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SUSTAINABLE ECONOMIC GOALS BASED ON DETERMINANTS OF RESOURCE PRODUCTIVITY IN THE NETHERLANDS AND HUNGARY

Abstract

Resource productivity has become an important indicator of sustainable economic growth in a situation when natural resources are becoming scarce and environmental stress is growing. This paper examines the drivers of resource productivity in the case of the Netherlands and Hungary, two countries featuring diversified economies and contexts. This paper evaluates the contribution of waste management, renewable energy sources, human capital, investment, and innovation to sustainability by adopting a combined methods approach. Data from Eurostat and ODYSSEE databases, covering the period from 2011 to 2021, were analyzed using time series comparison and structural equation modeling (SEM). The results indicate that factors such as employment rate, gross fixed capital formation (GFCF), waste recycling, and renewable energy significantly influence resource productivity. The results indicated absolute decoupling for the Netherlands, represented by a 40% increase in productivity with an 11% reduction in materials. In comparison, Hungary recorded relative decoupling with GDP and material consumption increasing by about 49% and 37%, respectively. These findings underpin the importance of tailored policies for the enhancement of resource efficiency and sustainable development.

Keywords efficiency, waste, imports, investments, infrastructure, energy, capital, regression, knowledge

JEL Classification Q56, Q53, O44, C33

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INTRODUCTION

Efficient and sustainable use of resources has emerged among the most imperative challenges of the 21st century, considering the continuous confrontation with economic growth and environmental protection. Besides the increase in global demand, the finiteness of the resources on the Earth forces movement toward mechanisms that balance development and sustainability. Further, the rapid pace of industrialization and urbanization increases the burdens on natural resources, adding to the burden while being part of economic growth. The resolution of these interactions implies long-term ecological stability and economic prosperity.

Resource productivity refers to the level of economic output per unit of used resource. It is another important perspective that usually puts into view the linkage of resource use with economic development. Policymakers and researchers increasingly use this metric to gauge how well economies succeed in keeping resource consumption in step with the chase for economic growth. This fact is relevant because it actually measures progress toward decoupling economic activity from environmental degradation – a core objective of global sustainability agendas, such as those presented by the United Nations through its

SDGs. Thus, increases in resource productivity will empower a nation to reduce adverse environmental impacts from its economic activities while remaining competitive within a resource-scarce world.

One underpinning scientific problem has to do with the fact that resource productivity is a multivariate and context-dependent attribute. In determining efficiency in the use of resources, there is an intricate interaction among economic, technological, social, and environmental factors. These interactions further vary substantially among countries at various levels of economic development with different structures of industry and different policy frameworks in place. Resource efficiency for the highly industrialized countries with well-developed infrastructure and technological capabilities, for example, could probably be driven mainly through innovation, while for the transitional economies, investment in basic infrastructure and human capital could remain key sources of productivity gain. These different pathways must be understood so that efficient resource efficiency enhancement strategies tailored to specific contexts are designed.

It is also underpinned by an interest in the study of resource productivity due to the implications of resource scarcity and environmental degradation. Resource use has been manifested in the forms of the depletion and degradation of raw materials, gigantic rates of deforestation, water shortages, biodiversity losses, and an increase in levels of greenhouse gases in the atmosphere at a rapidly growing global scale. The requirement for more innovative management of resources that is less detrimental to the environment while fostering economic development becomes arguably apparent. Within this growing awareness and framing of resource productivity as an operative target indicator, there remain vacuums of analysis regarding drivers of resource productivity, particularly on interactions of economic and environmental systems at different national levels.

1. LITERATURE REVIEW AND HYPOTHESES

The concept of sustainability has gained significant attention in recent decades, with various frameworks developed to address the challenges of balancing economic growth with environmental preservation. Meadows et al. (1972) stressed that infinite growth is impossible on a finite planet, but sustainability is theoretically feasible. The concept of sustainability was introduced into public consciousness by the Brundtland (1987) Report published by the United Nations. However, scientists were already aware of this fact 15 years earlier (Meadows et al., 1972). The resources of the planet Earth are limited and finite. The UN also addresses sustainability among the global problems (UNDP, n.d.). One of the possible solutions is the technological development related to Industry 4.0, which offers hope for a more efficient use of scarce resources. However, the issue is more complex than that. The IPAT equation, created in the context of the debate between Ehrlich and Holdren (1972) and Commoner et al. (1972), illustrates well that environmental impact is shaped by population, affluence, and technology together. Unfortunately, all three factors currently contribute to the increase in environmental impact. In addition, the more efficient and cheaper availability of resources also increases their consumption (Jevons & Flux, 1865; Saunders, 1992). Sustainability is characterized by several indicators (Bell & Morse, 2012; Yumashev et al., 2020). One of the most commonly used indicators is resource productivity, or efficiency. This is also one of the key indicators of this analysis, as it aims to explore which economic growth factors influence the efficient and economical use of resources. In simple terms, the goal is decoupling. This means that the economy grows faster than the burden on the environment (Hirschnitz-Garbers et al., 2013; Ruffin, 2006).

Resource productivity is the ratio of gross domestic product (GDP) to domestic material consumption (DMC). This indicator can be used to determine the extent to which natural resources are used for economic growth. Its increase indicates that economic growth is causing less environmental damage. DMC equals the difference between domestic extraction and imported and exported materials (KSH, 2023a). According to Huysman

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et al. (2015), the value of resource efficiency is influenced by several indicators, such as employment rate, gross fixed capital formation, research and development (R&D), waste recycling, use of renewable energy, training, the proportion of the tertiary sector, raw material imports, and circular material use. Different authors and studies have shown that the impact of these factors may vary from country to country.

The effects between employment rates and DMC may differ across countries, depending on the structure of the economy and the characteristics of the labor market. Mazzanti and Zoboli (2009) conclude that higher employment rates can increase material consumption in the industrial sector. On the other hand, increased employment in the service sector can reduce DMC. Several studies have shown that Gross Fixed Capital Formation (GFCF) has a direct impact on DMC. Higher investment rates tend to increase material consumption, especially in construction and infrastructure developments (Eurostat, n.d.). The expansion of the service (tertiary) sector is generally less material-intensive than industrial production. Some studies suggest that countries with a higher share of the service sector have lower DMC, as the provision of services requires less material consumption (Eurostat, n.d.). However, significant differences between countries in the structure and intensity of investment lead to different effects on DMC.

R&D activities promote innovation and resource efficiency, which can reduce material consumption. According to Horbach (2010), countries with higher R&D expenditure have lower DMC, as innovations contribute to more efficient material use and more sustainable production methods. Increasing waste recycling can reduce the demand for primary raw materials, thereby reducing DMC. In some countries, such as Germany and the Netherlands, high recycling rates have contributed to a decrease in DMC (OECD, 2019). However, in other countries, this effect is less significant due to lower recycling rates.

The use of renewable energy sources can reduce the demand for fossil fuels, which indirectly affects DMC. Some studies suggest that countries with a high share of renewable energy have lower DMC, as the use of renewable energy sources is less material-intensive (IRENA, 2018). However, the construction of renewable energy infrastructure as an investment may initially increase material use. High levels of training and education promote sustainable consumption and production habits, which can reduce material use. Some studies suggest that countries with higher levels of education have lower DMC, as a skilled workforce is more efficient and innovative (UNESCO, 2017).

Imports of raw materials directly increase DMC, as imported materials become part of domestic consumption. The degree of import dependence and the type of imported materials vary from country to country, which has different effects on DMC. For example, Japan has a high DMC due to high raw material imports, while Australia is dominated by domestic extraction (UNEP, 2016). Some countries, such as Finland and Sweden, have successfully integrated circular economy principles into economic and social strategies, which has contributed to reducing material consumption (Geissdoerfer et al., 2017). These countries encourage recycling, extending the life of products and reusing waste, all of which reduce DMC. In contrast, in countries where circular economy principles are less present in policy, such as some developing countries, DMC reduction is less effective. Differences between countries may be further exacerbated by technological access and level of economic development.

Differences between countries in the impact of factors influencing DMC have been well documented. Eisenmenger et al. (2020) have shown that in countries with high economic development, DMC growth slows down or stagnates as the economy shifts from resource-intensive sectors to the service sector. In contrast, in developing countries, DMC growth is faster due to industrialization processes.

One key factor in the differences in industrial structure is that while industrial production and infrastructure investments dominate in developing countries, R&D and the tertiary sector play the main role in developed countries (Schandl et al., 2016). In a comparison between OECD countries, countries with high recycling rates have lower DMC growth rates (OECD, 2019).

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The study explores how sustainable economic growth can be combined with an environmentally conscious, "green" approach. It examines the economic indicators that can be used to assess whether progress is being made toward this goal. Specifically, it focuses on comparing the sustainability indicators of Hungary and the Netherlands, examining similarities and differences in their paths and pace toward a green transition. The Netherlands is used as a reference due to its remarkable achievements in sustainability, especially in areas such as high-density management, adaptation to sea level rise, precision agriculture, and successful energy transition.

The impact on DMC varies across countries, and these differences can be explained by a number of factors, including economic development, industrial structure, sustainability policies and the level of social awareness. In developed countries, the development of DMC is significantly influenced by R&D, the expansion of the service sector, and the application of circular economy principles. In contrast, in developing countries, industrialization and infrastructure investments dominate, increasing material consumption. Waste recycling, renewable energy, raw material imports, and the level of education are also important factors that affect DMC differently in individual countries (OECD, 2019; IRENA, 2018; UNEP, 2016; UNESCO, 2017). In order to achieve the Sustainable Development Goals, countries need to take into account their own economic and social conditions while promoting more sustainable material use practices.

Achieving sustainability requires a multifaceted approach that considers not only technological advancements but also the complex interplay of factors such as population growth, affluence, and economic structure. The comparison of Hungary and the Netherlands highlights the varying paths countries take toward sustainable economic growth, with differing impacts shaped by policies, technological development, and resource efficiency. This analysis underscores the importance of context-specific strategies to balance economic growth with environmental preservation.

The purpose of the paper is to examine the extent to which growth factors (investments, material consumption, human capital, knowledge capital, research and development, the rate of use of renewable energy sources, and environmental awareness) contributed to the environmental impact in Hungary and the Netherlands in the period between 2011 and 2021. After reviewing the literature, the following hypotheses were formulated:

H1: *Each listed growth factor plays a role in the increase in environmental load.*

H2: *Better performance in knowledge capital, environmental awareness, and research and development mitigates the environmental burden caused by economic growth.*

2. METHOD

The methodology for this study is structured to ensure a comprehensive and consistent analysis of sustainability metrics across different European countries. The data sources and analytical techniques have been carefully chosen to provide reliable and comparable results.

Eurostat data were used for this study. This ensures sample representativeness and data collection and presentation methodological consistency while permitting cross-national comparability. Thus, the findings are broadly applicable. Use of the databases is ethical since they are freely accessible online. Finally, Eurostat's organizational structure assures data accuracy, which was important while picking data sources. Supplemental data come from an EU energy efficiency database – ODYSSEE.

Based on Bartus (2013b), the study selected database data for sustainability metrics. The indicators are linked to the Hungarian sustainability concept, as Bartus (2013a) explained. This definition of the UN is incorrect (UN Department of Economic and Social Affairs, n.d.). The narrower Hungarian definition of sustainability is resource conservation and efficient use. With a two-year report on sustainability indicator system development from 2007, the KSH has followed the Hungarian model (Szűcs & Rausz, 2007). KSH starts annual reports in 2020; the most current (KSH, 2023b) incorporates 2022 data. Time series comparison was the main data processing strategy for this study. This method also allowed it to compare countries and track the indicator's trend.

In three more groups, variables are examined. The first category includes economic growth-related indicators. Employment, gross fixed capital formation (GFCF), and tertiary sector GDP percentage are used to measure human resources, investments, and economic structure. GFCF is resident producers' fixed physical or intangible asset acquisitions minus disposals. This covers PP&E as a percentage of GDP. Economic crises greatly affect the GFCF. Following the reduction in consumption, the GFCF (especially private GFCF) fall is the second biggest factor in the COVID-19 recession (Licchetta & Meyermans, 2022). A year passed after the epidemic, while the GFCF needed 10 years to recover from the 2008 financial crisis. Public investment and decision-making are vital to economic progress.

Employment knowledge, the proportion of all occupations in high- and mid-tech sectors, is one of this study's second set of variables, which are related to knowledge capital. R&D is another factor. The systematic creative endeavor called "research and experimental development" (R&D) expands knowledge of individuals, cultures, and society.

The third aspect is environmental awareness. It includes the proportion of recycled rubbish, renewable energy, and imported raw materials. Another measure of environmental sensitivity is rail transit's share of public transportation.

The 28th figure in the sample of 27 EU countries is the EU average. Eurostat statistics were used to create the 2011–2021 time series. The tertiary sector ratio is calculated using World Bank statistics. Jamovi 2.3.21.0 and MS Excel for Mac v.16.74 handled data and ran tests. Also, the study used SMART-PLS and a structural equation model (SEM) (4.0.9.5). Table A1 and Figure 1 provide representative descriptive statistics. No item is missing from the collection of 308 items. The SEM model utilizes several explanatory variables: employment rate (EMP_RATE), gross fixed capital formation (GFCF), research and development (R&D), waste recycling (WAST_REC), renewable energy (REN_EN), training (TRAIN), tertiary sector (TERT_SEC), raw material import (RAW_IMP), and circular material use (CIRC_MAT). These are used to predict the dependent variable, resource productivity (RES_PROD).

Table 1. Output of normality test

Test	Statistic	p
Kolmogorov-Smirnov	0.0391	0.776

Table 2. Cook's distance statistics for influential observations detection

Cook's distance		SD	Range	
Mean	Median		Min	Max
0.00522	0.00113	0.0155	9.86E-9	0.205

In addition, there are no severe outliers according to the Cook's distance estimates (Table 2). The requirement of normalcy is satisfied as the

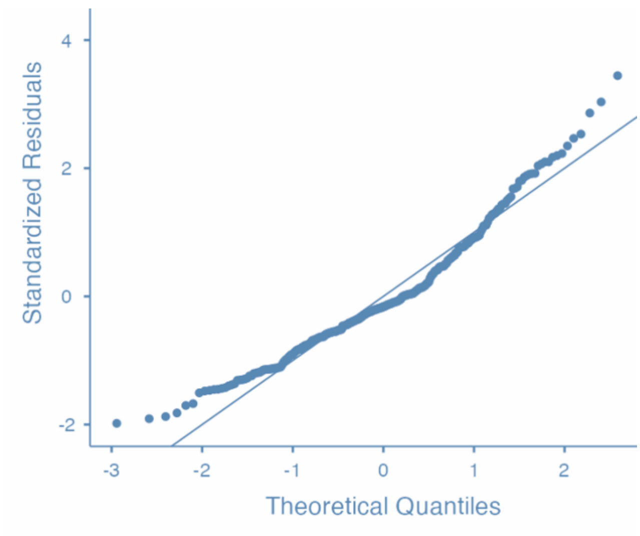

Figure 1. Q-Q plot of normality

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Kolmogorov-Smirnov test (Table 1) yields no significant results. Normalcy and linearity may also be presumed based on Figure 1.

The hypotheses are evaluated by regression. Resource productivity is the dependent variable, while the other factors are independent. The paper examines the model's building circumstances before characterizing it, starting with linearity. The independent and dependent variables are assumed to be linearly related. Investment volume, employment rate, employment knowledge, tertiary sector ratio, and R&D success should boost resource productivity. Environmental awareness indicators should also improve. Only raw material imports imply that the nation cannot sustain economic development on its own. Normality and linearity were established for sample descriptive statistics.

The next metric is homoscedasticity. This is supported by the Breusch-Pagan heteroscedasticity test (stat = 81.3, $p < 0.001$) (Breusch & Pagan, 1979). Multicollinearity – excluding variables that move together – is crucial as well. In this colinearity test, all VIF values are over 10, indicating strong multicollinearity. The correlation test revealed a significant correlation (Pearson's $r = 0.708$, $p < 0.001$) between WAST_REC and RAndD variables, disproving multicollinearity. Thus, the variables fulfill the requirements. The simplified model equation (1) is:

$$\begin{aligned} RES\_PROD &= \alpha + \beta_1 \cdot EMP\_RATE \\ &+ \beta_2 \cdot GFCF + \beta_3 \cdot RAndD \\ &+ \beta_4 \cdot WAST\_REC + \beta_5 \cdot REN\_EN \\ &+ \beta_6 \cdot TRAIN + \beta_7 \cdot TERT\_SEC \\ &+ \beta_8 \cdot RAW\_IMP \\ &+ \beta_9 \cdot CIRC\_MAT + \varepsilon, \end{aligned} \tag{1}$$

where RES_PROD: resource productivity; EMP_RATE: employment rate; GFCF: Gross Fixed Capital Formation; RAndD: R&D and renewable energy; EMP_KNOW: employment knowledge; WAST_REC: waste recycling; REN_EN: renewable energy; TRAIN: training; TERT_SEC: tertiary sector; RAW_IMP: raw material import CIRC_MAT: circular material use. To estimate slope parameters, the study used β1-β9 and ε as the error term. The original model includes variable interaction, however equation (1) excludes it to simplify the equation.

An SEM was created to determine whether the study factors impact resource production via GDP or DMC. The model has explained variables GDP and DMC and explanatory variables. Model calculations were done using PLS-SEM (weighting scheme: path, type of results: standardized, starting weight: default).

3. RESULTS AND DISCUSSION

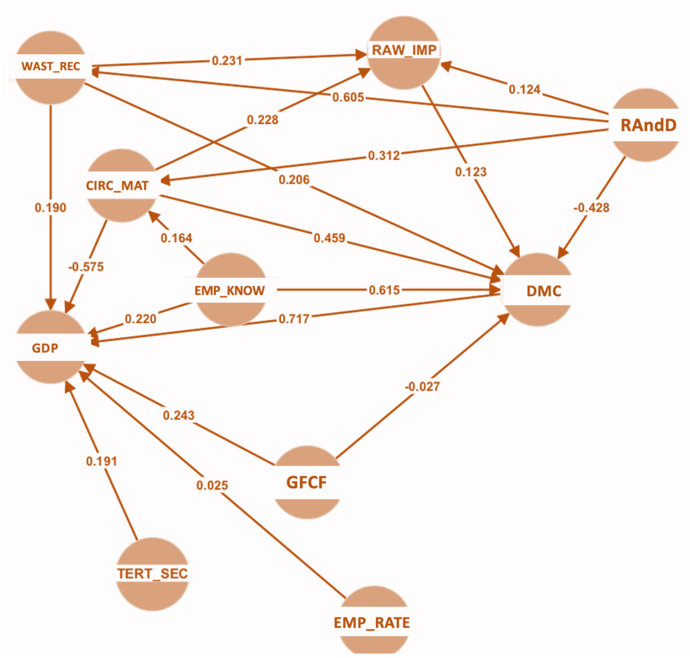
The description of the results starts with an examination of the fit of the model (Table 3). Based on the value of R^2, 78.7% is explained by the included variables, which indicates that there are many other factors in determining the performance of resource productivity. Based on the test result $F(20, 265) = 29.1$, $p < 0.001$, the predictors significantly predict the dependent variable. Equation (2) of the model based on the estimate values of the study is:

$$\begin{aligned} RES\_PROD &= -1193.08 \\ &+ 19.44 \cdot EMP\_RATE + 0.45 \cdot GFCF \\ &- 2.61 \cdot RAndD + 5.34 \cdot WAST\_REC \\ &- 1.79 \cdot REN\_EN + 29.31 \cdot TRAIN \\ &+ 18.47 \cdot TERT\_SEC - 0.06 \cdot RAW\_IMP \\ &- 0.32 \cdot CIRC\_MAT \\ &- 0.34 \cdot (RAndD \cdot REN\_EN) \\ &- 0.82 \cdot (EMP\_KNOW \cdot TRAIN) \\ &+ 0.31 \cdot (REN\_EN \cdot TRAIN) \\ &- 0.33 \cdot (EMP\_RATE \cdot TERT\_SEC) + \varepsilon. \end{aligned} \tag{2}$$

Table 3. Model fit test results

Model	R	R²	Adjusted R²	Overall Model Test			
				F	df1	df2	p
1	0.829	0.787	0.763	29.1	20	265	< .001

Variables with a non-significant effect and those interactions whose absolute value of the effect coefficient (estimate) is below 0.1 are not included in the equation, regardless of whether the given effect is significant or not.



Note: RES_PROD: resource productivity; *EMP_RATE:* employment rate; *GFCF:* Gross Fixed Capital Formation*; RAndD:* R&D and renewable energy; *EMP_KNOW*: employment knowledge; *WAST_REC*: waste recycling*; REN_EN:* renewable energy; *TRAIN:* training; *TERT_SEC:* tertiary sector; *RAW_IMP:* raw material import *CIRC_MAT*: circular material use.

Figure 2. SEM of resource productivity

Based on the estimate-coefficients, the significance of the model at the $p < 0.001$ level is actually based on the employment rate, the economic structure (the proportion of the textile sector) and the environmental awareness variables. Among the latter, primarily, the increase in the ratio of public rail transport significantly increases resource productivity. The other factors are interactions. Waste recycling is also associated with this at the $p < 0.05$ level.

The fit statistics of the SEM model are adequate (SRMR = 0.089, NFI = 0.836). The model is shown in Figure 2 and the direct, indirect and direct effects between the variables are shown in Table A2.

According to the regression model, EU nations may boost resource productivity in three ways. Increasing employment may help low-employment nations. The Netherlands' employment was constantly over 75% throughout the assessment

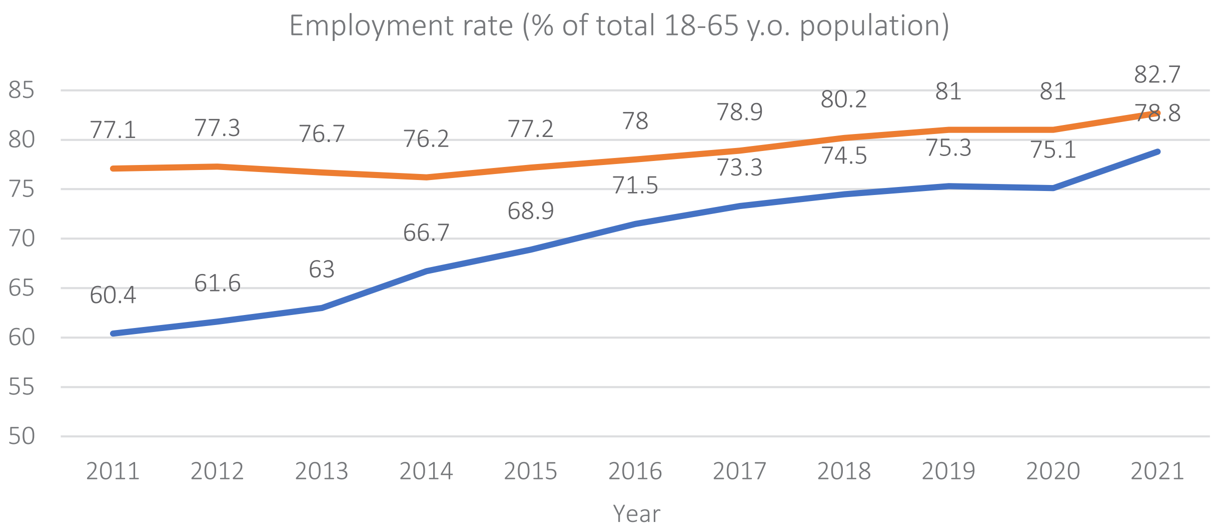


Figure 3. Employment rate in the Netherlands and in Hungary from 2011 to 2021

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period. The employment rate in Hungary rose by over 20% during the same time (Figure 3). This helped enhance resource productivity, but one cannot anticipate any more influence today.

Other options include increasing the tertiary GDP share. A higher service proportion decreases material consumption and boosts GDP, raising environmental protection costs relative to GDP. The Netherlands outperformed Hungary (Figure 4).

Based on the results, the main difference between the two examined countries lies in the political approach. Among government expenditures, environmental spending as a proportion of GDP was higher in the Netherlands than in Hungary throughout the examined period. Furthermore, the level of Dutch spending is steady, while Hungary's environmental spending is fluctuating (Eurostat, n.d.).

The development of resource efficiency in the two countries is similar, but the levels are different (UNECE, n.d.). Table 4 illustrates the development of the reciprocal of resource efficiency, resource productivity, and its components.

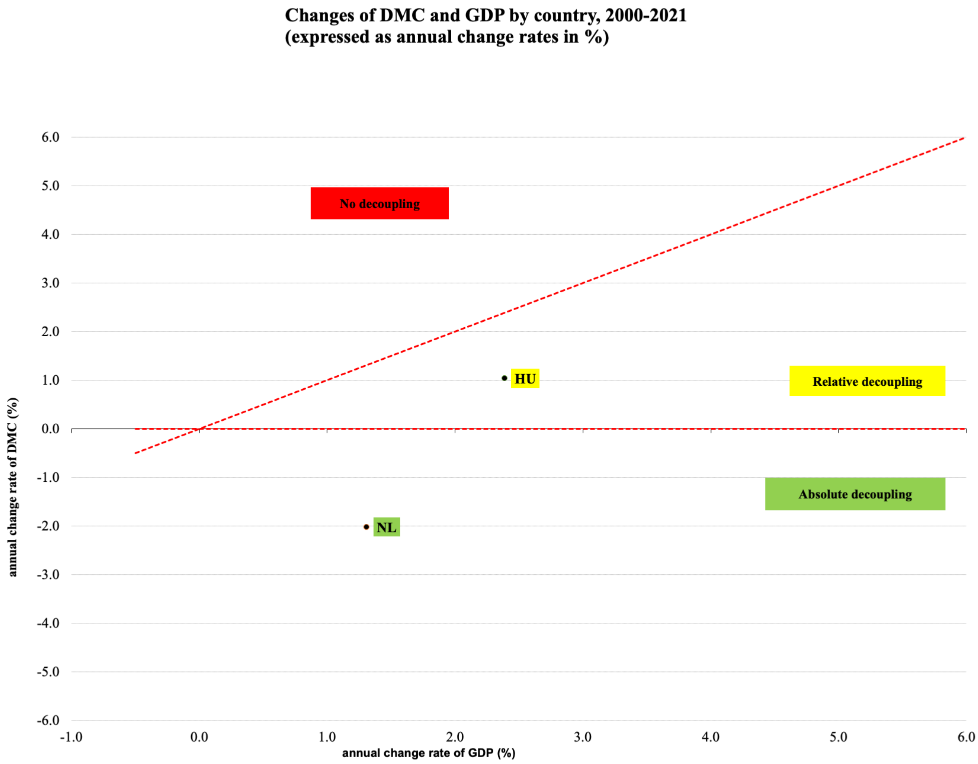
Table 4. Growth of resource productivity and its elements (2011–2022)

Variable	Hungary	Netherlands
GDP/capita (thousand EUR))	49%	25%
DMC/capita (kg)	37%	–11%
Resource productivity (€/1,000kg)	8%	40%

The changes clearly show the difference between the two countries. In Hungary, GDP per capita increased by 49% between 2011 and 2022, while in the Netherlands, the increase in the indicator was only 25%. Meanwhile, Hungary's domestic material consumption increased by 37%, and the Netherlands solved its more modest economic growth by reducing domestic material consumption by 11%(!). Hungary's resource productivity increased by 8%, while that of the Netherlands increased by 40%.

Based on Figure 4, the examined period was realized at the cost of increased environmental impact of Hungarian GDP growth, which is also seen in Table 6. GDP grew faster than DMC (relative decoupling). However, GDP is increasing in the Netherlands, but DMC can be considered constant (absolute decoupling).

Source: Eurostat (n.d.).



Note: GDP in chain-linked volumes, reference year 2015. (1) deviating index base year.

Figure 4. Decoupling in examined countries

The specific demonstrations of the results can be done by detailing the key findings, like what this equation represents in terms of resource productivity and the contribution of each factor. For example, in the given equation, RES_PROD is directly influenced by such variables as employment rate, investments (GFCF), waste recycling (WAST_REC), and renewable energy (REN_EN). This indicates that 78.7% of the variance in resource productivity is explained by the variables included in the model. Moreover, significant results, such as that of investments that reduce DMC or how public transport increases resource productivity, are important from the point of view of practical significance.

The SEM presents the direct, indirect, and total effects of factors. For example, WAST_REC and EMP_KNOW have the largest total effects on resource productivity, with a value of 0.358 and 0.623, respectively. An explanation of such an interaction will better show how many factors interact in producing an overall effect and how complicated some of these relationships could be, such as the interplay between R&D and renewable energy or circular materials.

Table 4 illustrates a comparison of resource productivity growth in Hungary and the Netherlands between 2011 and 2022, where different policy and economic choices yield various results. While Hungary's 49% GDP growth went hand in glove with a 37% increase in material consumption, the Netherlands was able to achieve a 40% increase in resource productivity while simultaneously reducing its material consumption by 11%. This comparison underlines the effectiveness of different approaches while at the same time highlighting the importance of specific policies and practices to resource efficiency.

The findings may be interpreted using the literature review. Resource productivity affects financial sustainability alongside economic development. Material prices rise when supplies run out. For green transition technologies, rare elements like lithium, cobalt, copper, silver, and phosphorus are needed in large quantities. The corporations engaged also use violence. Tesla CEO Elon Musk tweeted on the 2019 Bolivian military attempt: "We will coup anybody we choose!" Deal with it (Kolláth, 2021). Tesla's lithium supply was jeopardized by Morales' plans. Bolivia possesses 25% of the world's lithium deposits.

Thus, resource shortage may drive inflation (Schenabel, 2022; Baranyai & Banai, 2022).

It is hard to attain 100 years of intense production growth now, which exacerbates the challenges. When productivity growth slowed, the 2008 economic crisis began. Why productivity growth did not follow economic growth after the 2008 crisis is still unclear. This conundrum is called the productivity issue in economics (Newman, 2015).

Population, investment, and productivity drive economic development, hence stagnant productivity is an issue. The availability of skilled workers does not rise proportionally with global population growth. The sources of investments are savings (money not spent on consumption), although economic conditions do not simply affect them. Productivity is the third component, which research links to economic growth.

Bloom et al. (2020) report a considerable reduction in scientific production. In the previous century, the USA's Total Factor of Productivity (TFP) has not changed (left scale), while the number of researchers needed to boost productivity has grown twentyfold (right scale). Therefore, nations that emphasize population-savings-productivity may become economic superpowers. EU researchers effectively examined decoupling.

GDP and DMC change at the same pace along the diagonal line. Nations above the diagonal failed to decouple. Hungary and other nations below the diagonal have decoupled. Many European nations, notably the Netherlands and the EU, have achieved absolute decoupling below the horizontal line. This conclusion warrants more investigation since material and energy-intensive industries may have been outsourced abroad. The DMC indicator ignores these factors.

The comparative analysis indicates that employment rates significantly influence resource productivity trends, particularly in labor-intensive sectors. For instance, Hungary's employment increase corresponds to higher DMC, reflecting a

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resource-driven economic expansion. This discussion highlights the need for balanced employment policies that prioritize sustainable productivity in resource utilization.

The SEM model suggests basing public transit on rail for the greatest change. The Dutch railway network is almost countrywide, while Hungary has a highly centralized railway network. Thus, Hungarian railway expansion may boost green economic growth. Rail Carpathia is one of its ideas (Zasiadko, 2022). Another is the Budapest-Belgrade railway line reconstruction.

Paradoxically, increasing the mix of imported raw materials and renewable energy sources and R&D spending appear to be negative. A country compelled to import raw resources cannot base its economic development on its own raw materials, which may explain the negative impact. It reduces resource productivity. Increased renewable energy use depletes rare earth metals and fossil resources.

SEM findings show that GDP and DMC are not totally independent. GDP is directly affected by DMC (+0.71). The percentage of circular material usage (CMU) decreases GDP directly (–0.575) and improves GDP indirectly (+0.349) via raw material imports and DMC (+0.459). Circular material usage increases raw material imports since it uses the same commodities again. However, this may need imported raw ingredients again. Circular material utilization increases DMC since discarded materials are reused again. Waste recycling impacts DMC similarly but without direct reuse.

Paradoxically, increasing CMU in material consumption lowers GDP. This is because circular used materials already make up a large amount of material consumption (McKinsey & Company, 2015). To boost the ratio, considerable technological breakthroughs, and investments are now expensive and unproportional to GDP growth.

Waste is often used to measure environmental effects. Preventing trash is the best approach to lessen its environmental impact. Reuse, recycling, energy recovery, incineration, and landfill are other methods. Recycling and use decreases environmental impact, provides employment, and protects material value.

The Dutch Ministry of Infrastructure and Water Management has a waste reduction strategy for these locations. The ministry promotes sustainable procurement in the public and business sectors (Government of the Netherlands, n.d.). The Netherlands recycles 79% of garbage and uses the rest for energy (Rijkswaterstaat, n.d.). It turned 80% of garbage into a resource.

Investments and employment knowledge rank second in GDP direct impacts. They have 30% of DMC's effect, but their influence shows knowledge capital's importance in economic development. Investments affect both factors directly. They boost GDP and lower DMC due to advances.

R&D's model-based impact is crucial. The most significant effects are on trash recycling (+0.605) and material reuse (+0.312). The DMC drops by 0.428, indicating inventive solutions. It increases raw imports (total effect: +0.335) because new, sophisticated solutions need imported materials. Based on the SEM, the study indices explain GDP growth by 77% ($r2$ = 0.770) and DMC growth by 69% ($r2$ = 0.692).

Hypothesis 1 was supported by the findings, as the regression analysis indicated that several growth factors, such as employment rate, gross fixed capital formation (GFCF), and waste recycling (WAST_REC), were significantly associated with resource productivity, which in turn affects environmental load. The interaction effects, such as between employment knowledge and training, also played a role, suggesting that these factors contribute to the environmental impact.

Hypothesis 2 was partially supported. While knowledge capital (measured through R&D) and environmental awareness indicators (like waste recycling) showed significant positive effects on reducing the environmental burden, the results were mixed. For example, R&D had both positive and negative interaction effects depending on the context. This indicates that while these factors can mitigate environmental impact, their influence is complex and sometimes contradictory.

The model fit and regression analyses, particularly the high R^2 value and significant F-statistics, support the reliability of these findings.

The interaction regression model estimated the development of resource productivity along various factors in Hungary and the Netherlands. Results clearly show the difference in economic structure and resource efficiency between the two countries. From the level of average resource productivity, undoubtedly, one may state that the Netherlands manages its material resources much more efficiently in creating economic value. The reason for this difference is that the Dutch economic structure differs from that of Hungary in having higher levels of innovation and better environmental protection measures. The differences in GFCF to GDP ratios are opposite, i.e., the share of investments is higher in Hungary. Simultaneously, this may be an advantage since, in the long run, investments may create better opportunities for economic growth and/or productivity growth. On the other hand, at the level of the given parameters, the significantly higher level of employment in the Netherlands – while simultaneously and directly stimulating economic activities – contributes to increasing resource efficiency based on the equation. The 'relative advantage' of the Dutch economy is significant also in R&D expenditures. That is to say, the Dutch economy is more innovation- and technological development-oriented, and these are important factors in terms of resource productivity, too. More generally, the Dutch rate of waste recycling is higher, reflecting the more effective Dutch environmental policy, which contributes greatly to efficient material use. Following the larger economic share held by the tertiary sector (service sector), the Dutch economy is more based on high-value-added services, contributing significantly to resource productivity.

Renewable energy is used quite similarly in gross final energy consumption in the considered countries. As the difference is nearly negligible, it can be viewed that in both countries there is a scope for renewable energy sources. Hungary is importing more raw materials. It also means higher material consumption, which reduces resource productivity. The difference quite clearly shows that Hungary has much higher material consumption that negatively affects the resource productivity.

According to the SEM model, the Netherlands has a more sustainable and efficient economic structure because of the higher level of employment rate, R&D expenditure, waste recycling rate, and service sector ratio. Such factors bring higher GDP and lower DMC. Hungary only has a relatively better value of GFCF. However, high material consumption and lower innovation expenditures impede further sustainable development of the economy. With this in mind, Hungary should increase innovation and waste management and reduce material consumption in order to develop in the future.

That is, Hungary has more favorable results, mainly from the point of view of investments, while the Netherlands has an outstandingly higher resource efficiency, supported by advanced innovation activity, high employment, high recycling, and a considerable share of the service sector in the economic structure. Increasing the level of innovation and technological development and increasing the share of waste management and renewable energy sources would contribute to augmenting the resource efficiency of Hungary. The advantages of the Netherlands well reflect the sustainable economic structure that can serve as a model for Hungary during the course of its further development.

The findings are well represented by the so-called decoupling mentioned earlier. That is relative in the case of Hungary, i.e. both GDP and DMC increase, but the growth of GDP is faster. Dutch decoupling is absolute, meaning that while GDP increases, DMC decreases. To achieve absolute decoupling is the goal when striving for sustainable development, since it is the only way to diminish environmental impacts while extending the economy.

CONCLUSION

The paper investigated the factors that determine resource productivity in the Netherlands and Hungary, in order to establish how economic growth aligns with resource use in a sustainable manner. This was premised on the understanding that the finite resources of the Earth have to be used more efficiently if

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the Earth is to be ecologically and economically viable in the long term. The study presented a comparative perspective of two economies based on salient factors such as waste management, renewable energy, investments, and knowledge capital.

Results indicated that both countries have taken steps toward increasing resource productivity, but the process and results have been considerably different. In fact, the Netherlands has manifested an absolute decoupling wherein economic growth became realized, notwithstanding a decline in material consumption. This has been facilitated by high-level innovation, significant R&D capital investments, exceptionally adequate waste recycling systems, and a very high tertiary sector. On the other hand, Hungary has experienced relative decoupling, wherein GDP growth has become higher compared to the growth of material consumption but still becomes highly dependent on high input resources. Investments in Hungary became crucial for high resource productivity but became negated due to low innovation levels and less sustainable waste management methods.

From these findings, some points arise. First, innovation and circular economy principles are key drivers toward sustainable economic growth. Policies focused on R&D, waste recycling, and efficient use of resources can boost productivity with a lower environmental impact. Secondly, a country's economic structure significantly influences the way it achieves its sustainability performance. Moving toward service-based industries, as in the case of the Netherlands, implies lower material intensity. Lastly, specific investments in human capital and infrastructure, along with environmental awareness, are crucial to accomplishing transitions toward sustainability.

This series of studies underlines how significant it is that policies be tailored to respect national contexts while advancing a common cause of sustainability. By filling knowledge capital gaps, waste management, and renewable energy, countries like Hungary can only hope to emulate the affluence of efficiency and innovation seen in the Netherlands.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. Descriptive statistics of the sample with normality test and extreme outliers test

Variable	RES_PROD	EMP_RATE	GFCF	RAndD	EMP_KNOW	WAST_REC	REN_EN	TRAIN	TERT_SEC	RAW_IMP	CIRC_MAT
N	308	308	308	308	308	308	308	286	308	308	308
Missing	0	0	0	0	0	0	0	22	0	0	0
Mean	136	71.4	21	1.65	44.2	36.1	20.6	5.85	63.8	9,324	8.9
Median	130	71.8	20.6	1.38	44.1	36.2	17.6	5.65	64.1	2,857	7.5
Standard deviation	34	6.41	4.24	0.875	7.23	15	11.4	3.25	6.52	16,442	6.38
Minimum	63.6	53.1	10.7	0.38	24.9	8.3	1.88	0.4	42.3	31.8	1.2
Maximum	317	84.7	54.3	3.62	60	71.1	62.6	12.9	80.1	106,958	33.8

Note: RES_PROD: resource productivity; *EMP_RATE:* employment rate; *GFCF:* Gross Fixed Capital Formation*; RAndD:* R&D and renewable energy; *EMP_KNOW*: employment knowledge; *WAST_REC*: waste recycling*; REN_EN:* renewable energy; *TRAIN:* training; *TERT_SEC:* tertiary sector; *RAW_IMP:* raw material import *CIRC_MAT*: circular material use*.*

Table A2. Direct, indirect, and total effects of SEM

direct + indirect (total)	CIRC_MAT	DMC	EMP_KNOW	EMP_RATE	GDP	GFCF	RAW_IMP	RAndD	TERT_SEC	WAST_REC
CIRC_MAT	–	0.459 + 0.028 (0.487)	–	–	−0.575 + 0.34 (– 0.226)	–	0.228 + 0 (0.228)	–	–	–
DMC	–	–	–	–	0.717 + 0 (0.717)	–	–	–	–	–
EMP_KNOW	0.164 + 0 (0.164)	0.615 + 0.08 (0.694)	–	–	0.22 + 0.403 (0.623)	–		–	–	–
EMP_RATE	–	–	–	–	0.025 + 0 (0.025)	–			–	–
GDP	–	–	–	–	–	–	–	–	–	–
GFCF	–	−0.027 + 0 (−0.027)	–	–	0.243 – 0.019 (0.224)	–	–	–	–	–
RAW_IMP	–	0.123 + 0 (0.123)	–	–	0 + 0.088 (0.088)	–	–	–	–	–
RAndD	0.312 + 0 (0.312)	−0.428 + 0.309 (−0.119)	–	–	0 – 0.15 (–0.15)	–	0.124 + 0.211 (0.335)	–	–	0.605 + 0 (0.605)
TERT_SEC	–	–	–	–	0.191 + 0 (0.191)	–	–	–	–	–
WAST_REC	–	0.206 + 0.028 (0.235)	–	–	0.19 + 0.168 (0.358)	–	0.231 + 0 (0.231)	–	–	–

Note: RES_PROD: resource productivity; *EMP_RATE:* employment rate; *GFCF:* Gross Fixed Capital Formation*; RAndD:* R&D and renewable energy; *EMP_KNOW*: employment knowledge; *WAST_REC*: waste recycling*; REN_EN:* renewable energy; *TRAIN:* training; *TERT_SEC:* tertiary sector; *RAW_IMP:* raw material import *CIRC_MAT*: circular material use*.*

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