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Resource productivity and sustainability—a comparison of two European countries

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This research analyzes resource productivity by identifying key elements and their effects. The goal is to examine resource productivity and GDP-DMC correlations in EU member states, notably Hungary and the Netherlands. Researchers selected Eurostat sustainability statistics based on literature. Regression and path models were used to examine the data. GDP is strongly influenced by DMC, according to the research. The research also found that circular material usage might unexpectedly increase material consumption and lower national GDP. The ratio of GDP to DMC, Resource Productivity, oversimplifies sustainability analysis since its numerator and denominator are not independent. SEM showed that GDP and DMC are not separately explained. GDP is the only evident dependent variable, according to this study. The findings show that understanding the complex relationship between material use and economic production is essential to improving resource productivity and sustainability. Hungary and the Netherlands must develop measures to boost resource productivity while balancing economic development and environmental sustainability.

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Introduction

The imperative for sustainable growth has become increasingly evident due to global resource constraints and environmental pressures. This paper investigates a nuanced approach to balancing economic growth with sustainability principles by analyzing resource productivity, primarily through the GDP-DMC (Domestic Material Consumption) ratio. Traditional economic models have simplified this relationship, treating GDP and DMC as independent variables (Krugman and Wells, 2012). However, recent research, particularly within the European context, reveals that material use levels and economic output are intricately linked. This study focuses on Hungary and the Netherlands, two countries with distinct economic structures and sustainability challenges, providing a comparative analysis that highlights the role of resource productivity in aligning economic performance with environmental limits.

In the context of these differing structures, this paper further investigates how Hungary and the Netherlands' unique policy frameworks and economic compositions contribute to resource productivity within sustainability efforts. Prior research has often emphasized the broad impacts of resource productivity on economic growth, yet limited studies have provided a focused, comparative analysis of countries with such contrasting approaches to sustainability. This research aims to bridge this gap by examining not only the economic outcomes but also the social and environmental implications of circular economy (CE) practices in these two nations. By utilizing Structural Equation Modeling (SEM) alongside Eurostat data, this study offers a nuanced perspective on how policy and productivity indicators can be more effectively aligned to support sustainable growth trajectories.

Building upon the established understanding of resource productivity within the European context, this paper aims to bridge critical gaps by examining the role of unique national policies and economic structures that influence sustainable development outcomes in Hungary and the Netherlands. While prior research has addressed general correlations between GDP, DMC, and sustainability, there remains a need to dissect how specific factors such as economic diversification, environmental regulations, and the CE uniquely impact these relationships. This study extends existing frameworks by applying SEM to better capture the nuanced dynamics at play and to provide policymakers with actionable insights tailored to these diverse contexts.

Figure 1, drawn from the TARKI 2020 Report (Kolosi et al., 2020), underscores the public's evolving attitudes toward sustainability, showing a 30-year trend toward greater willingness to consume less rather than paying more for a comparable lifestyle standard. This shift reflects broader environmental awareness and a societal preference for sustainable practices amid financial pressures. Such findings support this study's exploration of how circular material use and resource efficiency impact economic outcomes differently across contexts (Ness and Xing, 2017; Magyarország Kormánya, 2021). By applying SEM and empirical Eurostat data, this paper underscores the need for refined indicators and integrative models that can capture complex dynamics of economic-environmental interdependence, especially in developing policies for sustainable resource use.

This paper seeks to fill a notable gap in existing literature by examining the nuanced and interconnected nature of resource productivity and sustainability in the context of two distinct European nations—Hungary and the Netherlands. Unlike previous studies that primarily focus on isolated economic or environmental factors, our approach combines an in-depth comparative analysis that considers the economic structures, policy orientations, and specific sustainability challenges faced by each country. Previous studies, such as those by Bleischwitz (2010) and Geissdoerfer et al. (2017), have highlighted broad challenges in sustainable material consumption and CE frameworks, but often without dissecting the influence of unique national strategies and contexts. By investigating this complex interplay within a comparative framework, this research provides insights into how distinct economic and environmental factors, along with tailored national policies, impact resource productivity, contributing to a more comprehensive understanding of sustainable development practices across varied European contexts.

The importance of this paper is signified by the following factors:

Country-specific analysis: The link between material use and economic performance is fundamentally different, depending on the individual specificities of a country's economic, environmental, and social situation. Further in the paper, Hungary and the Netherlands are discussed in regard to comparing two countries that, notwithstanding different challenges and different approaches taken toward sustainability, might help in devising strategies more specifically tailored to certain conditions rather than using overarching, generalized hypotheses.

Refining the Indicators: This study critically evaluates the Resource Productivity indicator (GDP/DMC) and reveals its deficiencies. While the correlation between the consumption of material and economic output is well-established, current indicators may simplify this relationship into a crude framework. The manuscript provides a further development in proposing more advanced approaches for analyzing sustainability for policymakers and researchers to use more refined tools.
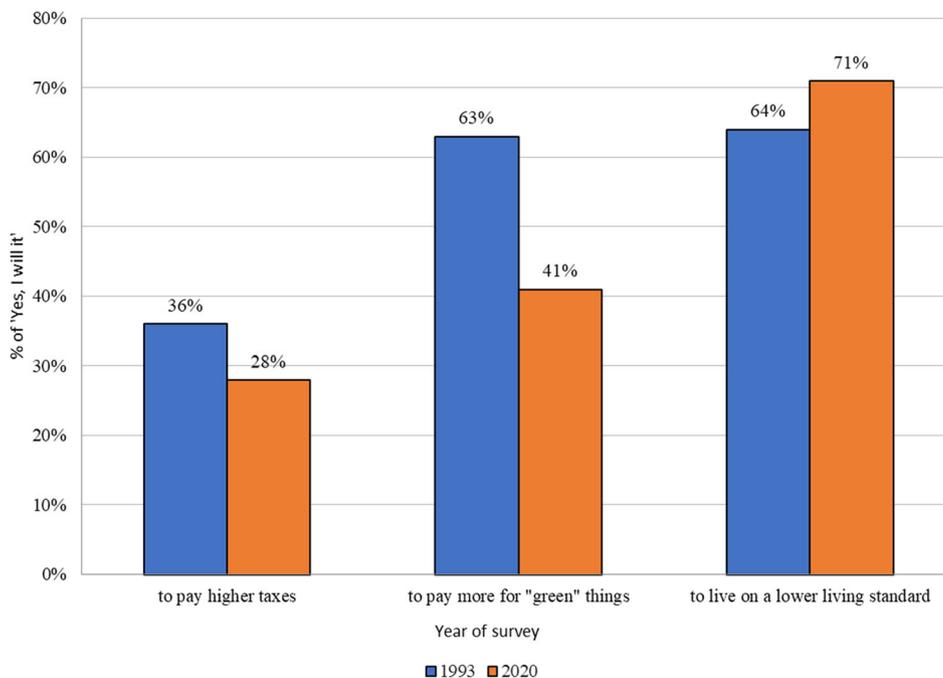
Empirical Validation: A study that empirically supports prevailing theories, or even challenges them, deserves support. Even prevailing concepts must be constantly validated in the real setting as a means of discovery either of shortfalls or of new growths. The present study does one better with new data and SEM to build our knowledge about the exact dynamics going on in Hungary and the Netherlands.

The paper also challenges some of the assumptions made today regarding unintended effects of using materials in a circular way-sometimes increasing material consumption but with less economic output. Such fine-grained findings lead to new insights and help further improve the design of strategies for sustainability.

Policy Guidance: Hard facts require pragmatic implementation. It translates theoretical knowledge into practice and provides pragmatically useful information that may further be used for making useful policies. It articulates a specific advice to the policy-makers regarding the trade-off of economic growth and sustainability in view of the complexity of relationships associated with the interaction of material use and economic activity.

The result is a study that provides context-dependent empirical and practical insights necessary in the elaboration of more effective policies in sustainability, besides further improvement of existing models in view of the big picture relationship between material consumption and economic performance.

This research identifies critical determinants in resource productivity, including economic structure, circular material use, and environmental awareness. Specifically, the study examines how GDP growth relates to Domestic Material Consumption (DMC) within distinct contexts of Hungary and the Netherlands. These elements—circular material usage, investment in renewable energy, and DMC ratios—form the basis for understanding sustainability challenges unique to each country's economic framework. Analyzing these components allows us to discern the complex interplay between economic and environmental factors, illustrating both the potential benefits and limitations of circular material practices in sustainable development.

Fig. 1 Results of TARKI 2020 report survey (Schneider and Medgyesi, 2020) (authors' own).

Following this introduction, the paper is organized to systematically address key dimensions of resource productivity and sustainability. "Theoretic background" delves into the theoretical background, laying out essential concepts and frameworks that inform this study. "Research question and hypotheses" presents the research questions and hypotheses, followed by an explanation of the methodology in "Materials and Methods", where data sources, variables, and analytical methods are detailed. "Results" discusses the results of our comparative analysis, highlighting the significant findings and their implications. Finally, "Conclusions" concludes the paper with insights into future research directions and policy recommendations for advancing sustainability in the context of resource productivity.

Theoretic background
The present study builds upon this literature by addressing a critical gap in current sustainability models—specifically, the challenges in accurately quantifying the impact of circular material use on economic growth and environmental outcomes (Agnibhoj, 2020; Ayres and Warr, 2009). Prior studies often explore the individual aspects of circular economies, such as waste reduction and recycling, without fully integrating these into broader economic metrics like GDP and resource productivity. Our research innovatively combines these elements by applying a comparative, country-specific approach to Hungary and the Netherlands, where we examine the diverse effects of circular practices on GDP and DMC. This analysis highlights the nuanced impact of circular material use, showing instances where it may inadvertently increase material use rather than decrease it, underscoring the need for refined sustainability indicators that capture the interdependencies between economic growth and material consumption.

Today, we live in the age of Industry 4.0 with the increase in demand for rare earth metals or the ever-increasing energy consumption. Reducing the environmental load and energy supply are the two most important problems of the future, which are often complicated by conflicting interests. There are two directions for realizing environmental awareness:

1. More efficient use of resources (an example of this is the energy-saving light bulb),
2. Reducing emissions (this is the purpose of the electric car).

In both, the goal is sustainability at the levels of production and consumption. Sustainability actually emerged as a widely known concept, particularly through the Brundtland Report (1987), even though scholars had recognized it back 15 years before that time (Meadows et al., 1972). The resources on Earth are not unlimited, and consumption by humans is increasingly outpacing its ecological boundary. This year, Earth Overshoot Day fell on August 2, 2023 (EOD, 2023). This is coherent with the model of the ecological footprint of Wackernagel and Rees (1996), who demonstrated that humans demand the productivity of over 1.75 Earths to sustain their lifestyle by 2022. Cited from Wackernagel et al., 2002.

It is important to note this interrelated relationship of awareness on sustainability, morals, and environmental legislation, as established through Pigou (2002); Steg and Vlek (2009); Li et al. (2021). The results of their research indicated that increased awareness by the public about issues related to the durability of sustainability with strong moral values could have a huge impact on influencing environmental legislation.

The environmental awareness in this study cannot be considered only as a simple cognizance of the ecological problems but rather as an incentive for the social and legislative changes. The development of consciousness in people and societies about sustainability often drives them towards positive opinion-making and, therefore, government agencies end up framing and enforcing much more stringent environmental policies. This is supported by Li et al. (2021), in which it was found that shared awareness of sustainability played a significantly instrumental role in cultivating beneficial legal frameworks towards sustainable environmental conservation.

This aspect, included in environmental awareness, would be a great addition to the review because it deals with wider ramifications: how moral input and group activism can force policy revisions that lighten the impact of human endeavors on the environment. More significant than individualistic thinking is a

society-level epiphany underlining the fact that, through legislation and regulation, there can be systemic change. The call, therefore, is for comprehensive sustainability education with moral engagement.

Several models describe this relationship between economic growth and impact on the environment. For instance, "the conventional PPF curve implies that as one consumes more goods, a larger drawdown is exerted on non-renewable resources" Antle and Heidebrink (1995). The Kuznets curve for the environment indicates that above a certain limit (Dogan and Inglesi-Lotz, 2020; Stern et al., 1996), economic growth can assist in preventing environmental destruction—Wang et al. (2022), though it has been challenged; Arrow et al. (1995). One more model is the IPAT equation of Ehrlich and Holdren (1972) and Commoner et al. (1972):

$$I = P \cdot A \cdot T \tag{1}$$

Where, I = Environmental Impact, P = population, A = Affluence, and T = Technology. While capturing the general trend, the equation actually shows technology advancement alone cannot achieve sustainability, Huong et al. (2021).

A major theoretical conception is Jevons (1865), under which improvements in energy efficiency can lead to increased aggregate consumption, as the decrease in cost increases economic growth, thereby increasing total energy consumption (Stern, 2011; Saunders, 1992).

Other policies, therefore, need to act as complements to efficiency gains—conservation standards, green taxes, or emission regulations. Added to that is the interdependence of resources: for example, with the move towards renewable sources of energy, demand rises for a number of rare metals, so the construction of wind turbines might add incremental demand for cement, say (Balavány 2022). Often, sustainability is gauged in terms of resource productivity; that is, GDP/DMC (Domestic Material Consumption) represents the amount of economic value realized from a unit of material use. Indicators in this regard are usually over-simplified in relation to rather complex links between economic growth and environmental pressure (Huysman et al., 2015; Hirschnitz-Garbers et al., 2013).

Chen et al. (2024) highlight that increased resource availability in natural forests enhances the positive effects of tree functional diversity on carbon and nitrogen accrual, emphasizing the importance of diversity in ecosystem productivity. Similarly, Trant et al. (2016) demonstrate that millennia of intertidal resource use have improved coastal forest productivity, suggesting a historical link between human management and ecological productivity. Wright et al. (2015) report that flood disturbances increase resource availability and productivity in plant communities, albeit with reduced stability. These studies suggest that resource availability and sustainable usage can positively influence ecosystem productivity and resilience.

In theory, dual separation should be a goal; however, it has been reached by only few countries. Absolute decoupling signifies a situation where economic growth proceeds while environmental pressures level off or decline (Ruffin, 2006).

There is also growing emphasis on CE concepts. Such is the objective to keep materials circulating in the economy for the longest duration, therefore reducing demand for virgin material supplies and eliminating wastes. This may stimulate GDP growth through new businesses that will be created in the reuse and recycling sectors, hence creating jobs (Stahel, 2016).

The concept of a CE has gained significant attention as a sustainable alternative to the traditional linear economy, which is based on a 'take-make-dispose' model. CE emphasizes the importance of designing out waste, keeping products and materials in use for as long as possible, and regenerating natural

systems (Geissdoerfer et al., 2017). This approach encourages businesses and policymakers to shift towards resource efficiency, rethinking product lifecycle management, and adopting closed-loop systems (Korhonen et al., 2018). One major benefit of CE is its potential to decouple economic growth from resource consumption, promoting a regenerative system that minimizes environmental impacts (Ellen MacArthur Foundation, 2020). Despite the promising potential, several barriers to its large-scale implementation remain, including regulatory challenges, lack of consumer awareness, and the need for technological innovation (Romer, 1990; Kirchherr et al., 2018). Furthermore, transition to CE requires cross-sector collaboration and integration of new business models, such as product-service systems, which prioritize access over ownership (Bocken et al., 2016). Understanding the drivers and inhibitors of CE is essential for achieving a sustainable future, where economic activities positively contribute to environmental and societal well-being (Murray et al., 2017).

Research question and hypotheses

Research questions guiding this study are:

What are the main determinants of productivity growth for Hungary and the Netherlands, and how do these differ? How does circular material use impact GDP and DMC in both countries?

It remains open what fraction of knowledge capital, environmental awareness, and technological innovation will offset the environmental burden generated by economic growth.

Based on the review of the related literature, the following hypotheses are advanced:

H1: Each growth factor, like investments, material consumption, human capital, knowledge capital, R&D, use of renewable energy, and environmental awareness, contributes to higher environmental impact.
H2: Knowledge capital, environmental awareness, and better R&D performance can ease the environmental burden imposed by economic growth.

These listed growth factors that may contribute to increasing the environmental load

The investments-only include Gross Fixed Capital Formation (GFCF): physical investments in infrastructures, machinery, and real estate. These increase productive capacity but more often than not result in rising resource use and higher environmental impacts.
Domestic Material Consumption, or DMC, involves the use of raw materials and energy sources, amongst other resources, directly impinging on the consequences of environmental sustainability.
Human Capital: While a higher skill level workforce assists in economic growth and labor productivity, it is outbalancing the resources, which may result in environmental stress.
Knowledge Capital: Research, innovation, and development often make processes more efficient but can also raise consumption via newer and better technologies.
While renewable energy would reduce dependence on fossil fuels, the extraction of materials necessary for renewable technologies may perpetuate environmental stress in other ways, such as the mining of rare earth metals.
Environmental consciousness: Perceptions in society about sustainability can have an impact on policies and individual actions that mitigate or intensify environmental burdens.
Exports and Imports: Higher import rates will decrease the environmental load on one country and increase it in

another. Economies with high rates of exportation tend to increase extraction and use of energy.

Whereas most would argue that knowledge capital, environmental awareness, and research and development benefit efforts toward the reduction of environmental burdens, testing is required for a number of reasons:

Quantification of impact: While it may seem quite obvious, the contribution of each one of those factors towards cushioning from environmental burdens differs with context, industry, and country. Testing helps us quantify these impacts and understand which of those factors are most effective.

Contextual validation means what may hold true in one context, say, in a highly industrialized nation, may not apply precisely in another context, say, in a developing economy. Empirical testing ensures that policies can be correctly designed using real data for contexts.

Unintended Consequences: Even the positive factors, such as R&D and innovation, may have as side effects things like the Jevons Paradox, which actually encourage increased material consumption. Testing helps uncover whether these factors mitigate environmental impacts or introduce new challenges. Policy formulation: The policy decisions on resource allocations are based on solid evidence-based research. This test creates an avenue for evidence-backed policy decisions that can precisely reach the desired area for investment and action.

While intuitively we may understand what such benefits from knowledge capital, environmental awareness, and R&D could mean, empirical testing remains necessary to confirm such a relationship if the solutions are to be tailored appropriately.

To address the specific research gaps, this study investigates the dual challenge of advancing economic growth while minimizing environmental burdens in Hungary and the Netherlands. Building on prior studies, which often highlight single factors like renewable energy or circular material use, this research uniquely aims to explore the complex interplay among GDP, DMC, and CE practices. By examining these interconnected variables, this study seeks to reveal nuanced insights that challenge simplified assumptions, such as the direct environmental benefit of increased circular material use. Identifying these interactions will contribute to more refined indicators that capture the dynamics between resource productivity and environmental sustainability, thereby supporting informed policy decisions in diverse economic contexts.

Future research should explore how different countries beyond Europe approach sustainability and resource productivity, considering geopolitical and cultural factors. Expanding this study to include developing nations would provide a broader perspective on how sustainability challenges differ across economic contexts.

While this study builds upon a foundation of past research, it is crucial to consider newer insights in sustainability metrics and resource productivity to ensure that the applied frameworks align with the latest findings. Several referenced studies, such as early works on GDP and DMC metrics, may no longer fully represent the complexity of contemporary resource challenges, particularly with rapid advancements in CE practices and sustainable technologies. Future studies should thus incorporate recent publications to capture evolving dynamics, such as the impact of rare earth metals on sustainable energy solutions or the nuances in circular material consumption across different economic contexts.

Additionally, expanding the geographic scope to include regions such as Asia and the Pacific could reveal how diverse governance systems, as seen in countries like Australia and Hong Kong, shape public perceptions and practices related to sustainability. The study by highlights the significant role of artificial intelligence in enhancing local government services in these regions, suggesting that advanced technological integration could

further optimize resource productivity (Bijnsdorp, 2015). By incorporating findings from varied geopolitical contexts, future research can contribute to a more comprehensive framework for sustainable resource management globally.

Suggestions for future studies, such as expanding the analysis to include developing nations, could be further elaborated in the discussion or conclusion sections. This allows for a clear focus in the main body on current study results, while also providing a structured space for potential future directions and extended implications.

This research uniquely contributes to the literature by emphasizing the role of interconnected variables within resource productivity indicators, specifically GDP and DMC, in understanding the limits of sustainability models. While prior studies have acknowledged the correlation between material use and economic output, few have tackled the complex, often paradoxical relationship where increased circular material use might inadvertently lead to higher material consumption and lower GDP, challenging traditional CE models. This study further underscores the limitations of current sustainability indicators, calling for refined metrics that capture nuanced relationships and interactions within diverse economic and ecological contexts.

By refining sustainability indicators and incorporating more comprehensive models that account for the interdependency between GDP and DMC, future studies can offer more actionable insights for policymakers and industries. Additionally, the long-term effects of CE practices should be critically evaluated to ensure they contribute to both economic and environmental sustainability.
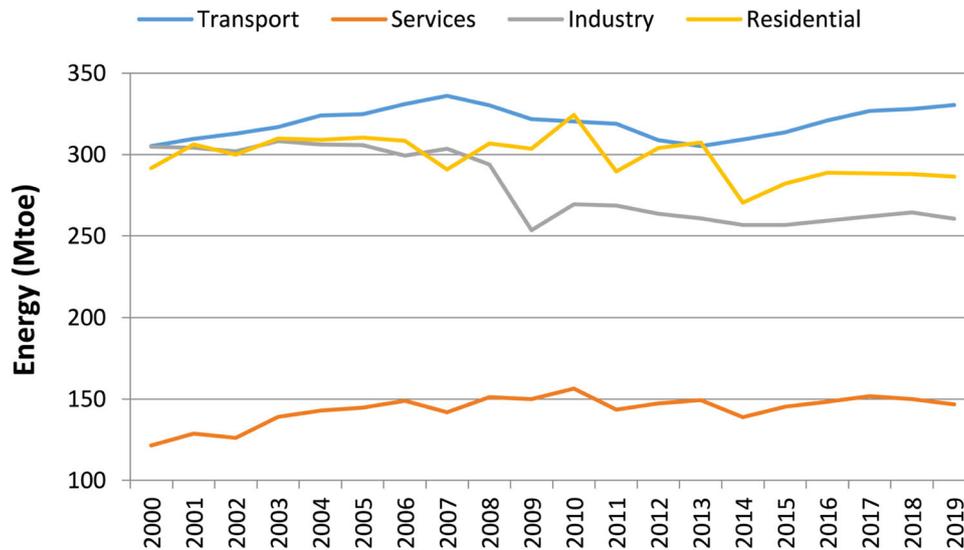
Materials and methods

Data. This study is based on data from Eurostat databases. This ensures the representativeness of the samples, the methodological unity of data collection and presentation, and enables international comparison. Therefore, the conclusions drawn can also be used in general. The databases are freely accessible and usable on the Internet, so their use does not pose any research ethics problems. Finally, the fact that the organizational nature of Eurostat guarantees the reliability of the data was also an important aspect when selecting the data sources. The source of additional data is another EU database with energy efficiency indicators (ODYSSEE, 2021).

Based on the study of Bartus (2013a), we selected the data from the databases that can be used as indicators of sustainability. Therefore, the indices used in this study are related to the Hungarian interpretation of the concept of sustainability, which is described in detail in the study by Bartus (2013b). This interpretation differs from that of the United Nations (UN) (UNDP, 2015; UN Department of Economic and Social Affairs, 2015). The Hungarian interpretation is more focused, sustainability primarily means the preservation and efficient use of resources (KSH, 2023b). In accordance with this Hungarian conceptual system, since 2007 the Hungarian Central Statistical Office (hereinafter: KSH) has published its report on the development of the sustainability indicator system every 2 years (Szűcs and Rausz, 2007). KSH prepares an annual report from 2020, its latest report describes the data for 2022 (KSH, 2023a). The data used in this study were processed primarily by comparing time series. With this method, it was also possible to assess the trend of the given indicator over time and to compare the countries.

Indexes and variables

Indexes of economic growth. The examined variables form three larger groups. The first group includes the factors that directly influence economic growth, among which in this study the

Fig. 2 Energy consumption of economic sectors in EU (source: Tsemekidi Tzeiranaki et al, 2023).

indicator of investments resources (GFCF), the employment rate representing the role of human resources, and the indicator of the structure of the economy (for the tertiary sector as a percentage of GDP) is included. The GFCF consists of resident producers' acquisitions, less disposals, of fixed tangible or intangible assets. This covers the property plant and equipment (PP&E) as percentage of GDP. The size of the GFCF is significantly affected by economic crises. In the recession caused by COVID-19, after the decrease in consumption, the literature mentions the significant drop in the GFCF (and especially the private GFCF) as the second most important factor (Licchetta and Eric, 2022). However, while after the 2008 crisis, the GFCF reached its pre-crisis level in 10 years, the post-pandemic recovery occurred in roughly 1 year. This draws attention to the importance of public decision-making and public investment in economic growth.

The employment rate represents the employment date, by citizenship. This indicator measures the share of the population aged 20 to 64 which are employed. Employed persons are defined as all persons who, during a reference week, worked at least 1 h for pay or profit or were temporarily absent from such work. The data is presented by citizenship. Human resources play a significant role in the process, as it is the basis of, for example, R&D, knowledge capital and innovation (Bell and Morse, 2012; Yumashev et al., 2020). Since the publication of Keynes's (2013) book in 1936, it has been recognized in the international economic literature that employment is a key element of economic growth. If people have jobs, they will have money to consume. And the increase in consumption helps businesses grow and create more jobs. Countries with a low unemployment rate will therefore always be economically more viable than those with a high unemployment rate. The study of the European Commission (2022) also describes numerical relationships. According to this, a 1 percentage point increase in the unemployment rate causes a 0.42 percentage point decrease in GDP. Another basis for the importance of employment is the human capital theory (Fogel, 1994; Schultz, 1961), according to which employees should be invested in the same way as assets. If companies undertake the cost and time implications of training and training, provide flexible working hours, appropriate equipment and an atmosphere, then employees will also be committed and more productive.

This study models the economic structure by the percentage of the tertiary sector (services) in GDP. Without the tertiary sector,

businesses would have difficulty finding the capital they need to grow, and consumers would have difficulty accessing basic goods and services (Mankiw, 2019). The sector also increases employment and government tax revenues and generates exports. By increasing the quality and efficiency of services, the tertiary sector contributes to the sustainable growth of GDP. It is a generally accepted proposition that the increase in the share of the service sector is the result of the structural transformation of economic development. In the first phase of this process, the role of industry and services increases at the expense of agriculture. In the second phase, the proportion of services continues to increase, now to the detriment of industry and agriculture (Sukkel, 2018). The more developed countries of Europe were already in this second phase at the beginning of the 2000s (Gergely, 2006). According to the current development model, GDP growth is accompanied by an increase in the weight of services, although this statement is questioned by some previous results (Krishna Dutt and Young Lee, 1993). However, it is a statistical fact that the share of services in the EU's DGP in 2022 is nearly 70% (European Commission, 2023). According to 2022 data, the tertiary sector accounts for 62.2% of Hungarian GDP, while in the Netherlands the same proportion is 68.8%. The modern manufacturing industry also uses more and more services. For example, the production of an airplane requires the coordinated activities of thousands of suppliers, which would be impossible without transportation and telecommunications services.

The high share of the tertiary sector in the production of GDP also raises the question of how much energy consumption characterizes this sector. Based on Fig. 2, it can already be said that the services sector is much less energy-demanding than other sectors of the economy. The Y-axis unit is Mtoe. The acronym stands for megatons oil equivalent. It shows how many megatons of crude oil would be necessary to burn to achieve the given energy value.

Tsemekidi Tzeiranaki et al. (2023) found that the main driver of the 20.7% increase in energy consumption in the tertiary sector between 2000–2019 is total worked hours. The more time employees spend at their workplace, the higher the number of heating days in winter and cooling days in summer. In the European climate, this mainly depends on the number of heating degree days, since on cold days the premises must be heated continuously and regularly for customers. Due to climate change, however, the role of cooling degree days is expected to increase.

Fig. 3 Energy consumption in tertiary sector (source: ODYSSEE, 2021—own edited).

Consumption therefore plays a crucial role in improving energy efficiency. Economic stability and the lack of it also have an impact. Based on Fig. 3, it can be concluded that the added value of services has been growing since 2014 at almost the same rate as before the 2008 crisis (+2.16%/year).
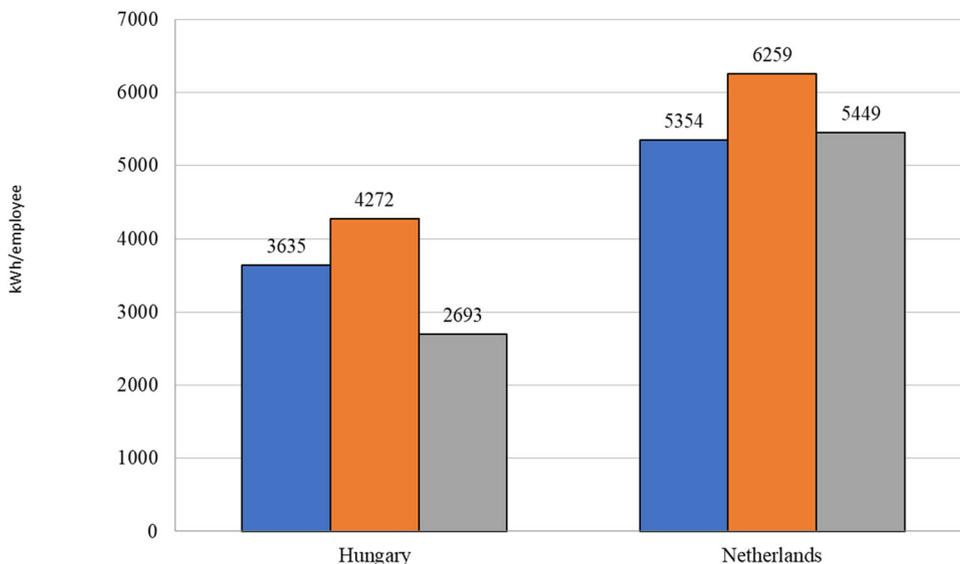
In contrast, the energy consumption of services is almost stable. remained (+0.1%/year compared to +3%/year), and electricity consumption grew much more slowly than before 2008 (+0.7%/year compared to +3.5%/year). In the post-crisis period (2008–2014), total energy consumption fell sharply (−1.2%/year), electricity consumption also decreased (−0.3%/year), with a limited increase in added value (+0, 5 years). The authors of the mentioned study also draw attention to the fact that the appropriate energy policy is also important because the consumption in 2019 still significantly exceeded the EU's goals for 2020 and 2030. The effectiveness of the appropriate energy policy is confirmed by literature data (Bertoldi and Mosconi, 2020). Already in 2013, the EU's energy consumption was reduced by 13% with the appropriate measures. However, the savings were more significant in the industrial sector, which is smaller in terms of size but characterized by intensive energy consumption (secondary sector). In the tertiary sector, however, further steps are necessary.

A prominent area of energy consumption is electricity consumption. The (ODYSSEE, 2021) database shows the consumption per employee. Based on the time series, electricity consumption increased between 2000–2019 in 2/3 of the EU countries, including the Netherlands, but decreased significantly in Hungary (Fig. 4).
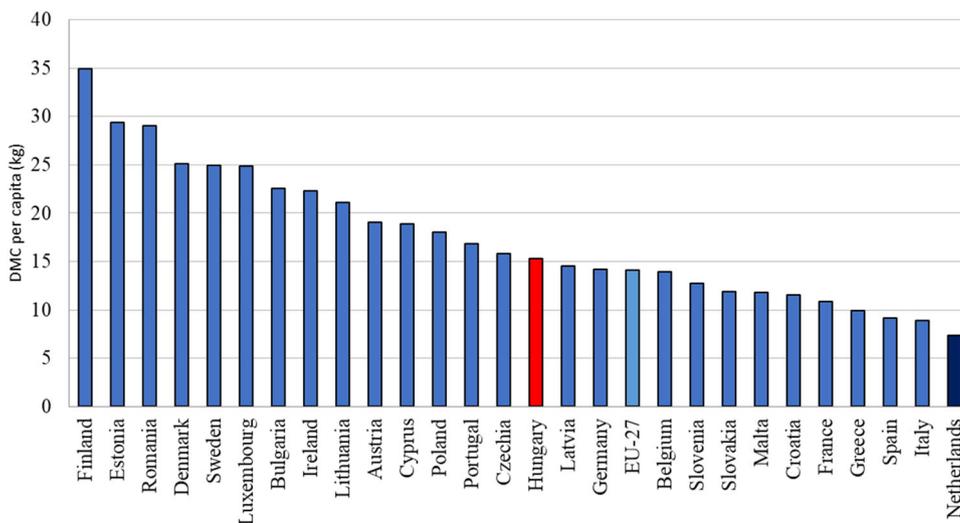
Indexes of environment-economy correlation. The relationship between the environment and the economy is illustrated by resource productivity calculated as the ratio of GDP to DMC. Resource productivity is calculated in €/kg as an index on year 2000, for comparing countries in different years. DMC is an indicator derived from economy-wide material flow accounts. It measures the total amount of materials directly used in the farm in kilograms or tons. DMC equals domestic production plus imports minus exports. These materials become part of the material stock within the economy or are returned to the environment, e.g., in the form of air emissions (European Environmental Agency, 2019). At the same time, not all materials used in production appear in the product. Many manufacturing processes require large amounts of water, which will not be part of the product. Mining and extraction processes move a lot of land without using it for production purposes. Such hidden material flows are called ecological bagpack in the literature (Ritthoff et al., 2002; Robèrt et al., 2002). Resource productivity is an important indicator of goal number 12 of the UN sustainable development framework, called "responsible consumption and production". DMC is measured using the material flow analysis (MFA) method (Bleischwitz, 2010). This method is used to measure the flow of matter and energy between the natural and human spheres. DMC is the direct material flow, total material consumption (TMC) is the sum of DMC and the ecological bagpack.

The more efficient use of materials enables greater energy savings, as well as savings in material costs and thus an increase in competitiveness (Porter and Linde, 1995). All possible replacements for fossil fuels, such as biofuels and renewable energy sources, depend on natural resources such as steel and platinum. Securing these natural resources in the most sustainable way will be a key strategy for climate change mitigation and green growth. There has been international competition for access to resources for decades. However, the increase in extracted quantity has not been accompanied by a decrease in prices, as the demand for these resources is also constantly increasing. According to forecasts (Bleischwitz et al., 2018; Krausmann et al., 2009; OECD, 2012), by 2030 the global extraction of resources will increase to at least 2.5 times the level of 1980. In particular, the mining of minerals and metals is increasing. In the case of fossil fuels, two problems arise. One is that these energy carriers pollute the atmosphere and increase the greenhouse effect, so reducing their use and replacing them in an environmentally friendly way is justified (European Environment Agency, 2019). The other reason is geological. New deposits are located in more challenging regions, far from the place of use, and the quality of the resources that can be extracted there is getting worse and worse. Despite increasing investment, the number of significant deposits and world-class discoveries has therefore been declining since the mid-1990s. Metal mining is unsustainable even within the human time scale. Primary metal stocks will be depleted in about 50 years (Jowitt et al., 2020). In addition to overturning the biological balance, competition can lead to ownership conflicts and even wars. Among the unspoken causes of the current Russian-Ukrainian conflict is the demand for Ukrainian agricultural land and mineral resources (EBRD, 2022; Osusky, 2022; Roels, 2022).

Fig. 4 Trends of electricity consumption in examined countries (source: ODYSSEE, 2021—own edition).

Fig. 5 Domestic material consumption, EU-27 (Source: Eurostat).

While natural scientists say that the depletion of raw materials makes sustainability impossible, economists argue that through double decoupling (Hirschnitz-Garbers et al., 2013) energy use and growth can be made independent of each other. Increasing the role of renewable energy sources also contains an important pitfall. Although the energy of the sun, wind, and water is indeed renewed, we do not use it in its original form. Wind turbines and hydroelectric power plants contain a lot of cement and plastic, and solar collectors contain many expensive and rare metals. Lithium, for example, is running out. Due to the oligopolistic market and unequal localization (Lithium Triangle: Chile, Argentina, Bolivia), it is increasingly difficult to meet the growing demands for the production of electric cars.

The IEA (2020) published the current version of the fial list of critical minerals in 2023. This includes metals essential for national security and industry, which can typically be obtained from exports, so damage to their supply chain can have a critical impact on industrial production and thus competitiveness. Critical minerals and rare earth are indispensable in industries such as electric vehicles, fuel cells, photovoltaic solar technologies,

wind energy technologies, and the aviation sector (IFPEN, 2023). Currently, the metal industry accounts for ~10% of global energy consumption, which is associated with intensive water consumption, significant energy consumption related to mining and processing, or sector emissions. In addition to lithium and rare earth, the latest models emphasize the critical role of copper (Hache, 2022).
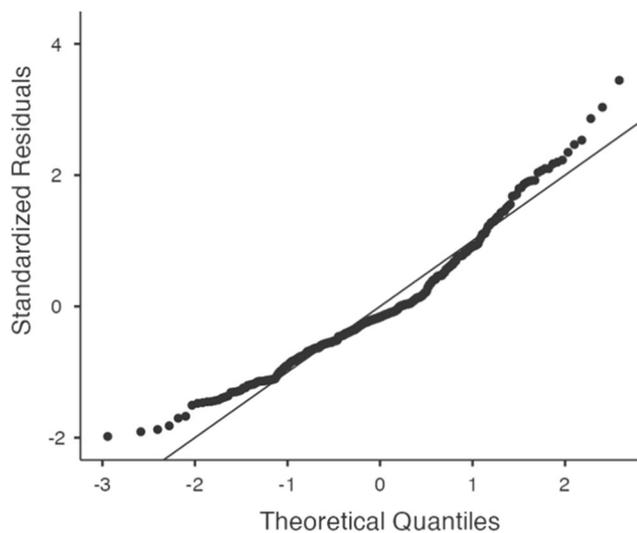
Significant differences can be observed in the value of DMC between EU member states. Bleischwitz reported in 2010 that there is a significant difference between the old and new member states of the union. However, by 2017, the material consumption of the new member states reached the same level as that of the old member states (EEA, 2022) and in 2021 a higher energy consumption in the north and a lower energy consumption in the south can already be observed (Fig. 5).

Indexes of knowledge capital. The third group of variables examined in this study is related to knowledge capital, one of its indices is employment knowledge (the proportion of high-/mid-tech sectors employments as % of all employmnets). The other is the area of

Table 1 Variables and abbreviations.

Variable	Name of variable in this research
Resource Productivity	RES_PROD
Employment rate	EMP_RATE
Gross Fixed Capital Formation	GFCF
Tertiary sector's share in GDP	TERT_SEC
Employment Knowledge	EMP_KNOW
Research and Development	RAndD
Recycled Waste	WAST_REC
Imported Raw Materials	RAW_IMP
Materials Used Circular	CIRC_MAT
Proportion of Renewable Energy	REN_EN
Proportion of Trains in People Transport	TRAIN

Source: author's own.

Fig. 6 Q-Q plot of normality (Source: author's own).

research and experimental development (R&D). Research and experimental development (R&D) comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. R&D expenditures are shown as a percentage of GDP (R&D intensity).

Indexes of environmental consciousness. The fourth group of variables is related to environmental awareness. proportion of recycled waste as % of all waste (Torgler et al., 2008), a share of use of renewable energy in total energy consumption (Zarnikau, 2003), the proportion of imported raw materials from total raw materials (Sorrell, 2010). Environmental awareness is also measured by the ratio of rail transport in public transport. The variables and their abbreviated names used in this research are summarized in Table 1.

The authors examined data from the period 2011–2022. This decision was motivated on the one hand by the need for balance. On the one hand, by 2011, the recovery following the 2008 crisis was already visible in the economic statistics of the EU countries (European Commission, 2011; Eurostat, 2012; Darvas, 2011). This fact reduces the risk of data distortion. On the other hand, the reliable application of statistical methods used to investigate research questions and hypotheses requires long time series (Greene, 2003; Kline, 2016).

Descriptive statistics of the sample. The sample includes the 27 member states of the European Union, and the EU average is listed as the 28th value. The time series compiled from the Eurostat databases is 11 years long, from 2011 to 2021. The data on the ratio of the tertiary sector comes from the data of the World Bank. The data were processed and the tests performed using MS Excel for Mac v.16.74 and Jamovi 2.3.21.0 software. A Structural Equation Model (SEM) was also created using SMART-PLS program version 4.0.9.5. SEMs can also be used to estimate models that include several explained (dependent) variables. The method can be compared to multiple simultaneous regression. However, when using SEM, by performing the estimations simultaneously, it is not necessary to narrow our thinking about models to only one dependent variable (Kline, 2005). In the case of indirectly measurable, latent variables, however, it is in order to make a comparison, we have to use certain assumptions. Accordingly, in addition to the change in the sample, the difference between two variables can also be caused by the fact that the variable used in the two measurements does not measure exactly the same thing. SEM helps answer such questions.

The descriptive statistics of the sample are shown in Fig. 6 és a Table 2. We have a total of 308 items, there are no missing items.

Based on the Cook's distance values, there are no extreme outliers either. The Kolmogorov-Smirnov test is not significant, so the condition of normality is met. Based on Fig. 6, normality and linearity can also be assumed.

Models. The hypotheses are tested using a regression model. In this, the dependent variable is resource productivity, the other variables are listed as independent variables. Before describing the model, the conditions necessary for its construction must be examined. First is linearity. The basic assumption is that there is a linear relationship between the independent variables and the dependent variable. The volume of investments, the increase in the level of employment rate and employment knowledge, and the ratio of the tertiary sector, as well as the success of R&D, presumably improve the performance provided in the resource productivity variable. A positive effect is also expected in the case of environmental awareness indicators. The only exception is raw material import, which indicates that the country cannot cover economic growth solely from its own resources. When describing the descriptive statistics of the sample, normality and linearity have already been verified. The next condition is homoscedasticity. This can be stated based on the results of the Breusch–Pagan heteroscedasticity test (stat = 81.3, $p < 0.001$) (Breusch and Pagan, 1979). A very important condition is multicollinearity, i.e., the exclusion of variables moving together. In the colinearity test performed for this purpose, all VIF values are above 10, which indicates pronounced multicollinearity. However, the result of the correlation test between the independent variables showed a correlation above 0.7 only between the WAST_REC and RAndD variables (Pearson's $r = 0.708$, $p < 0.001$), which in turn refutes multicollinearity.

The discrepancy between the VIF and the correlation test results suggests complex interdependencies among the variables that may not be fully captured by simple correlation alone. VIF values reflect multicollinearity, indicating variables that might move together due to underlying relationships not always observable in pairwise correlations. The difference may be due to how VIF assesses all variables collectively, revealing interactions that correlation tests might overlook. Additionally, the correlation test results indicate strong pairwise relationships only in specific cases, like WAST_REC and R&D, suggesting that isolated dependencies exist but are not widespread across all

Table 2 Descriptive statistics of the sample with normality test and extreme outliers'test.

	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	9324	8.9
Median	130	71.8	20.6	1.38	44.1	36.2	17.6	5.65	64.1	2857	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

	Statistic	p
Kolmogorov-Smirnov	0.0391	0.776

Cook's distance			Range	

Mean	Median	SD	Min	Max
0.00522	0.00113	0.0155	9.86E-9	0.205

Source: author's own.

variables. This variance underscores the importance of using both tests for a comprehensive understanding of multicollinearity and dependency nuances within the model.

Since the variables used to build the model meet the criteria, the next step is to build the model. The simplified Eq. (2) of the model is as follows:

$$\begin{aligned} RES\_PROD = {} & \alpha + \beta_1 * EMP\_RATE + \beta_2 * GFCF + \beta_3 * RAndD \\ & + \beta_4 * WAST\_REC + \beta_5 * REN\_EN + \beta_6 * TRAIN \\ & + \beta_7 * TERT\_SEC + \beta_8 * RAW\_IMP + \beta_9 * CIRC\_MAT + \varepsilon \end{aligned}$$
(2)

where the abbreviations correspond to the variables in Table 1. $\beta 1–\beta 9$ are the slope parameters to be estimated, and ε is the error term. The original model also included the interaction of the variables, but these are not included in Eq. (2) in order to simplify the equation of the model.

An SEM was also prepared (Awang, 2014; Kline, 2016) to investigate whether the variables used in the research affect resource productivity through GDP or DMC. GDP and DMC are included as explained variables in the model, the other variables are explanatory variables. The calculations related to the model were made with the PLS-SEM algorithm (weighting scheme: path, type of results: standardized, initial weight: default).

Results

The description of the results starts with an examination of the fit of the regression model (Table 3).

In examining the quality of the SEM, indicators such as R-square and Variance Inflation Factor (VIF) play a critical role in assessing model reliability and the strength of relationships between variables. R-square values provide insights into the proportion of variance explained by the independent variables in the model, while VIF values indicate the level of multicollinearity among predictors. This approach aligns with the methodology outlined by Deeprasert in 'Factors that Affect Individuals in using Digital Currency Electronic Payment In China: SEM and fsQCA Approaches,' which underscores the importance of these indicators for validating model robustness and accuracy in complex economic analyses (Deeprasert, International Review of Economics and Finance, 103418).

Based on the value of R^2, 78.7% of our model is explained by the included variables, which indicates that there are many other factors in determining the performance of resource productivity.

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	<0.001

Source: author's own.

Based on the test result F(20, 265) = 29.1, $p < 0.001$, the predictors significantly predict the dependent variable. Equation (3) of the regression model based on the Estimate values of the study:

$$\begin{aligned} RES\_PROD = {} & -1193.08 + 19.44 * EMP\_RATE + 0.45 * GFCF - 2.61 * RAndD \\ & + 5.34 * WAST\_REC - 1.79 * REN\_EN + 29.31 * TRAIN \\ & + 18.47 * TERT\_SEC - 0.06 * RAW\_IMP - 0.32 * CIRC\_MAT - 0.34 \\ & * (RAndD \cdot REN\_EN) - 0.82 * (EMP\_KNOW \cdot TRAIN) + 0.31 \\ & * (REN\_EN \cdot TRAIN) - 0.33 * (EMP\_RATE \cdot TERT\_SEC) + \varepsilon \end{aligned}$$
(3)

The • means interaction. 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.

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 Fig. 7 and the direct, indirect and direct effects between the variables are shown in Table 4:

Based on Eurostat data and our own 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 (Fig. 8).
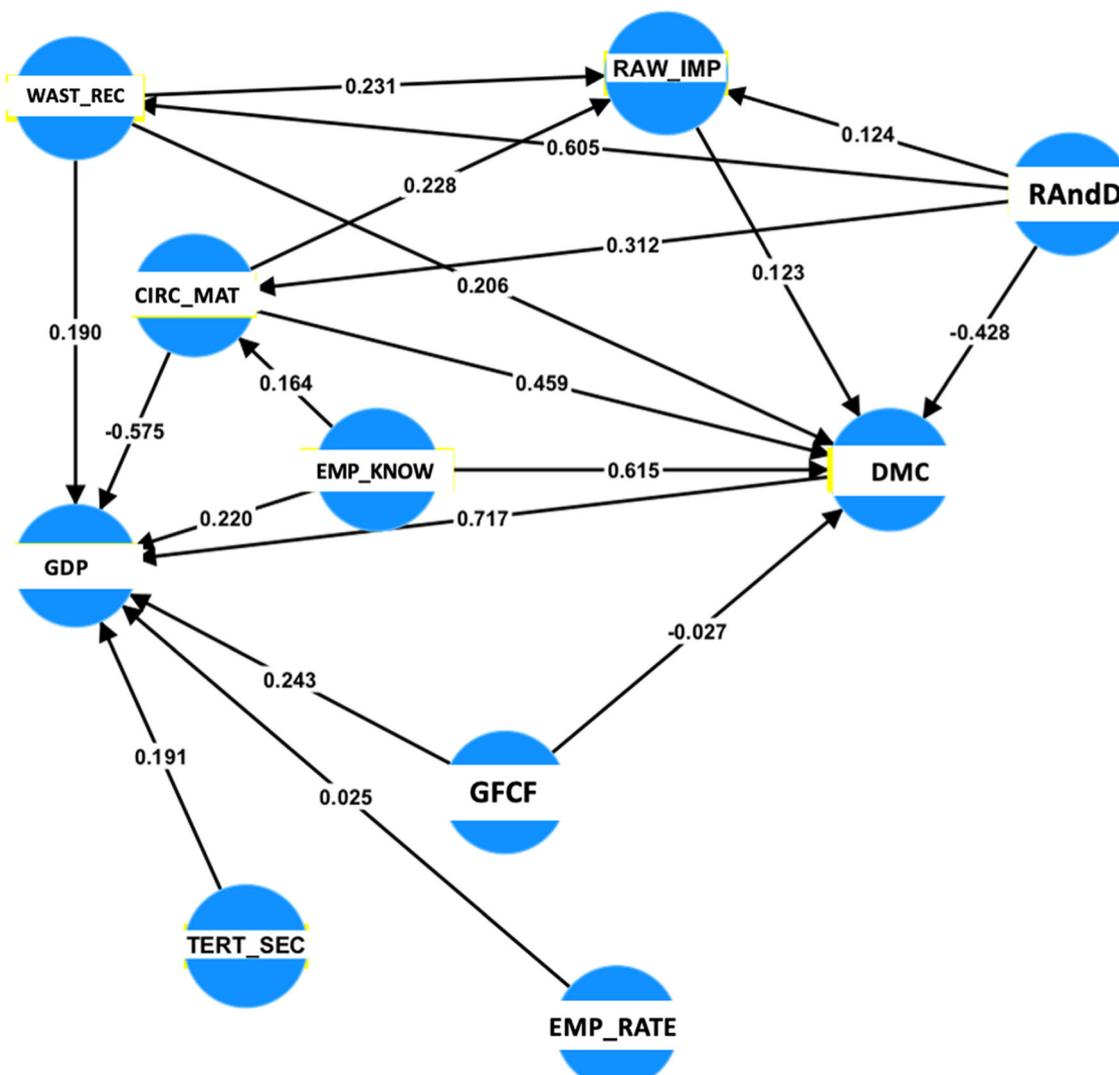
Fig. 7 SEM of resource productivity (Source: author's own).

The development of resource efficiency in the two countries is similar, only the level is different (Fig. 9).

Table 5 illustrates the development of the reciprocal of resource efficiency, resource productivity and its components.

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 DMC increased by 37%, and the Netherlands solved its more modest economic growth by reducing DMC by 11%(!). Hungary's resource productivity increased by 8%, while that of the Netherlands increased by 40%.

Based on Fig. 10, the examined period was realized at the cost of increased environmental impact of Hungarian GDP growth, which we also saw in Table 5. GDP grew faster than DMC (relative decoupling). In the Netherlands, however, GDP is increasing, but DMC can be considered constant (absolute decoupling).

The results can be interpreted in the light of the literature as follows. In addition to economic growth, resource productivity also has a significant impact on financial sustainability. The price of the materials increases as the available materials run out. Especially for rare materials (such as lithium, cobalt, copper, silver, phosphorus), of which a significant amount is required for green transition technologies. The companies involved do not shy

away from open violence either. A good example is the Twitter message of the head of the Tesla company, Elon Musk, regarding the military coup in Bolivia in 2019: "We will coup whoever we want! Deal with it" (Kolláth, 2021). Bolivia owns more than a quarter of the world's lithium reserves, and the measures planned by the Morales government threatened Tesla's lithium supply.

The scarcity of resources can therefore become one of the main inflation-stimulating factors. (Prins et al, 2011; Schnabel, 2022; Baranyai and Banai, 2022).

The problems are aggravated by the fact that today it is absolutely impossible to achieve such intensive productivity growth as a hundred years ago. The slowdown in productivity growth coincided with the start of the 2008 economic crisis. However, it is still questionable why economic growth was not followed by productivity growth during the recovery from the 2008 crisis. Economic literature calls this paradoxical phenomenon on Fig. 11 the productivity puzzle (Newman, 2015).

Stagnant productivity is a problem because the three main sources of economic growth are population, investment and productivity. The global growth of the population does not mean a proportional increase in the supply of trained, appropriately skilled labor. The sources of investments are savings (income not spent on consumption), but the realization of investments is not only influenced by economic factors. The third factor is productivity, which in the field of research can be linked to economic

Table 4 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 + 0.349 (−0.226)		0.228 + 0 (0.228)			0.605 + 0 (0.605)
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)			−0.15 (−0.15)		0.124 + 0.211 (0.335)			
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)			

Source: author's own.

Table 5 Growth of resource productivity and it's elements (2011–2022) (Source: Eurostat—own calculation).

	Hungary	Netherlands
GDP/capita (thousand €)	49%	25%
DMC/capita (kg)	37%	−11%
Resource productivity (€/1000 kg)	8%	40%

Source: author's own.

growth with relation (4) (Solow, 1956; Swan, 1956).:

$$\text{economic growth}(\%) = \text{research productivity}(\%) * \text{number of researchers}$$

(4)

Bloom et al. (2020), however, scientific productivity has declined significantly (Fig. 12).

In the last hundred years, the USA Total Factor of Productivity (TFP) has not changed (left scale), while the number of researchers required for a unit increase in productivity (right scale) has increased twentyfold. So, the countries that prioritize the three factors of population-savings-productivity can be the economic superpowers of the future.

The phenomenon of decoupling was also investigated by the EU (Fig. 13).

The diagonal line represents the same rate of change of GDP and DMC. Decoupling failed in the countries above the diagonal line. The countries below the diagonal line have achieved at least relative decoupling, like Hungary. Absolute decoupling below the horizontal line has been achieved by many European countries, including the Netherlands and the EU as a whole. However, this result needs to be further investigated, as it is possible that material and energy intensive sectors have been outsourced to other parts of the world. The DMC indicator does not cover these aspects.

Based on the regression model, resource productivity can be increased in the countries of the European Union in three ways. Increasing employment can work in countries where the employment rate is low. In the Netherlands, employment was consistently above 75% during the period under review. In Hungary, the employment rate increased by almost 20 percentage points during the same period (Fig. 14). This certainly contributed to the development of resource productivity; however, we cannot expect any further significant impact on this path today.
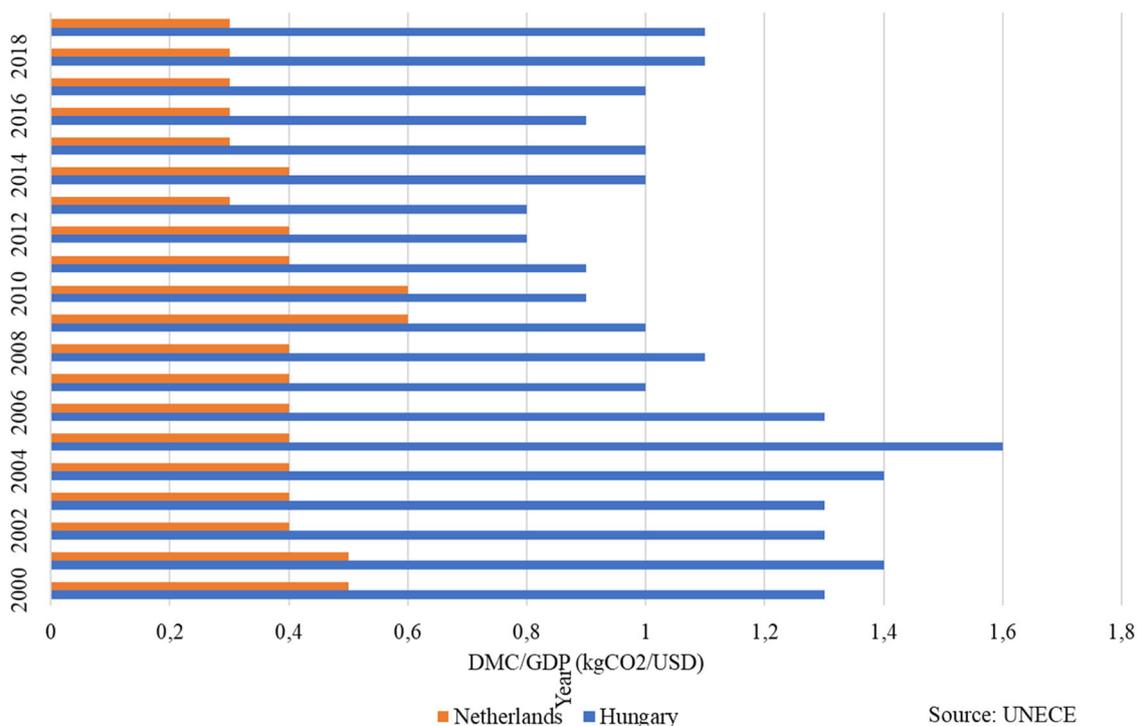
Another avenue is increasing the tertiary sector's share of the GDP. According to Tukker and Dietzenbacher, 2013, increases in service sector share reduce material use while increasing GDP simultaneously. This structural shift in the economy also heightens the underlying cause of the expenditure on environmental protection vis-à-vis the GDP (OECD, 2019). In this respect, the Netherlands fared better vis-à-vis Hungary during the period under consideration (Fig. 8) as per Eurostat (2020). A third potential intervention could be increasing environmental awareness.

According to the SEM model, the greatest change can be achieved by basing public transport on rail transport. The Dutch railway lines form a real network with practically nationwide coverage. Hungary's railway network, on the other hand, is highly centralized (Fig. 15). Therefore, Hungarian railway development can significantly contribute to environmentally friendly economic growth. One of its concepts is the Rail Carpathia plan (Zasiadko, 2022). The other is the renovation of the Budapest-Belgrade railway line.

The increase in the ratio of imported raw materials and renewable energy sources, as well as the increase in R&D expenses, seem paradoxically to have a negative effect. A possible explanation for the negative effect of raw material imports is that

Fig. 8 Environmental spendings in proportion of GDP (Source: Eurostat—own edition).
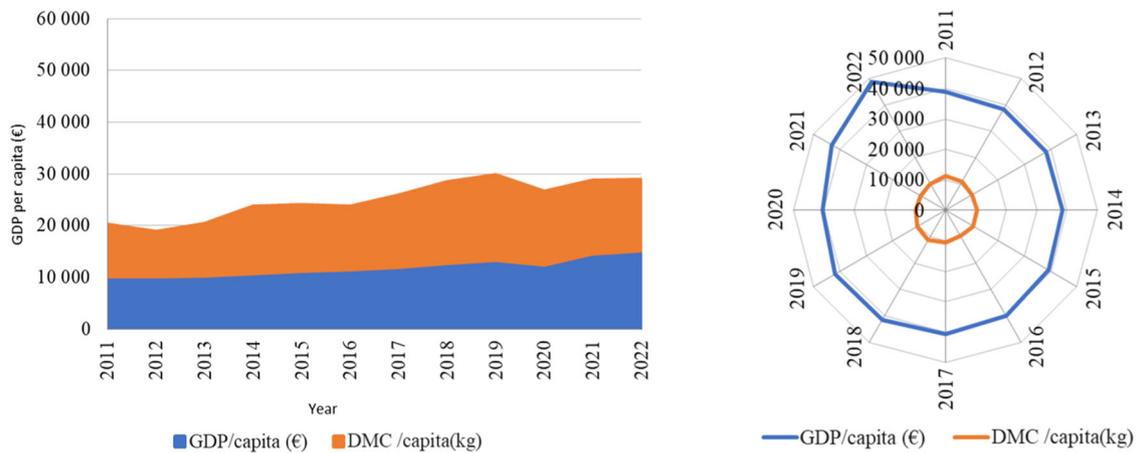

Fig. 9 Resource efficiency trends in examined countries (Source: UNECE, 2023—own edition).
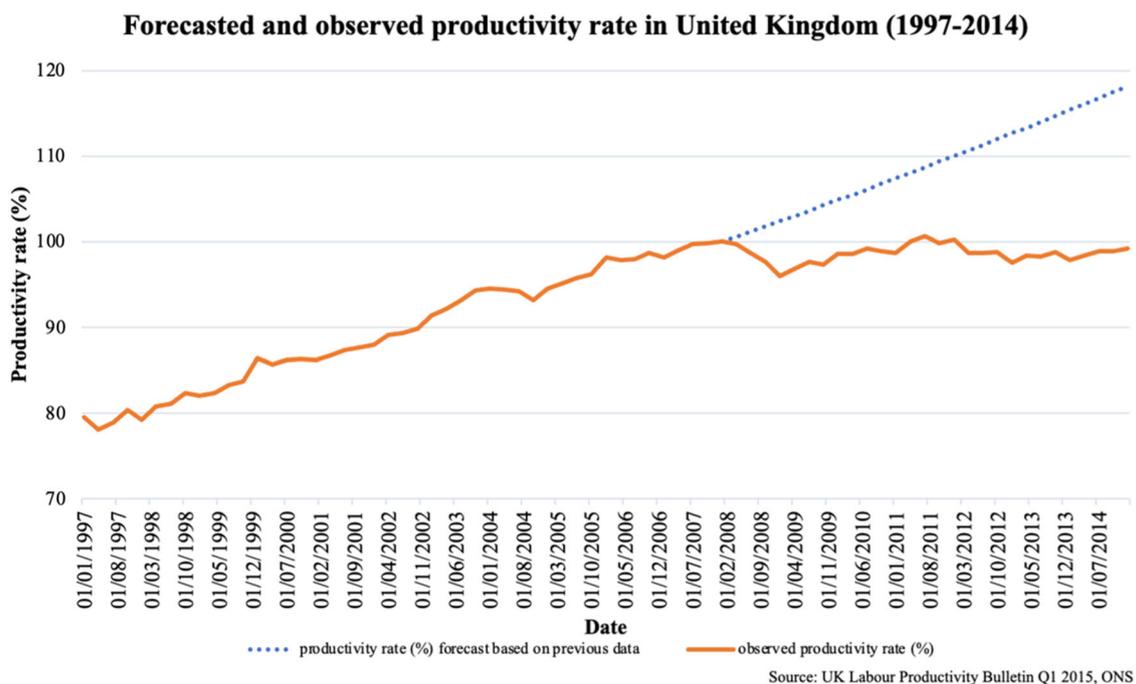
a country forced to import raw materials cannot base its economic growth on its own raw materials. This weakens resource productivity. As we have seen, increasing the proportion of renewable energy sources also increases the depletion of rare earth metals and fossil materials. Due to R&D, we will come back later.

Based on the SEM results, although the resource productivity factors (GDP, DMC) are not completely independent of each other. DMC has a significant direct effect (+0.71) on GDP. The increase in the ratio of circular material use (CMU) reduces the GDP directly (−0.575) and increases (+0.349) the GDP through the increase of raw material imports and DMC (+0.459). The effect of increasing raw material imports is explained by the fact that the essence of circular material use is the repeated use of the same materials. However, this may again require raw materials that can only be obtained from imports. And the DMC-increasing effect of circular material use is based on the fact that the reused is again added to the material use. Waste recycling also affects DMC with a similar mechanism, although there is no direct reuse here.

Fig. 10 Decoupling in examined countries (Source: Eurostat—own edition).

Fig. 11 The productivity puzzle (Newman, 2015).

Seemingly paradoxically, if the proportion of CMU in the TMC increases, it reduces GDP. The explanation for this phenomenon (McKinsey, 2015) is that circular used materials are already a significant proportion of TMC. To further increase the ratio, significant technical developments and investments would be needed, the cost of which is already unaffordable and not proportionate to the growth of the available GDP.

The generated waste is a frequently used indicator of environmental impact. The most effective way to reduce the environmental load resulting from waste production is to prevent waste generation. Other ways include reuse, recycling, recovery, energy recovery, incineration and finally waste disposal (landfill). The transition from landfill to recycling and utilization reduces the environmental burden, creates more jobs and preserves the intrinsic material value (Otten and Ron Sint, 2020).

In these areas, the Dutch Ministry of Infrastructure and Water Management has developed an action plan to reduce waste streams. The ministry pursues a policy of sustainable procurement, encouraging the public and private sectors to do the same (Government.nl, 2023). In the Netherlands, 79% of waste is recycled and the remainder is used for energy production (Rijkswaterstaat, 2023). That is, 80% of the waste became a resource.

Among the direct effects on GDP, investments and the effect of employment knowledge are tied for second. Their impact is 30% of the impact of DMC, but it clearly indicates the significant role of knowledge capital in economic growth (Fogel, 1994; Schultz, 1961; Schumpeter, 1980; Schwab, 2016). Investments have a direct effect on both explained variables. They increase the GDP and, thanks to the developments, reduce the DMC.

An important question is the effect of R&D according to the model. It has a direct effect on all types of material use: it increases waste recycling ($+0.605$) and material reuse ($+0.312$) the most. It significantly reduces (-0.428) the DMC, so these are the results of innovative solutions. It increases raw imports (total effect: $+0.335$), since the materials needed for new, more advanced solutions can only be obtained from imports. With the help of the indices examined in the research, based on the SEM, the development of GDP can be explained in 77% ($r^2 = 0.770$) and the development of DMC in 69% ($r^2 = 0.692$).

Fig. 12 Aggregate data of growth and research effort (Source: Bloom et al., 2020). US TFP total factor productivity of the USA.

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

Source: Eurostat (online data codes: env_ac_mfa, nama_10_gdp)

Fig. 13 Decoupling in European Union (Source: Eurostat). BE Belgium, BG Bulgaria, CZ Czechia, DK Denmark, DE Germany, EE Estonia, IE Ireland, EL Greece, ES Spain, FR France, HR Croatia, IT Italy, CY Cyprus, LV Latvia, LT Lithuania, LU Luxembourg, HU Hungary, MT Malta, NL Netherlands, AT Austria, PL Poland, PT Portugal, RO Romania, SI Slovenia, SK Slovakia, FI Finland, SE Sweden, IS Iceland, NO(¹)– Norway, CH Switzerland, MK(¹)– North Macedonia.

Conclusions

The indicator examined by the authors (Resource Productivity) is the ratio of GDP to DMC. Authors' results draw attention to the fact that the Resource Productivity indicator greatly simplifies the analysis of sustainability. Because the numerator and denominator of the fraction are not independent of each other. The SEM results indicate no two explained variables (GDP and DMC). The present research found that GDP is the only clean dependent variable. Clean variables are summarized in Table 6.

Fig. 14 Employment rate in Netherlands and in Hungary from 2011 to 2021 (source: authors' own elaboration, based on Eurostat, 2024).

Fig. 15 Railroads in Hungary and in Netherland (source: Mapping Europe).

Table 6 Summary of variables and their effects on GDP and DMC in the Structural Equation Model (SEM).		
Clean Variable	**Dependent/Independent**	**Direct effect on...**
GDP	Dependent	------
R&D	Independent	GDP(+), DMC(+)
employment knowledge	Independent	GDP (+), DMC(+)
GFCF	Independent	GDP (+), DMC(−)
employment rate	Independent	GDP(+)
tertiary sector	Independent	GDP(+)

Source: author's own.
Dependent/Independent: Indicating whether the variable is a dependent or independent factor in the SEM analysis.
Direct Effect on...: Clarifying whether the variable directly influences GDP, DMC (Domestic Material Consumption), or both, and whether the effect is positive or negative.
DMC domestic material consumption.

History has told a story of development and growth in the annals of various economic systems (Ghisellini et al., 2016). Yet Earth is the only known home mankind has, and its material and energy resources are finite. This very circumstance creates a natural limit to renewability in regard to economic growth. The higher the level of resource depletion, the louder the call to find long-lasting solutions. The challenge, therefore, is to buy time for prospecting and development of substitute resources that are equally sustainable by stretching out the life of what is at hand. Among them will be the improvement of resource productivity—the value creation with less material and energy input.

This paper, therefore, presents critical insights into the relationship that keeps economic growth and resource use integrated, mainly based on Hungary and the Netherlands. DMC was seen to explain a high fraction of the variability in GDP and thus implied strong correlations between material use levels and economic performance.

However, this evidence showed that the use of circular materials only increased the abuse of material and might even lower national income levels. It did not make the broad generalization that any action under a CE is inherently sustainable. A good scholarly contribution shows that the latter simplifies assessments concerning sustainability by accepting GDP and DMC as two different entities, yet actually they are interconnected. This is an important scholarly contribution in pointing out the limitations

of some of the most widely used indicators for sustainability assessment and, moreover, calling for more integrative models.

The SEM was used for the analysis, and as a consequence of that, there is only one dependent variable, GDP; hence, relying on the multi-faceted difficulty of disentangling economic growth from its environmental impact.

Future directions. Further research should, therefore, be channeled into coming up with sophisticated sets of indicators which could capture the most complex dynamics between economic growth and resource use. Deep insights could be gained from studying how different countries in different geopolitical and natural settings address the challenge of linking economic growth with sustainability. The expansion to countries outside Europe, especially those experiencing growth in their economies, could shed light on many issues and solutions in the global quest for sustainability. In particular, a need is felt in practice for the further research of the unforeseen consequences of CE policies and how to evade them. Moreover, more research needs to be done that takes into account upscaling development into renewable energy technologies and resource-efficient innovations—scaling that would not worsen material scarcity, in particular that of rare earth metals.

Policy Implications would indicate that government agencies in Hungary and the Netherlands need to further develop policy packages toward an increase in resource efficiency that is not purely incremental but also takes into account the risks associated with CE activities. Respective policymakers will hopefully secure that the newly conducted attempts for sustainability will not accidentally create more environmental damage or economic instability.

Conscious allocations towards R&D, renewable sources of energy, and ecologically friendly technologies will be highly essential in building a more robust and sustainable economic framework. Economic growth has always been the priority in human development. Earth's dwindling resources require nothing short of a radical shift in the paradigm towards more responsible and sustainable development. This new study presents the lack of existing sustainability indicators within the framework of general debates on potential and important ways that tailored strategies can be developed for enhancing the efficiency with which resources are utilized. By being more productive with resources and energy use, and by harmonizing our economic policies with environmental reality, we will go a long way toward a sustainable future.

This study illustrates that the normal measure for Resource Productivity, or GDP/DMC, too often overly simplifies an analysis of sustainability because both GDP and DMC are not independent variables. This complicates most present economic models and invites further research into more subtle measures of sustainability. Increasingly applying circular materials turns out—quite surprisingly—into higher material consumption and less national income. This proves the theory of a CE, which should also refine applied practice with respect to Hungary and the Netherlands.

Sustainability Strategies for Hungary and the Netherlands: It was realized that each of these countries could only have a very specific kind of development which was actually sustainable. For instance, in Hungary, there should be a focus on enhancing energy efficiency and waste production decrease, while the Netherlands could further purify water management and reduce its reliance on fossil fuels. Businesses and industries in every country are supposed to be aware that the use of circular materials will not necessarily contribute to improved resource productivity or business benefits. Investments in a CE approach need more careful evaluation in terms of their overall impacts on material use.

The case of policies in the field of resource productivity and the CE would, therefore, be enlarged for both Hungary and the Netherlands. This constitutes one of the key findings which

brings home the reality that policy measures on these circular materials do have a way of catalyzing, otherwise unknown, negative effects owing to increased material consumption.

Energy efficiency is of prime importance for Hungary due to the country's dependence on imported energy. In the Netherlands, policy should continue with a focus on reducing material imports coupled with the increase in renewable energy technologies and also cover potential shortages of critical rare earth materials. Targeted investments into green transition must further interest governments in financing research and development of the programs for enhancing resource efficiency, developing renewable energy, and waste management. These will be essential steps in both the countries to secure better results in the way of sustainability.

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