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IMPACT OF MATERIAL CONSUMPTION AND CIRCULAR ECONOMY ON NATIONAL INCOME IN EUROPE – CHAPTER 1

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ABSTRACT

Objective: This study investigates resource productivity by exploring the factors that influence it and the strength of their impact using sustainability statistics from Eurostat.

Theoretical Framework: The research analyzes the interdependence between national income and material consumption, with a focus on the paradoxical effects of circular material use on these variables.

Method: Data from bibliographic sources are analyzed using statistical methods, including regression and path models, to assess the relationships between material consumption, national income, and the use of circular materials.

Results and Discussion: The study concludes that national income and material consumption are interdependent, with material consumption directly affecting national income. Notably, the use of circular materials, contrary to expectations, increases material use and decreases national income. The cases of Hungary and the Netherlands are specifically examined to illustrate these findings.

Research Implications: The findings suggest that strategies to increase resource productivity and sustainability performance need to consider the complex and sometimes counterintuitive impacts of circular material use on national income and material consumption.

Originality/Value: This study provides new insights into the relationship between resource productivity, national income, and material consumption, highlighting the unexpected effects of circular material use. It contributes to the broader understanding of sustainability performance, particularly in the context of Hungary and the Netherlands.

Keywords: Resource Productivity, Sustainability, Economic Growth, Environmental Impact, Netherlands, Hungary.

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OBJECTIVOS ECONÓMICOS SUSTENTÁVEIS – CAPÍTULO 1 DETERMINANTES DA PRODUTIVIDADE DOS RECURSOS NOS PAÍSES BAIXOS E NA HUNGRIA

RESUMO

Objetivo: Este estudo investiga a produtividade dos recursos explorando os factores que a influenciam e a força do seu impacto utilizando estatísticas de sustentabilidade do Eurostat.

Referencial Teórico: A pesquisa analisa a interdependência entre a renda nacional e o consumo de materiais, com foco nos efeitos paradoxais do uso circular de materiais sobre essas variáveis.

Método: Os dados de fontes bibliográficas são analisados utilizando métodos estatísticos, incluindo modelos de regressão e caminhos, para avaliar as relações entre o consumo de materiais, a renda nacional e o uso de materiais circulares.

Resultados e Discussão: O estudo conclui que o rendimento nacional e o consumo material são interdependentes, com o consumo material a afectar directamente o rendimento nacional. Nomeadamente, a utilização de materiais circulares, contrariamente às expectativas, aumenta a utilização de materiais e diminui o rendimento nacional. Os casos da Hungria e dos Países Baixos são examinados especificamente para ilustrar estas conclusões.

Implicações da Pesquisa: As conclusões sugerem que as estratégias para aumentar a produtividade dos recursos e o desempenho da sustentabilidade precisam de considerar os impactos complexos e por vezes contra-intuitivos da utilização de materiais circulares no rendimento nacional e no consumo de materiais.

Originalidade/Valor: Este estudo fornece novos insights sobre a relação entre a produtividade dos recursos, a renda nacional e o consumo de materiais, destacando os efeitos inesperados do uso circular de materiais. Contribui para uma compreensão mais ampla do desempenho da sustentabilidade, particularmente no contexto da Hungria e dos Países Baixos.

Palavras-chave: Produtividade dos Recursos, Sustentabilidade, Crescimento Económico, Impacto Ambiental, Países Baixos, Hungria.

IMPACTO DEL CONSUMO MATERIAL Y DE LA ECONOMÍA CIRCULAR EN LA RENTA NACIONAL EN EUROPA – CAPÍTULO 1

RESUMEN

Objetivo: Este estudio investiga la productividad de los recursos explorando los factores que influyen en ella y la fuerza de su impacto utilizando estadísticas de sostenibilidad de Eurostat.

Marco Teórico: La investigación analiza la interdependencia entre la renta nacional y el consumo material, centrándose en los efectos paradójicos del uso circular de materiales sobre estas variables.

Método: Los datos de fuentes bibliográficas se analizan utilizando métodos estadísticos, incluidos modelos de regresión y de trayectoria, para evaluar las relaciones entre el consumo de materiales, el ingreso nacional y el uso de materiales circulares.

Resultados y Discusión: El estudio concluye que el ingreso nacional y el consumo material son interdependientes, y el consumo material afecta directamente al ingreso nacional. En particular, el uso de materiales circulares, contrariamente a lo esperado, aumenta el uso de materiales y disminuye el ingreso nacional. Los casos de Hungría y los Países Bajos se examinan específicamente para ilustrar estos hallazgos.

Implicaciones de la investigación: Los hallazgos sugieren que las estrategias para aumentar la productividad de los recursos y el desempeño de la sostenibilidad deben considerar los impactos complejos y a veces contradictorios del uso de materiales circulares en los ingresos nacionales y el consumo de materiales.

Originalidad/Valor: Este estudio proporciona nuevos conocimientos sobre la relación entre la productividad de los recursos, el ingreso nacional y el consumo de materiales, destacando los efectos inesperados del uso circular de materiales. Contribuye a una comprensión más amplia del desempeño en materia de sostenibilidad, particularmente en el contexto de Hungría y los Países Bajos.

Palabras clave: Productividad de los Recursos, Sostenibilidad, Crecimiento Económico, Impacto Ambiental, Países Bajos, Hungría.

1 INTRODUCTION

1.1 PREFACE

This study attempts to find an answer to the question of how an environmentally conscious 'green' approach can be combined with sustainable economic growth. Economic indicators indicate whether we are going the right way and making progress, as well as the options and possible approaches to dealing with the problem.

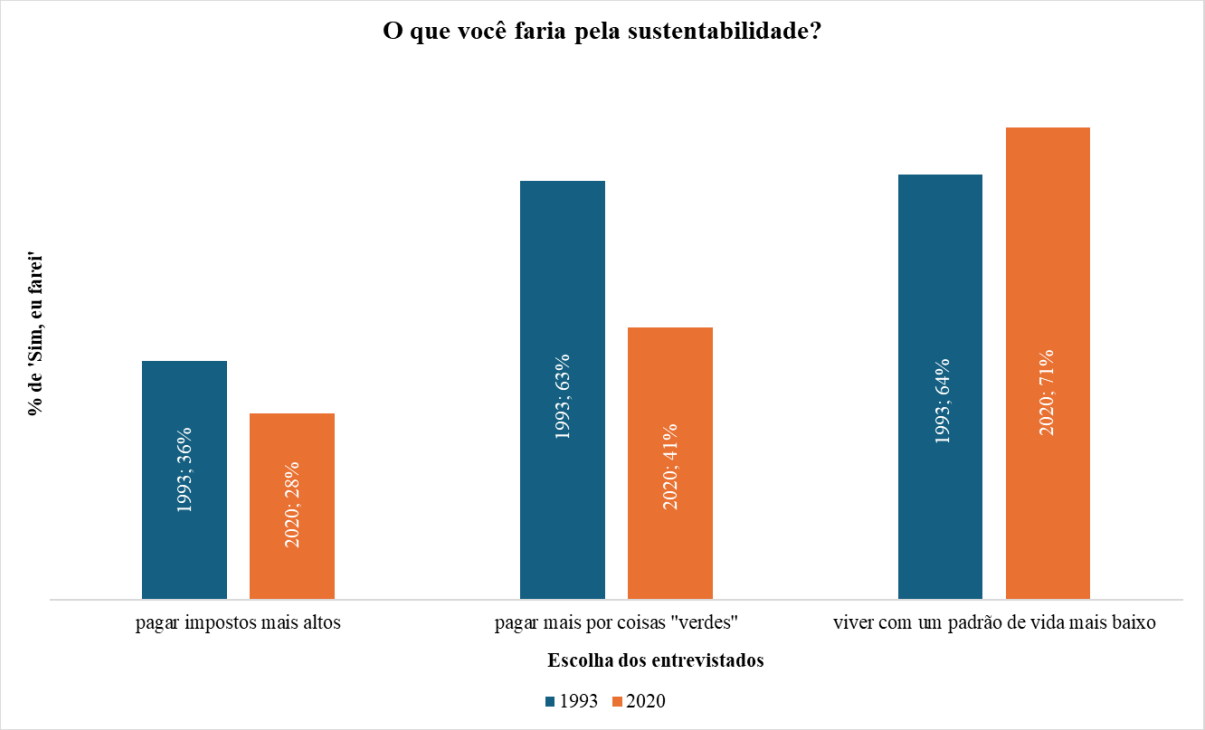
The Earth doesn't have much to offer. We can't estimate the exact time it will take. However, all evidence shows that the current strategy is unsustainable due to a lack of resources (Princ et al., 2011; OECD, 2012).

Raw materials are the bottleneck between the three most essential elements needed to maintain the current way of life: money, energy and raw materials. Even in terms of the circular economy, materials that are incorporated into a product cannot be fully reused. So, by working more efficiently, the only result is more time to find a solution.

Unlike changing consumer habits, most policy strategies focus on technological innovation. That is why the 2020 Hungarian Social Report, published by the Institute for Social Research (TÁRKI) (Kolosi et al., 2020), is significant. It includes an opinion poll on whether the Hungarian population is willing to spend money to support sustainability. The researchers made a comparison between the results of the current research and a previous study conducted in 1993 (Figure 1).

Figure 1

Search results for the TARKI 2020 report



Source: Schneider & Medgyesi, 2020, authors themselves

For almost 30 years, it can be concluded that the population's priorities have changed. Most individuals prefer to consume less, rather than a life that is unchanging and costly. Between the two surveys and a more environmental awareness, the global financial crisis of 2008 can be considered as a reason for this attitude transformation (Schneider & Medgyesi, 2020).

The above conclusions are complemented by the Environmental, Social, and Governance (ESG) perspective (Gillan et al., 2021). The goal is for society and the environment to develop sustainably throughout time, while financial risks are also reduced as a result of this development (Tapaszti, 2018).

This study focuses on Dutch and Hungarian sustainability indices. Based on the performance of the two countries in the chosen indices, the author examines how similar and different the path and pace of environmentally friendly transition are. The author's residence is one of the countries. Regarding sustainability, the Netherlands is cited because it has achieved considerable results due to its high population density, sea level rise, precise agriculture (Sukkel, 2018) and successful energy transition (IEA, 2020).

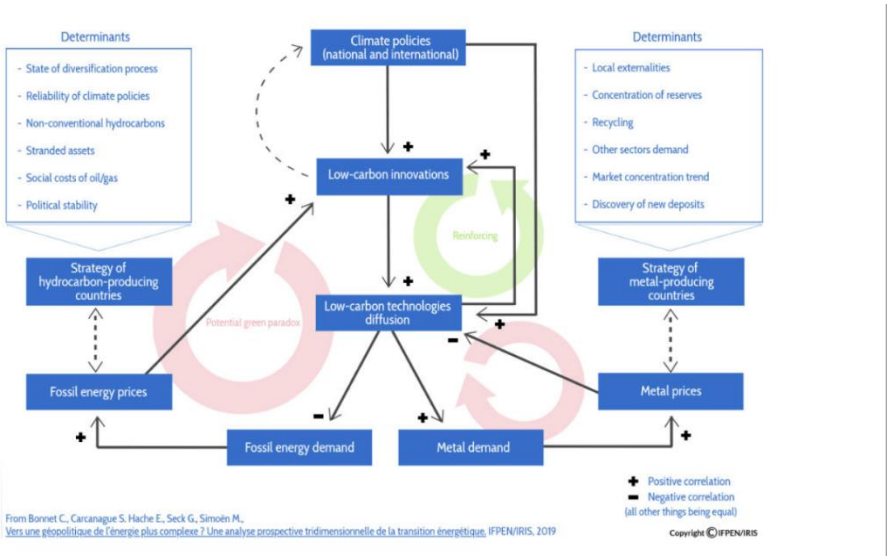
2 THEORETICAL BACKGROUND

We are now living in the era of Industry 4.0, which is linked to the increased demand for rare earth elements or the increasing use of energy. Reducing the environmental effect and energy supply are two of the biggest issues facing the future, often complicated by competing interests. The increase in defense spending since February 2022 is a relevant issue. The high costs of the military sector must be attributed to its high energy efficiency.

The Integrated Time Assessment Model (TIAM) was developed by the French energy company IFP Energies nouvelles (IFPEN).

Figure 2

Model IFPEN-TIAM



Source: Marignan & Sauzet, 2020

The following are the main components of the model. Low-carbon technologies require more materials than conventional technologies, so increased use of mineral resources is related to energy efficiency. Due to inconsistent distribution and use (Van Den Berg et al., 2016), the model states that lithium is more economically limited and cobalt is more geopolitically limited in the energy transition (Hache, 2022). There are two ways to promote environmental awareness:

1. more efficient use of resources (an energy-saving lamp is one example),
2. reduce emissions (the electric car target).

But increasing consumption and production is the common goal of both strategies. But this cannot be maintained for long. There are several ways to increase resource efficiency. This

includes improving production efficiency (Lai & Cheng, 2016; Sugimori et al., 1977), reducing losses and waste through reuse or recycling of materials. Consumption habits can also change. This includes reducing the amount of leftovers, making buildings more energy efficient, repairing or renovating rather than buying new ones.

The Brundtland report, published in 1987 by the United Nations, raised public awareness of the concept of sustainability. But scientists have known this for 15 years (Meadows et al., 1972). Planet Earth has few resources available. The term "ecological overload" was originally developed by Andrew Simps in 1970 (Dhyani, 2022). The date when the still sufficient amount of use for annual regeneration is reached represents the extent of the excess (Catton, 1982). This day starts to change to earlier dates. It was on August 2, 2023 (EOD, 2023). The term "environmental footprint" (Wackernagel & Rees, 1996) addresses the same problem. By 2022, more than 1.75 Earths would be needed to maintain humanity's standard of living (Earth Overload Day, 2023; Wackernagel et al., 2002).

The IPAT equation, developed in connection with the debate between Ehrlich & Holdren (1972) and Commoner (1972), shows the root of the problem:

$$I = P \cdot A \cdot T \qquad (1)\ (2)$$

Where I means the human impact on the environment, P is the population, A is the wealth and T is the technology. Unfortunately, each of these three elements is now increasing the environmental burden (I). The main trends are clearly explained by the theory (Huong et al., 2021), but there are also controversial opinions in the literature (Koblitz, 1981). However, there is a problem. According to the UNDP (2015), sustainability is one of the main topics of global concern of the United Nations. In addition, each state recognized the importance of the issue. In Hungary, annual reports on the subject were produced for 15 years (Szűcs & Rausz, 2007), and the country's government developed the National Sustainability Framework Strategy (Bartus, 2013). Prior to 2010, the Netherlands already had sustainability targets, as in Deventer (Deventer Municipality, 2009). Since then, the city has worked to make operations sustainable (Deventer City, 2011; Bijnsdorp, 2015; Otten & Ron Sint, 2020). In addition, several laws were passed by the Dutch parliament and government (Climate Law, 2019; Klimaat, 2019). One of the main goals of municipal government is to promote the circular economy (Ness & Xing, 2017).

Hungary has made significant progress in terms of energy efficiency in recent years. A new energy ministry has been established (Government of Hungary, 2021). National energy

consumption fell by 15% in the first quarter of 2023 compared to the same period a year earlier, according to data from the Hungarian Central Statistical Office (KSH, 2023). The country's electricity producers produce almost 14% of the country's electricity from renewable sources and waste. EU subsidies also promote energy efficiency.

At the end of 2022, the European Commission provided Hungary with funding of EUR 74.3 million from the EU Modernization Fund. This can be used to generate electricity from renewable sources, modernize energy networks and increase energy efficiency in the energy sector, industry, buildings and transport. It can also be used to replace coal with a less carbon intensive fuel (Kerner, 2022). A crucial task is to increase the energy efficiency of buildings. Apartments in Hungary have energy performance rated "FF" in most energy certificates, or approximately 50%; this means they consume more energy than a modern building of similar size (MEHI, 2023). Of the total of 4 million apartments, only 5.5% are classified as modern from the energy point of view. In addition, in 2019, Hungary consumed one and a half times more energy for domestic heating than the EU average, although half of that consumption could be saved through renovations.

Unfortunately, however, renovations are mostly done for repair purposes and most energy renovations are not carried out on the basis of plans drawn up by an expert.

Since 2011, MEHI has been an independent, non-profit professional defense organization. Its main goal is to encourage energy consumption to be reduced through the construction of energy-saving buildings (MEHI, 2022). Similar objectives are pursued by the Passive House of Hungary (Passzívház Hungary, 2021).

However, technological development is not the only way to achieve sustainability and resource efficiency. This was proposed by Jevons 150 years ago, in 1865, in the Jevons paradox. Jevons stated that increased efficiency by means of technological development increases the consumption of materials. Energy is cheaper when efficiency increases, which leads to higher utilization. Increasing energy efficiency also boosts economic growth and increases incomes. In addition, this increases the energy consumption of the economy in general. Therefore, faster economic growth is driven by more efficient and therefore cheaper energy. In the end, this leads to an increase in energy consumption throughout the economy (Saunders, 1992). As a result, increasing energy efficiency is not enough to safeguard the environment. In addition, to counteract the Jevons effect, other tools are needed, such as nature conservation rules, increased usage costs (e.g. through green taxes) or stricter emission standards. The situation becomes even more difficult because the possibility of reducing the consumption of one resource is usually related to the behavior of another resource (Van Den Berg et al., 2016). For example,

switching to renewable energy sources from fossil energy carriers accelerates the depletion of rare metals, such as solar energy, or the demand for cement, the production of which requires a significant amount of fossil energy, such as wind turbines.

The literature reports a variety of indices that can be used to characterize sustainability (Bell & Morse, 2012; Yumashev et al., 2020). Resource productivity is one of the most widely used indicators. Furthermore, this is one of the most important indices of the present research, since the objective is to investigate which elements of economic growth impact the economic and efficient use of resources. The ratio between GDP and MIC (the MIC is the internal consumption of materials) is used to calculate the index. Therefore, the use of raw materials, carriers of energy, water, land, air and ecosystems are all linked to DCM (UNEP, 2011). The reciprocal indicator (DMC/GDP), or resource efficiency, is also often used. In fact, this refers to material input per service unit (MIPS). So, as far as resource productivity is concerned, growth is a positive change if we can produce more value per unit of material consumption. And if producing a unit of value requires as few materials as possible, the value of the resource efficiency indicator increases. Otherwise, the indicator value decreases. The concept of double dissociation is related to these two indices (Hirschnitz-Garbers et al., 2013). This idea is based on the assumption that the environmental burden is linked to economic growth. Decoupling aims to separate these two phenomena from each other. Thus, the aim is to ensure that economic growth does not harm the environment in proportion to growth. More directly, economic growth grows faster than environmental impacts. Absolute decoupling indicates that the environmental burden continues to increase as the economy grows. When the growth of the environmental burden is greater than that of the economy, we speak of relative decoupling (Ruffin, 2006).

Existing literature states that a variety of factors influence the value of resource efficiency (Huysman et al., 2015). Real output growth, or real GDP, is the most common way to measure economic growth. In addition to increased consumption and emissions, costs associated with environmental impact are also referred to as negative externalities (Pigou, 2002). The increasing use of non-renewable resources, increased levels of pollution, global warming and damage to environmental habitats are some of these problems (Agnibhoj, 2020). But growth is not only bad for the environment. Individuals can devote more resources to environmental preservation as real income increases. In addition, technological advancement enables higher performance and solves the problem with less pollution.

The literature uses a variety of models to explain the relationship between economic growth and the environment. Consumption increases along with the depletion of non-renewable resources, according to the classic PPF (Production Possibility Frontier) curve. The maximum

consumption that can be achieved with a specific loss of resources is represented by the curve (Antle & Heidebrink, 1995). External costs of growth include short- and long-term costs of environmental damage, such as climate change, biodiversity decline and long-term degradation toxins, affecting future generations (Brown et al., 2019). The inverted U-shape of the Kuznets environmental curve shows that development can begin to diminish the harmful environmental effects of growth after a certain level of growth (Wang et al., 2022). But in the 1990s, this theory was already questioned (Arrow et al., 1995). The most obvious counter-argument is that the amount of non-renewable resources will never increase with economic growth. Because of this, several new models emerged. Limit theory states that achieving a specific level of environmental pollution already slows down and reverses economic growth. Ecologists divide studies on the relationship between growth and the environment into two main categories. The first category argues that there is no economic growth without environmental pressure. However, economists believe that growth can be achieved without environmental impact, for example by lowering renewable energy prices or applying a carbon tax.

2.1 RESEARCH QUESTION AND HYPOTHESES

From the beginning, Meadows et al. (1972) emphasized that a finite planet cannot support infinite growth. His model indicates that there are still about a hundred years of growth. Currently, half of this has already been completed in 2023. In addition, economic growth has as many benefits as problems. One is that companies compete for workers by offering ever higher wages as a result of the high employment rate. The increase in wage costs affects prices and causes inflation. The balance of payments is made worse by the increase in imports due to the increase in consumption, and at the same time makes investors less responsible, who are only concentrating on growth. The growing burden on the environment and the scarcity of non-renewable resources are another concern. The relationship between GDP growth and the growing environmental burden has already been addressed in several studies (Dogan & Inglesi-Lotz, 2020; Stern et al., 1996). This research investigates the environmental impacts in Hungary and the Netherlands from 2011 to 2021 through a variety of growth factors, including investments, material consumption, human capital, knowledge capital, research and development, rate of utilization of renewable energy sources and environmental awareness. After a review of the literature, the authors developed the following theories:

H1: Each of the listed growth factors has an impact on increasing the environmental burden.

H2: The environmental burden caused by economic growth is lessened by better performance in the areas of knowledge capital, environmental awareness and research and development.

3 MATERIALS AND METHODS

3.1 DATA

Data from Eurostat databases are the basis for this study. The representativeness of the samples, the unity of the methodology for collecting and presenting the data, and the possibility of international comparison are guaranteed for this reason. Thus, the discoveries can also be applied in general. The use of databases does not present ethical problems for research, as they are accessible and available on the Internet. Last but not least, the organizational nature of Eurostat ensures that the data are reliable. This was an important factor in the choice of data sources. Another EU database with energy efficiency indicators provides more information (ODYSSEE, 2021).

Based on the Bartus study (2013a), we chose data from several databases to use as sustainability indicators. As a result, the indices used in this study are related to the interpretation of the concept of sustainability in Hungary, which was detailed in the Bartus study (2013). The United Nations (UN) does not provide this interpretation (UN Department of Economic and Social Affairs, 2015). In Hungary, sustainability refers mainly to the preservation and economic use of resources. According to this Hungarian conceptual system, KSH publishes every two years a report on the development of the sustainability indicator system (Szűcs & Rausz, 2007). KSH produces an annual report in 2020, and the most recent report for 2022 describes the data (KSH, 2023). Comparison of time series was the main way to process the data used in this study. This method also allowed to assess the trend of a specific indicator over time and to compare countries.

3.2 INDEXES AND VARIABLES

3.2.1 Economic Growth Indices

Three larger groups were formed by the variables examined. The first group consists of elements that have a direct impact on economic growth. This study includes the economy

structure indicator (for the tertiary sector as a percentage of GDP), the investment resource indicator (gross fixed capital formation - GFCF) and the employment rate, which represents the role of human resources. GFCF consists of the acquisition of property, plant and equipment or intangible assets by resident producers, less disposals. As a percentage of GDP, this includes fixed assets. The size of GFCF is strongly impacted by economic crises. The literature indicates that the substantial drop in GFCF (mainly private GFCF) was the second most significant factor in the COVID-19 recession after the decrease in consumption (Licchetta & Eric, 2022). However, although GFCF reached the pre-crisis level in ten years after the 2008 crisis, the recovery after the pandemic took about a year. This highlights the importance of public investment and public decision-making for economic growth.

The employment rate shows the date the worker was hired, by nationality. This indicator represents the percentage of the population aged 20-64 that is occupied. All persons who worked at least one hour for money or profit during a reference week are considered to be employees. The citizen provides the data. Human resources are the basis of R&D, knowledge capital and innovation (Yumashev et al., 2020). Therefore, they are essential for the whole process. Since the publication of Keynes's book (2013) in 1936, scholars of the world economy have recognized that employment is an essential part of economic growth. People will have money to spend if they have work. In addition, increased consumption allows companies to expand and create more jobs. Therefore, nations with low unemployment rates will always be more economically viable than nations with high unemployment rates. Numerical relations are also discussed in the European Commission's study (2022). As a result, GDP will decrease by 0.42% as a result of a 1 percentage point increase in the unemployment rate. The theory of human capital (Fogel, 1994; Schultz, 1961) holds that employees should be invested in a similar way to assets. Employees will be more committed and more productive if companies accept the costs and time associated with training and training, provide flexible working hours, equipment, and an appropriate work environment.

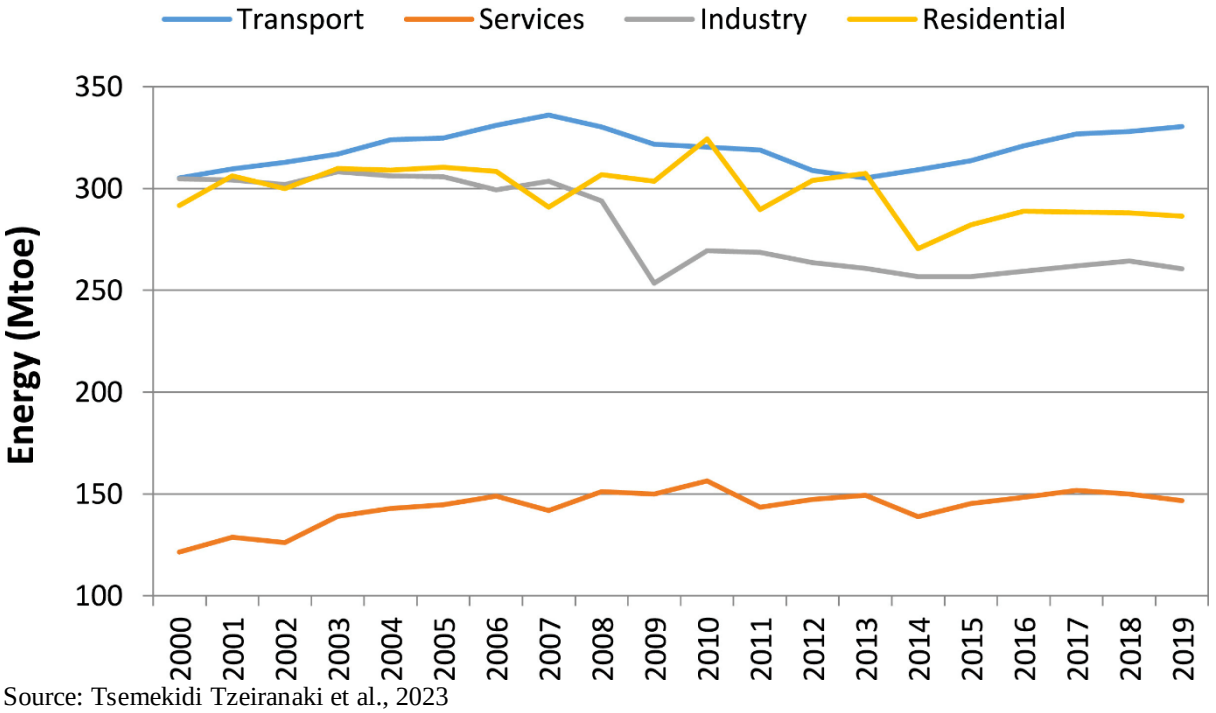
This study simulates the economic structure using the percentage of GDP of the tertiary sector, or services. Consumers could not obtain basic goods and services without the tertiary sector. In addition, the sector increases employment, government tax revenues and exports. The tertiary sector helps to increase GDP in a sustainable way by improving the quality and efficiency of services. The general consensus is that the structural transformation of economic development is responsible for increasing the participation of the services sector. In the initial stage of this process, the influence of industry and services grows to the detriment of agriculture. In the second phase, the percentage of services continues to increase, now to the

detriment of agriculture and industry. By the early 2000s (Gergely, 2006), Europe's most developed nations were already in this second phase. Some earlier results dispute this claim, but the current development model states that the increase in the weight of services accompanies GDP growth (Krishna Dutt & Young Lee, 1993). However, it is a statistical fact that the share of services in the EU GDP in 2022 is almost 70% (European Commission, 2023). Data from 2022 showed that the tertiary sector accounts for 62.2% of Hungarian GDP. In the Netherlands, the same percentage is 68.8%. In addition, the use of services is increasing in contemporary manufacturing. For example, the construction of an aircraft requires the coordination of the activities of thousands of suppliers, which would be impossible without transport and telecommunications services.

The question of the extent to which energy consumption characterizes the tertiary sector arises due to its high share in GDP production. As Figure 3 shows, it is clear that services require much less energy than other economic sectors. Mtoe is the unit of the Y axis. The acronym stands for petroleum megatons. shows the number of megatons of crude oil needed to produce the specified energy value.

Figure 3

Energy consumption of economic sectors in the EU



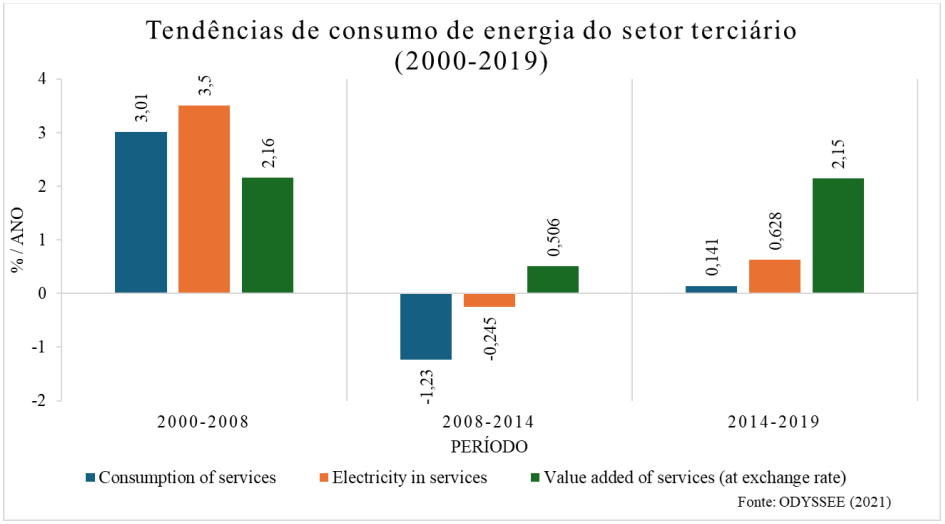
Source: Tsemekidi Tzeiranaki et al., 2023

Tsemekidi and Tzeiranaki (2023) found that total hours worked were the main factor responsible for the 20.7% increase in energy consumption in the tertiary sector between 2000

and 2019. The number of hot days in winter and cooling in summer increases with the time employees spend at the workplace. This mainly depends on the number of heating degree-days (HDD) in the European climate, as the facilities must be heated regularly and continuously for customers on cold days. But the role of cooling degree days (CDDs) should increase as a result of climate change. Therefore, improving energy efficiency depends on consumption. In addition, economic stability and the lack of it have an effect. Figure 4 shows that since 2014, the added value of services has grown at almost the same pace as before the 2008 crisis (+2.16% per year).

Figure 4

Energy consumption in the tertiary sector



Source: ODYSSEE, 2021 - own edition

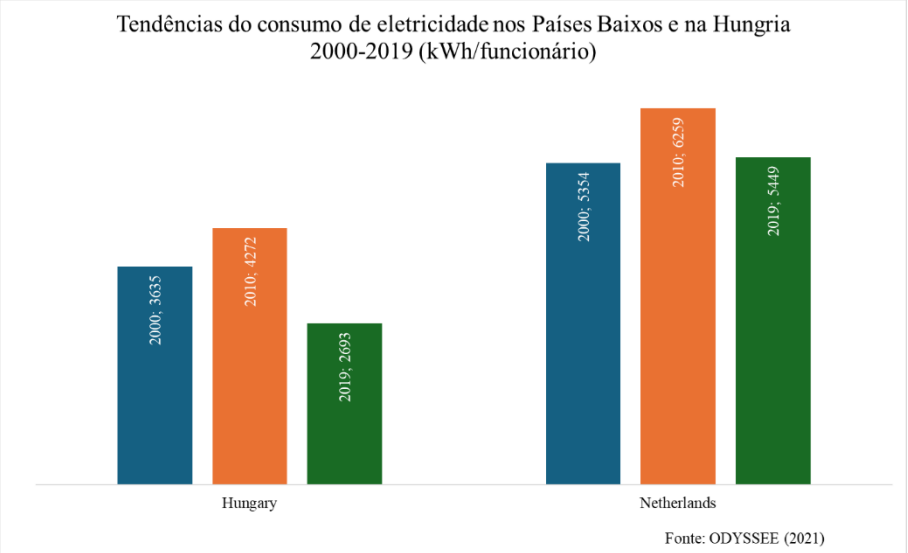
On the other hand, energy consumption of services remained almost stagnant (+0.1% per year compared to +3.5% per year), and growth was significantly slower than in the previous year. Between 2008 and 2014, total energy consumption fell drastically (-1.2% per year), and electricity consumption also fell (-0.3% per year), although value added only increased by 0.5 years. As consumption in 2019 still exceeded EU targets for 2020 and 2030, the authors of the study highlight the importance of an adequate energy policy. Literature results show that an effective energy policy works (Bertoldi & Mosconi, 2020). With the appropriate measures, the EU's energy consumption has already been reduced by 13% in 2013. However, the cuts were most noticeable in the secondary industrial sector, which is smaller but has a high energy use. However, further action is needed in the tertiary sector.

The use of electricity is an important aspect of energy consumption. The consumption per employee is shown by the database (ODYSSEE, 2021). Electricity consumption increased

in 2/3 of EU countries, including the Netherlands, between 2000 and 2019, but decreased significantly in Hungary, based on time series (Figure 5).

Figure 5

Trends in electricity consumption in the examined countries



Source: ODYSSEE, 2021 - own edition

3.2.2 Environmental-Economic Correlation Indices

Resource productivity, which can be calculated as the ratio between GDP and domestic material consumption (MIF), shows the relationship between the environment and the economy. To compare countries in different years, resource productivity is calculated using an index of Euros/kg in the year 2000. The economy-wide material flow indicator is known as DMC. Indicates the total amount of materials directly used on the farm in kilograms or tons. DMC is equivalent to more imports less exports. These substances are returned to the environment, such as atmospheric emissions, or are incorporated into the stock of economical materials. At the same time, not all materials that were used in production are present in the product. Many manufacturing processes require a significant amount of water, which will not be incorporated into the final product. Much land is moved by mining and extraction operations without being used for production. Literature refers to these hidden material flows as "ecological backpack" (Ritthoff et al., 2002; Robèrt et al., 2002). A significant indicator of goal number 12 of the United Nations sustainable development framework, called "responsible consumption and production," is resource productivity. The material flow analysis (MFA) method is used to measure DMC (Bleschwitz, 2010). This method is used to calculate the flow

of matter and energy between the natural and human spheres. Direct material flow (DMC) is the term for total material consumption (TMC). The sum of the DMC and the eco-backpack is the TMC.

More effective use of materials results in greater energy savings and material costs, resulting in increased competition. Biofuels and renewable energy sources depend on natural resources such as steel and platinum. A key approach to green growth and climate change mitigation will be to ensure these natural resources in a more sustainable way. Decades ago, there was a global dispute over access to resources. However, as demand for these resources is constantly increasing, the increase in the quantity extracted has not been accompanied by a fall in prices. Global resource extraction is expected to increase to at least 2.5 times the 1980 level by 2030 (Bleischwitz, 2010). In particular, there is an increase in the extraction of metals and minerals. There are two problems with fossil fuels. One of the reasons for reducing the use of these energy carriers and replacing them with less polluting alternatives for the environment is that they pollute the atmosphere and increase the greenhouse effect. The additional explanation lies in geography. The new deposits are located in more difficult locations and far from the area of use, which means that the resources that can be extracted from them are deteriorating over time. Since the mid-1990s, the number of significant deposits and world-class discoveries has been decreasing despite increasing investment. Even on the human timescale, metal mining is not feasible. Primary metal stocks will be depleted in 50 years (Jowitt et al., 2020). Competition can cause property conflicts and wars, as well as disturbing the biological balance. The search for agricultural land and mineral resources in Ukraine is among the likely causes of the ongoing conflict between Russia and Ukraine (EBRD, 2022; Osusky, 2022; Roels, 2022).

Natural scientists say that sustainability is impossible with the depletion of raw materials. However, economists argue that growth and energy use can complement each other (Hirschnitz-Garbers et al., 2013). In addition, there is a significant obstacle to increasing the importance of renewable energy sources. The energy from the sun, wind and water can be reused, but we do not use it in its original form. Wind turbines and hydropower plants use a significant amount of cement and plastic, while solar collectors use a significant amount of rare and expensive metals. For example, lithium is running out. It is increasingly difficult to meet the growing demand for electric cars due to the oligopolistic market and the inequitable location (Lithium Triangle: Chile, Argentina, Bolivia).

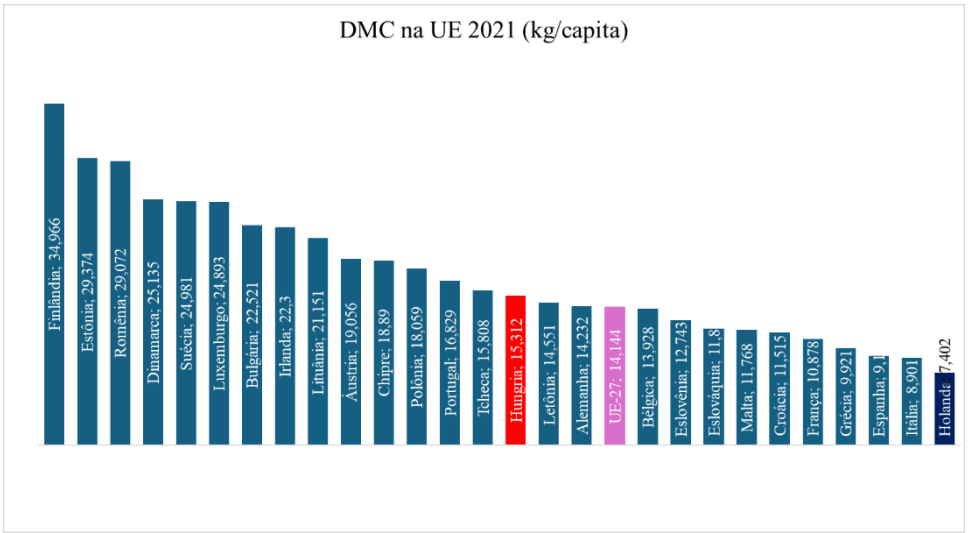
The final list of vital minerals in 2023 was published by the IEA. This includes metals that are typically obtained through exports and are essential to national security and industry. Therefore, damage to the supply chain can significantly affect industrial production and thus

competitiveness. Rare earths and critical minerals are vital for sectors such as electric vehicles, fuel cells, solar photovoltaic technologies, wind energy technologies and aviation (IFPEN, 2023). The metallurgical industry requires a lot of water, requires a lot more energy than mining and processing, and causes a lot of emissions. The latest models highlight the importance of copper, in addition to lithium and rare earths (Hache, 2022).

The value of CMD varies significantly between EU Member States. In 2010, Bleischwitz stated that there is a big difference between the old and new member states of the union. However, the material consumption of the new member states reached the same level as that of the older member states in 2017 (EEA, 2022), and energy consumption in the north was observed to be lower in 2021, while energy consumption in the south was observed to be higher (Figure 6).

Figure 6

Internal material consumption, EU-27



Source: Eurostat

3.2.3 Knowledge Capital Indices

Knowledge of employment, which is the proportion of jobs in the high-tech and media sectors in % of all employment networks, is one of the variables of the third group studied in this study. The other is research and experimental development. Creative work done systematically to increase the body of knowledge, which includes knowledge about humans, culture and society, and use it to create new applications is known as experimental research and

development (R&D). R&D expenditures are expressed as a percentage of GDP (R&D intensity).

3.2.4 Environmental Awareness Indices

The fourth group of factors affecting environmental awareness is as follows: the percentage of recycled waste in relation to total waste; the percentage of renewable energy in total energy consumption; and the percentage of imported raw materials in relation to total raw materials. The relationship between rail and public transport is another factor that measures environmental awareness. Table 1 contains a summary of the variables used in this research and their short names.

Table 1

Variables and abbreviations

Variable	Variable name in this search
Resource Productivity	(PHP 4 = 4.0.5)
Employment rate	EMP_RATE
Gross Fixed Capital Formation	GFCF
Share of the tertiary sector in GDP	(PHP 4 = 4.0.5)
Knowledge of employment	(PHP 3 = 3.0.6, PHP 4)
Research and development	R and D
Recycled Waste	(PHP 4 = 4.0.5)
Imported Raw Materials	(PHP 4 = 4.0.5)
Circular of used materials	(PHP 3 = 3.0.6, PHP 4)
Proportion of renewable energy	REN_EN
Proportion of trains in passenger transport	TRAIN

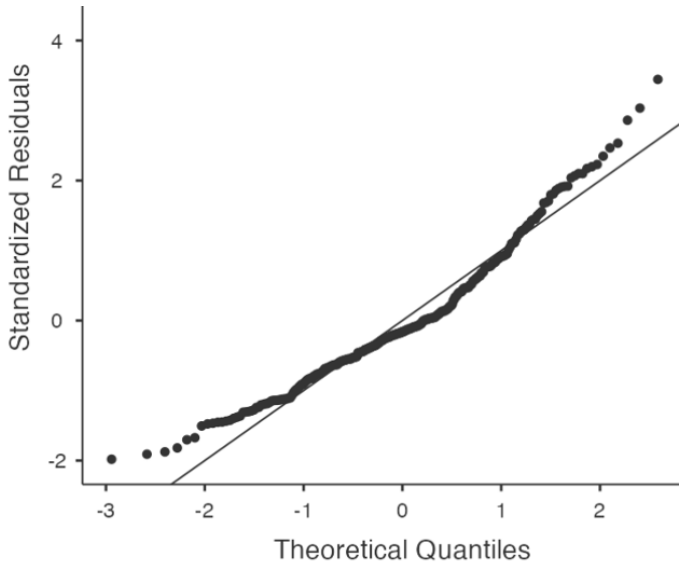
Source: author's own

3.3 SAMPLE DESCRIPTIVE STATISTICS

The sample covers the 27 EU countries, with the EU average ranked as the 28th value. The time series, compiled from Eurostat databases, runs from 2011 to 2021. The data on the tertiary sector relationship are from the World Bank. The MS Excel for Mac v.16.74 and Jamovi 2.3.21.0 programs were used to process and test the data. In addition, the SMART-PLS program version 4.0.9.5 was used to create a Structural Equation Model (ESM). Figure 7 shows Table 2 containing the descriptive statistics of the sample. There are no missing items in our 308 items.

Figure 7

QQ Chart of normality



Source: author's own

Table 1

Descriptive statistics of sample with normality test and extreme outlier test

	(PHP 4 = 4.0.5)	EMP_RATE	GFCF	R and D	(PHP 3 = 3.0.6, PHP 4)	(PHP 4 = 4.0.5)	REN_EN	TRAIN	(PHP 4 = 4.0.5)	(PHP 4 = 4.0.5)	(PHP 3 = 3.0.6, PHP 4)
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	1,6442	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	10,6958	33.8

Source: author's own

Table 3

Statistical

	Statistics	p
Kolmogorov-Smirnov	0.0391	0.776

Table 4

Distance from Cook

Distance from Cook			Range	
Mean	**Median**	**SD**	**Minimum**	**Max.**
0.00522	0.00113	0.0155	9.86E-9	0.205

Source: author's own

There are also no extremely divergent values according to Cook's distance values. The normality condition is met because the Kolmogorov-Smirnov test is not significant. In addition, linearity and normality can also be assumed based on Figure 7.

3.4 MODELS

A regression model is used to test hypotheses. Resource productivity is the dependent variable in this case, and all other variables are considered independent variables. The conditions necessary for the construction of the model must be examined before its description. The first is the concept of linearity. The fundamental assumption is that the independent variables and the dependent variable have a linear relation. The performance provided in the resource productivity variable is presumably improved by investments, the tertiary sector ratio, the increase in the employment rate and knowledge of employment, the success of research and development. In addition, this is expected to have a positive impact on environmental awareness indicators. The only exception is the import of raw materials, indicating that the country cannot sustain economic growth with its own resources. Normality and linearity have already been verified when describing the descriptive statistic of the sample. Homocedasticity is the following condition. This can be completed based on the results of the Breusch-Pagan heterokedasticity test. The results show that the state is 81.3 and the probability of error is 0.001. Multicollinearity, or the exclusion of variables that move together, is a crucial condition. For this purpose, all VIF values are above 10, indicating significant multicollinearity. However, only the variables WAST_REC and RAndD showed correlation above 0.7 in the result of the correlation test between the independent variables (r=0.708 of Pearson, p=0.001), which refutes the multicollinearity. Because the variables used to build the model meet the criteria, the next step is to build the model. The simplified equation (2) for the model is:

$$RES\_PROD = \alpha + \beta\ 1\ *EMP\_RATE + \beta\ 2\ *GFCF + \beta\ 3\ *\ RAndD + \beta\ 4\ *WAST\_REC + \beta 5\ *REN\_EN + \beta 6\ *TRAIN + \beta\ 7\ *TERT\_SEC + \beta 8\ *RAW\_IMP + \beta\ 9\ *CIRC\_MAT + \varepsilon \quad (1)$$

where the abbreviations correspond to the variables in Table 1. The slope parameters to be estimated are b1-b9, and the error term is ε. The original model also included the interaction of the variables; however, to simplify the model equation, these variables are not in equation (2).

In addition, a SEM was developed to determine whether the variables surveyed affect resource productivity through GDP or DMC. In the model, GDP and CMD are considered explanatory variables; all other variables are considered explanatory variables. The PLS-SEM algorithm (weighting scheme: path, type of results: standardized, starting weight: default) was used to perform the model-related calculations.

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