth in North Macedonia remains only partially coupled to environmental pressures. The significant error correction term indicates that the system is stable and converges quickly to long-run equilibrium, confirming the presence of a durable relationship between GDP and the included variables.

Overall, the results of the ARDL model suggest that sustainable growth in North Macedonia will depend less on traditional capital accumulation and

more on labour productivity, resource efficiency and effective energy transition policies. Strengthening these areas will be essential for meeting EU accession goals and achieving long-run sustainable convergence.

To ensure sustainable economic growth, North Macedonia must prioritize labour market development through strategic investments in education, vocational training and workforce mobility. Advancing resource efficiency by promoting eco-innovation and CE practices is essential for aligning productivity with environmental goals. Capital allocation reforms should redirect investment toward high-productivity and low-carbon sectors, while the renewable energy transition requires phased subsidies and infrastructure modernization. Finally, implementing robust decarbonization measures such as carbon pricing and emissions monitoring will help decouple growth from environmental degradation, positioning the country toward a resilient and inclusive future.

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