

GREEN FINANCE AND CIRCULAR ECONOMIC TRANSITION IN HUNGARY

In the context of sustainable development¹

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ABSTRACT

This study examines the correlation between green finance, the circular economic transition, and sustainable development in Hungary. Its novelty lies in interpreting the circular economy as a potential theoretical linking mechanism between green finance and sustainable growth. The analysis draws on annual data from the National Bank of Hungary (MNB), Eurostat, and the World Bank. For the longer time series of 2000–2025, it applies descriptive statistics, trend analysis, and Pearson correlation. Developments in green finance indicators over 2020–2026 are presented descriptively, while the short-term correlation analysis between green finance and the circular economy is based on the common observations for 2020–2025. The results show that resource productivity has the strongest and most consistent relationship with economic, energy, and productivity indicators. Favourable co-movements in recycling performance are better interpreted as part of broader technological and institutional modernization, while relationships involving domestic material consumption are weak. Based on the short time series, green finance may support the transition primarily by improving financing conditions for sustainable and resource-efficient investments. However, the correlations do not establish causality or a formal mediating effect; the results are therefore exploratory. The policy implication is there is a need to coordinate financial, industrial, and environmental policy instruments.

JEL codes: G21, G23, O44, Q01, Q56

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1 INTRODUCTION

Sustainable economic development has become one of the central issues of economic policy, and financial and corporate decision making over the past decade. Climate change, overexploitation of resources, energy dependency and the environmental impact of production systems demand economic models to be set up that are capable of supporting growth, reducing environmental damage and promoting more efficient use of resources. In the process two areas play a key part: green finance and transition to a circular economy.

Green finance includes financial instruments, investments and institutional solutions that support environmentally sustainable activities. Such are, among others, green loans, green bonds, sustainable investment funds as well as financial regulatory and incentivising systems that drive both businesses and institutions towards environmentally responsible operations. Green finance is particularly important in countries where the restructuring of the economy, the improvement of energy efficiency and financing investments of low carbon intensity are key development objectives.

Circular economy appears parallel with that, as an alternative to linear economic models. The linear model is built upon the logic of “extraction-production-consumption-waste”. On the other hand, the goal of a circular economy is to keep materials and resources in an economic cycle, to increase recycling, reduce waste production and improve resource productivity. A circular economic transition, in that way, is not a simple environmental issue but also a challenge of economic competitiveness and innovation.

The topic is particularly relevant for Hungary. Being a small country with an open economy, it is highly dependent on international markets, energy import, and the regulatory environment of the European Union. The EU’s green transition goals, stricter regulations regarding sustainable finance and the policy expectations of a circular economy all exert pressure on the domestic players of the economy. It is still a question how much green finance can actually contribute to the transition into a circular economy and, through it, to sustainable development.

The international literature pays considerable attention to the relationship between green finance and economic growth as well as the environmental and economic impact of a circular economy. However, there is less research on whether a circular economy can be interpreted as a mediating agent connecting green finance and sustainable development. This research niche is particularly important for Central and Eastern European countries including Hungary, where the funding, institutional and structural prerequisites of a green transition may be different from the same in the more developed economies of Western Europe.

The objective of this paper is to conduct empirical research to find out how green finance can be linked to the transition to a circular economy and sustainable development in Hungary. The key question we are trying to answer is whether green finance can directly contribute to sustainable development, or its impact will be exerted indirectly by improving the performance of a circular economy. Accordingly, the study uses the example of Hungary to reveal the connections between green finance, circular economic transition and sustainable development.

This study can offer scientific contribution to three areas of the issue. On the one hand, by focusing on Hungary, it will enhance the empirical literature on the relationship between green finance and sustainable development. On the other hand, it interprets circular economy as a potential theoretical mediating mechanism rather than an independent indicator of environmental performance. And finally, the study can contribute to identifying the conditions that are necessary so that the instruments of green finance can effectively support sustainable economic restructuring in an EU Member State located in Central and Eastern Europe.

2 LITERATURE REVIEW

2.1 Green finance and sustainable economic restructuring

Green finance refers to the instruments, institutions and incentives of a financial system supporting the implementation of investments that are sustainable from an environmental aspect (Schoenmaker, 2020). They include, among others, green loans, green bonds, sustainable investment funds, banking practices integrating aspects of climate risk or regulatory and market mechanisms channelling capital towards economic activities involving lower environmental pressure. According to the relevant literature, the financial system is not a neutral player in sustainability transition (Gilchrist et al., 2021), because it exerts a major influence on the transformation of economic structures by investment decisions, credit allocation, and risk management practices (Schoenmaker–Schramade, 2019).

The literature on sustainable finance underlines that financial decisions increasingly tend to be linked to aspects of the environment, society, and corporate management. Green finance is not simply a tool kit box of new financial instruments, but it represents a reshaping of the objectives of financial mediation where, in addition to financial return, long term environmental and social value creation play a major part in capital allocation. Based on a summary of the findings of over two thousand empirical studies, Friede et al. (2015) have found that the relationship of ESG performance and corporate financial performance is not negative in the ma-

jority of the cases, and it is positive to a significant rate. According to Ng (2018), however, the operation of green finance systems is closely related to how companies and financial institutions measure and report sustainability performance and what price tag they attach to it. The efficiency of green finance, therefore, does not only depend on the quantity of available sources but also on the quality of the information, regulatory and institutional environment.

Research on green finance has been given increasing attention in the context of sustainable development and climate change. According to D’Orazio–Popoyan (2019), promoting green investments and managing climate risk is not simply a micro-level financial issue but it is also a macro-prudential task of economic policy. The authors emphasise financial regulations and central banking policies may play a part in mitigating environmental risks and encouraging green investment. This is particularly relevant in countries where the structure of the economy relies on carbon intensive industries, its dependence of energy import is significant, or resource efficiency is lower.

Of green tools of finance, green bonds play a particularly important part in funding sustainable investments. Empirical studies by Flammer (2021) have shown that corporate issue of green bonds is related to the improvement of environmental performance of the issuing companies, particularly if the bonds have independent third-party accreditation and the markets can assess them to be credible commitments to sustainability. Tolliver et al., (2020) also point out that the development of green bonds is linked to national goals of sustainability and climate policy. Therefore, the success of green finance is highly dependent on how much it is embedded into the institutions and policy agents.

The EU taxonomy regulation is a central element of the EU sustainable financial regulations. It has established a uniform framework of classification to determine what economic activities can be regarded to be sustainable from the aspect of the environment. In line with the regulation, an economic activity must significantly contribute to at least one environmental target, it cannot cause major damage with respect to the implementation of other environmental objectives, and it must comply with minimum security requirements and the relevant criteria of technological inspections (European Parliament – Council of the European Union, 2020). The objective of the taxonomy is to harmonise the identification of sustainable activities, to reduce informational insecurity and to drive capital towards environmentally sustainable investments.

The National Bank of Hungary (hereinafter: MNB) plays a decisive part in the institutional development of the green money market. Its annual Green Finance Report provides a comprehensive review of the environmental sustainability related risks of the domestic financial market, its funding activities, and the sustainability programmes of the Central Bank (MNB, 2026b). Regular reporting

and the presentation of green financial stocks statistically separated can contribute to the transparency of the domestic market and allows monitoring of green financial processes.

The MNB's discount programme linked to green capital requirement is a particular component of the domestic regulatory environment. Subject to certain definite requirements, the programme grants capital requirement discount to the participating banks on their corporate and municipality credit and bond exposure assessed to be green. Its objective is to strengthen green bank portfolios, mitigate climate risk related exposure and promote environmentally sustainable funding. The reporting and compliance requirements of the programme can also promote the identification and control of the activities funded (MNB, 2026a).

Empirical research has supported that green finance may relate to improved environmental performance. Meo-Karim (2022) studied the relationship between green finance and CO₂ emission and has found that the improvement of green finance may contribute to the reduction of emission. Taghizadeh-Hesary-Yoshino (2019), however, emphasise that green investment often requires private sources to be involved as well as financial incentives improving the risk - profit profile of green projects.

Still, the findings of the literature should be interpreted critically. According to a review by Gilchrist et al. (2021), side by side with the corporate advantages related to green bonds and green credit there are still major limitations presented by the differences in identifying green financial products, asymmetry of information, the lack of proper control and the threat of greenwashing. Therefore, simply classifying financial products as green will not guarantee that such funding results in measurable extra environmental impact. To achieve that you need reliable classification, reporting and control systems as well as monitoring the actual environmental performance of the investments funded.

So green funding cannot guarantee sustainable development in itself. The impact of financial sources depends on the types of investments they support, the institutional environment they operate in and the extent they can contribute to actual changes in the structure of the economy. Green finance can mainly exert an impact by improving the conditions of funding sustainability transition; however, it cannot substitute interventions into environmental, industrial, or innovative policy. Therefore, to examine the relationship between green finance and sustainable development, you should consider the mediating mechanisms of real economy by which financial sources can be transformed into resource efficiency or improved technological and environmental performance.

2.2 Circular economy as a model of sustainability

Circular economy can be interpreted as an alternative to the linear “extraction–production–consumption–waste” model. Its objective is to keep materials, products, and economic resources in an economic cycle by increasing recycling, repair, re-manufacturing, reusing and to improve resource effectiveness (Sauvé et al., 2016, Geissdorfer et al. 2017) interpret circular economy as a sustainability paradigm that can contribute to the harmonisation of economic and sustainability goals by mitigating the use of natural resources and making material flows more enclosed.

The academic history of the circular economy is linked to several fields including ecological economics, industrial ecology, the management of product life cycle and studies on sustainable business models. Pearce–Turner (1990) pointed out in the context of natural resources and ecological economics that the material and energy flows of economic structures cannot be separated from environmental limitations. The “cradle to cradle” approach by McDonough–Braungart (2002) also contributed to the idea by interpreting products to be potentially recyclable or reusable resources rather than waste.

Nevertheless, the concept lacks a uniform definition. Based on an analysis of the definition of circular economy, Kirchherr et al. (2017) stated there are different emphases in the relevant literature: some approaches emphasise the reduction of waste and recycling, while others point out economic restructuring at systemic level, the renewal of business models and creating patterns for sustainable consumption. The methodology of diverse definitions is a challenge for empirical research as well, since there is no uniformly adopted set of indicators to measure the transition into a circular economy.

In their comprehensive review of the relevant literature, Ghisellini et al. (2016) pointed out that circular economy is not a simple question of waste management, but it is a process of transition involving economic, environmental, and social dimensions. The authors believe it can contribute – at macro level – to reducing resource exploitation, improving the effectiveness of production systems, and mitigating environmental pressure. Stahel (2016) came to a similar conclusion emphasising that a central element of circular economy is prolonging the lifespan of products and materials, which would create economic value and reduce the demand for primary resources at the same time.

On the other hand, circular economic transition will not only assume technological development but also a change of institutional and business models. According to Bocken et al. (2016), circular business models can support sustainable value creation by extending the lifespan of products, enclosing material circular flows, using models based on sharing and establishing product - service systems. Mur-

ray et al. (2017) underline that the relevant literature on circular economy often focuses on technological and economic issues while societal and ethical dimensions are neglected.

So, the relationship between circular economy and sustainability cannot be taken for granted. According to Korhonen et al. (2018), there are some limitations regarding the application of the concept, particularly if policies or corporate practices focus on the cycle of material flows only and fail to consider energy consumption, rebound effects or societal consequences. Circular solutions alone cannot guarantee that sustainability goals are met; their success greatly depends on the technologies applied, the institutional environment and the structural specification of the economy in question.

The policy relevance of circular economy has been gaining momentum in the European Union for the past years. According to the OECD report 'Towards a National Circular Economy Strategy for Hungary', transition to a circular economy in Hungary is not only an issue of environmental policy but also of competitiveness. The report underlines that, due to the country's material and energy intensive economic structure, the improvement of resource productivity, higher rate of using secondary raw materials and incentivising circular business models are particularly important (OECD, 2023). At the same time, the strategy points out that the success of a circular transition does not only depend on technology developments, but it also requires the proper regulatory, financial, and institutional conditions to be in place.

According to the above, circular economy can be interpreted as a complex transitional model, which affects both resource management, production and consumption systems, business models, and the policy environment at the same time. The many-dimensional nature of the concept, however, makes empirical measurements difficult, but it justifies the joint application of several complementary indicators to assess the performance of a circular economy.

2.3 Circular economy and sustainable growth

Sustainable growth means economic performance that is not accompanied with the overuse of natural resources and increased environmental pressure in the long run (OECD, 2011). Circular economy is linked to that because it can improve resource productivity, mitigate the production of waste, reduce the demand for primary raw materials, and encourage the establishment of innovative business models. According to Barbier (2011), a primary challenge facing green economic policy is to connect economic growth to mitigating environmental pressure and improving resource efficiency.

Interpreting the economic impact of circular economy, you should distinguish between short term costs and the long-term benefits of competitiveness. The implementation of circular solutions may require investments, technology development, and corporate learning, but in the long run it can reduce material expenses, mitigate supply risks, and create new market opportunities. According to D'Amati et al. (2017), the common component of the concept of green economy, circular economy and bioeconomy is that they all wish to transform economic operations to promote environmental sustainability while they represent different emphases and policy logics.

Bina (2013) underlines the relationship between green economy and sustainable development is not problem free. Transforming economic growth to become sustainable can only be considered well founded if environmental limitations and societal effects are built into economic policy decisions. Such an approach is particularly important in a circular economy, since circularity in itself will not necessarily result in sustainability in case material circulation results in enhanced energy consumption or new environmental pressure. Korhonen et al. (2018) also emphasise that the operation of the whole system must be considered, not only material flow trends, when you want to assess the success of circular economy.

From an empirical aspect, a circular economic transition can be measured by resource productivity, the rate of the circular use of materials, the rate of recycling or the performance of waste management. In their analysis of the global material flow, Haas et al. (2015) pointed out that the circularity of the world economy is limited, and most material flows continue to operate on a linear logic. This supports that circular economic transition cannot be simply measured using recycling rates, but wider indicators of resource efficiency and material consumption must also be considered.

This is particularly important for Hungary, because sustainable development cannot be interpreted by the evolution of the GDP alone. Both resource intensity, the performance of waste management and changes in environmental pressure define how much one can regard economic growth to be sustainable. Accordingly, the indicators of circular economy are applicable jointly to describe the different dimensions of sustainable development.

However, based on the relevant literature, no clear, valid statement can be made for all countries, saying there is a clear connection between circular economy and sustainable development. The strength of interconnections is influenced by how developed a country is, and what the structure of the industry, the institutional environment and the set of policy incentives are like. Therefore, assessing the impact of circular economy on sustainability requires empirical studies, particularly in the case of such an open economy as Hungary.

2.4 Relationship between green finance and circular economic transition

The relationship between green finance and circular economy is less elaborate in the literature than that of between green finance and carbon emission or circular economy and sustainability. However, connecting the two fields is theoretically justified. Geissdoerfer et al. (2023) point out that circular economic transition is a process requiring intensive investment, including technological development, a recycling infrastructure, energy efficient production structures, sustainable supply chains, and innovative business models. To implement such developments requires appropriate financial sources, incentives, and reliable institutional conditions.

According to Schoenmaker–Schramade (2019), green finance is not simply financing environmentally friendly investments, but the prerequisites of an economic restructuring must also be met. Following the approach by Geissdoerfer et al. (2017), if a financial system drives capital towards activities that improve resource efficiency, mitigate waste production, and increase the recycling of materials, green finance may support the circular economic transition. As a result, the connection between green finance and sustainable development can be partly interpreted along real economic processes such as the improvement of resource productivity, development of recycling and the spread of circular business models. That is, however, a theoretical correlation and does not mean, in itself, the presence of formal mediation or a cause-and-effect relationship.

Based on the relevant literature, the relationship of green finance and circular economy can be interpreted using at least three mechanisms. Firstly, Taghizadeh–Hesary–Yoshino (2019) emphasise that the appropriate financial incentives can improve the risk-benefit profile of green investments, and, in that way, they can ease the financing pressure on projects aimed at energy efficiency, recycling or cleaner production. Second, according to Geissdoerfer et al. (2018), the introduction of circular business models requires changes in structure, technology, and value creation. Their implementation may be encouraged through targeted financial sources and financial conditions related to sustainability performance. Third, the NGFS (2019) points out that if the risk management practice of financial institutions considers climate and environmental risks, companies may be incentivised to pay more attention to resource efficiency, the vulnerability of supply chains or environmental compliance.

Nevertheless, the operation of mechanisms is not automatic. According to Veres (2026), greenwashing, less-than-optimal reliability of corporate ESG information, and the lack of their comparability may distort financiers' risk management as well as capital allocation towards sustainable activities. Therefore, the increase of green financial products and financing volumes is not sufficient to prove that

the resources will really result in actual extra environmental or circular impact. To validate the connection, you need appropriate classification, reporting and control systems, while the actual environmental performance of the financed investments must be monitored.

This approach is particularly relevant for Hungary, where incentives of green finance, the policy efforts relating to European Union sustainability goals and the transformation into a circular economy are all present at the same time. So, it is an important issue from the aspect of achieving a sustainable growth path in Hungarian economy. Economic actors must clearly see the relationship between green financial instruments and the processes of the real economy that can improve the effectiveness of resource utilisation and mitigate environmental pressure.

This paper, accordingly, offers an interpretation of circular economy as a potential theoretical linking mechanism between green finance and sustainable development. The study is not aimed at testing a formal mediation model; it does not wish to prove causal effects, but it wants to reveal whether co-movements consistent with the set of theoretical connections described in the relevant literature can be observed among Hungarian indicators.

2.5 Research niche and hypotheses

A significant part of the relevant literature investigates the environmental and economic contexts of green finance separately. However, there are fewer empirical findings on the relationship between green financial instruments and the performance of the circular economy, and on how such co-movements fit into a wider set of interrelationships within a Central and Eastern European economy.

The study intends to examine the above research niche by offering an analysis of time series data of Hungary. The study is not aimed to assess a formal mediation model or to prove causal effects. It interprets circular economy as a potential linking mechanism through which green finance can be connected to sustainable development. Therefore, the hypotheses relate to the direction and strength of the co-movements of the indicators.

- H1: Of the indicators of circular economy, the connection of resource productivity is positive with the economic and productivity indicators of sustainable development, but the connection with energy intensity is negative.
- H2: The connection of the improvement of recycling performance is positive with certain indicators of sustainable development, while it is weaker and less consistent with domestic material consumption.
- H3: The co-movement of the indicators of green finance is positive with certain performance indicators of circular economy, particularly with resource pro-

ductivity. The relationship may reveal that green finance supports circular economic transition by improving the funding conditions of sustainable and resource-effective investments.

3 DATABASE AND METHODOLOGY

3.1 Data sources and variables

The analysis is built on secondary annual data. The indicators of green finance have been taken from the statistics of the National Bank of Hungary, the indicators of circular economy from the database of Eurostat, while the variables describing sustainable growth and the wider macroeconomic environment come from the database of the World Bank's World Development database. Because of the differences in data coverage, three different kinds of data coverage have been separated in the study. The longer time series analysis of the indicators of circular economy, sustainable growth and macroeconomic indicators cover the period from 2000 to 2025, while the green finance figures are available for the period from 2020 to 2026. Since however the database does not include the 2026 figures for circular economy and sustainable growth, the correlational analyses also including the green finance variables are based on monitoring the six common years from 2020 to 2025. Separating the different data coverages allows the longer-term structural co-movements to be analysed separately from green financial relations formed recently.

The dimension of green finance is represented by the green corporate loan portfolio (GF_1), the green housing loan portfolio (GF_2) and the green bonds portfolio (GF_3). Circular economic performance is provided by the rate of circular material consumption (CE_1), resource productivity (CE_2), domestic material consumption (CE_3), the rate of recycling municipal waste (CE_4) and that of packaging waste (CE_5). The indicators of sustainable growth are GDP per capita (SG_1), the ratio of renewable energy (SG_2), energy intensity (SG_3), gross fixed asset accumulation relative to GDP (SG_4) and labour productivity (SG_5). Inflation (C_1), trade openness (C_2) and net direct foreign capital inflow (C_3) are included in the analysis as additional macroeconomic indicators. The study does not use them as control variables since they are not part of a multi-variable regression model; their role is to help interpret the wider economic environment of the co-movements analysed. CE_3 and SG_3 are indicators of a negative direction, that is, a lower value there indicates better sustainability performance.

3.2 Method of data preparation and analysis

The time series coming from different data sources have been presented in a uniform database and the source of the data, the unit of measurement, the time covered and the direction of interpretation have been recorded for each variable. The data from MNB have been added as annual observation. No automatic supplementary data, interpolation or reassessment have been applied since they could artificially modify the trends and the correlations between the variables particularly in the event of short time series. The calculations for all pairs of variables are based on the common observations actually available.

The empirical study applies descriptive statistics, trend analysis, and two-variable correlational analysis. Descriptive statistics illustrate the level and variance of the indicators; the trend analysis presents time paths while correlation coefficients reflect the direction and strength of the co-movements of the variables. Longer time series analysis focuses on the connections between the indicators of circular economy, those of sustainable growth and the supplementary macroeconomic variables. On the other hand, the short-term analysis focuses on the co-movements of the indicators of green finance and the circular economy in the period from 2020 to 2025.

Pearson-type correlation coefficients have been calculated to measure linear relationships. The database also includes Spearman's rank correlations for the assessment of the sensitivity of the findings because they are less sensitive to extreme values and to assumptions of linear relations. The comparison of the findings of the two methods serves as robustness check, but neither procedure can be regarded as a causal or forecast model due to the length of the available time series. The interpretation of the part played by green finance calls for particular care since the correlations come from common observation of not more than six years.

3.3 Limitations of interpretation

The findings of the study are exploratory. The correlation coefficients represent the co-movements of variables, but they are not suitable for verifying causal directions, delayed effects, or formal mediating mechanisms. Therefore, the study does not assess a mediation model while it interprets the part played by circular economy as a linking mechanism assumed theoretically. The findings indicate that the indicators studied move in the directions identified in the hypotheses, but they fail to prove that green finance, in itself, can trigger changes in circular economy or sustainability performance.

Longer macroeconomic time series represent trend-like movements in the case of several variables, so the high correlations calculated between the levels may originate from partly common time trends. Lacking formal stationarity, co-integration or causal tests, the correlations cannot be interpreted to be connections of stable long-term equilibrium. The Spearman correlations provide supplementary sensitivity tests, but they will not eliminate the threat of being a correlation of illusion. The extremely low number of elements in the green finance part is another limitation, because the coefficients may be sensitive to changes in one or another observation, while their statistical insecurity is significant.

The findings relate to Hungary and the period studied, so they have limited relevance to other countries or different institutional environments. The findings may first of all be interpreted as the starting point for further research to be conducted on longer time series, using the data of other countries or studies using more developed time series and panel econometric methodology.

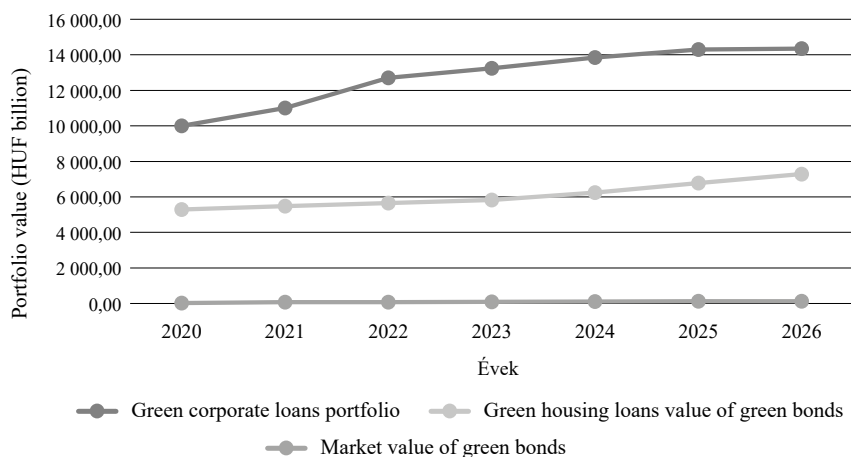
4 EMPIRICAL ANALYSIS OF CIRCULAR ECONOMY, GREEN FINANCE AND SUSTAINABLE DEVELOPMENT

4.1 Descriptive analysis of the variables applied in the study

The objective of this subchapter is to provide a descriptive analysis of the green finance, circular economy and sustainability indicators applied in the study as well as to present their evolution in time. In addition to an overview of the descriptive statistics, the trends of development of the different indicators are given special attention, because they serve as an important basis for the interpretation of further correlation analyses.

The variables studied have different dynamics, which reflects well the multidimensional nature of sustainability transition. The indicators of green finance present quick growth mainly in the period after 2020, while those of circular economy indicate longer term step-by-step structural changes. On the other hand, the indicators of sustainable development follow a more balanced path, which indicates that macroeconomic adaptation is a slower process than financial or regulatory changes.

At the same time, the different development paths justify why long- and short-term relationships are discussed separately. Long time series allow the discovery of structural relations between circular economy and sustainable growth, while in the case of green finance indicators the emphasis is placed on the analysis of connections recently established because of the shorter time series available.

Figure 1**Evolution of green finance indicators in Hungary from 2020 to 2026**

Source: own design

Based on the descriptive statistics, the green finance indicators (Figure 1) have reached significant growth within a short time. Green corporate credit stocks increased by 43.3% from 2020 to 2026, green housing loans grew by 37.7% and the green bonds portfolio by 483.3%. The values suggest that funding channels supporting investment into sustainability have been formed and gained momentum in the Hungarian financial system within a short time. Therefore, Figure 1 is not simply an indication of financial volumes but of a readjustment of financial institutions, which can be interpreted as one of the prerequisites of green transition. This interpretation is consistent with the approach of Schoenmaker–Schramade (2019) according to which the most important role of sustainable finance is not to generate short term growth but to redirect capital allocation towards economic activities that can be maintained in the long run.

On the other hand, the indicators of circular economy reveal a much more heterogeneous picture. The rate of circular material consumption (CE_1) only fluctuated at a modest rate while resource productivity (CE_2) showed quite significant improvement in a longer term. The evolution of domestic material consumption (CE_3) is not unambiguously declining; it has a rather cyclical path under structural effects. Of the indicators of recycling, the rate of recycled municipal waste has increased spectacularly, while recycling of packaging waste has been more moderate but relatively stable. Circular economic transition cannot be presented by a single indicator. This confirms the views of Kirchherr et al. (2017), who believe circular economy is a concept of several dimensions both from the aspect of

definition and measuring, which requires the joint analysis of the material loop, reuse, recycling, resource efficiency, and changes in business models.

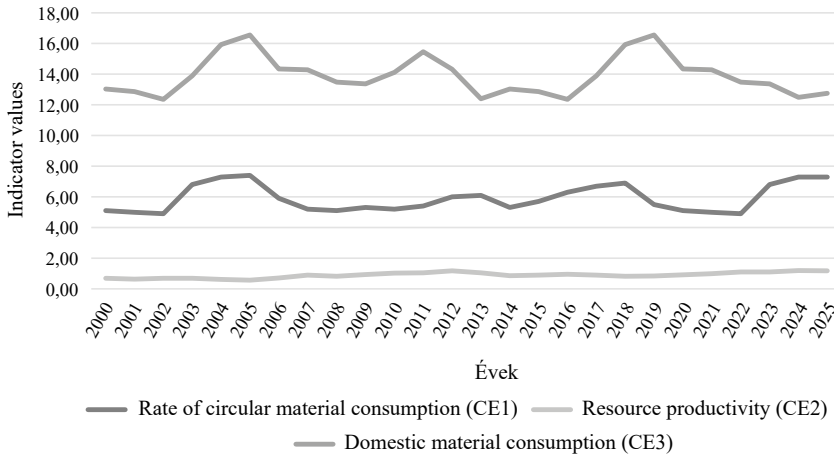
The indicators of sustainable development represent the third empirical path. GDP per capita has typically increased in the long run, the improvement in labour productivity has been more moderate but positive, while the reduction of energy intensity can be understood as a favourable move towards energy efficiency. The use of renewable energy has also improved although its path has not been really smooth. On the other hand, the indicator of gross fixed asset accumulation in relation to GDP has not been increasing steadily, which is a reminder of the fact that the dynamics of investments and the structure of sustainability investments cannot be simply identified with the whole rate of investments. Sustainable development in Hungary can rather be interpreted as a step-by-step structural adaptation than a quick turn governed by a single political or financial intervention.

The evolution of supplementary macroeconomic indicators adds a shade to the interpretation of short-term green finance results. The inflationary spike following 2020 may have exerted an impact on the conditions of funding and investment decisions, while the high trade openness and FDI volatility of Hungary suggest that sustainability transition is closely embedded into international production networks, the regulatory environment of the EU and the global cycles of investment. Therefore, the growth of green finance indicators, in itself, cannot be regarded to be the one actor triggering the improvement of sustainability indicators.

Based on the empirical review, green finance, circular economic transition, and sustainable development suggest different dynamics in time. The indicators of green finance can respond to the changes of regulations and those of the market faster while the indicators of circular economy reflect structural adaptation in the longer run. Accordingly, this study investigates long term (2000–2025) structural co-movements and the short-term (2020–2025) connections of green finance separately. *Figure 1* illustrates the evolution of green finance indicators, while *Figure 2* shows the long-term trends in the indicators of circular economy.

Figure 2

Evolution of circular economy indicators in the period from 2000 to 2025



Source: own design

The arrangement identifies the further structure of the study. Firstly, the long-term correlations of circular economy and sustainable development, next the short-term connections of green finance and circular economy are analysed. The joint interpretation of each analytic level contributes to grasping the part played by green finance in the connection between circular economic transition and sustainable development.

4.2 Long-term structural correlations between circular economy and sustainable development

4.2.1 Connection between resource productivity and sustainable development

Following a review of descriptive statistics and long-term trends, it is justified to analyse in detail the correlations of certain dimensions of circular economy and the different indicators of sustainable development. The objective of the long-term correlational analysis is to describe the structural co-movements that reflect the key characteristics of sustainability transition in the Hungarian economy rather than to prove direct causal relationships. The period from 2000 to 2025 allows the analysis of longer-term co-movements, while the effect of short-term fluctuations cannot be excluded either. *Table 1* is a description of long-term Pearson correlations.

Table 1

Pearson's correlational coefficients of circular economy, sustainable development, and additional macroeconomic indicators (2000–2025)

Variable	SG1	SG2	SG3	SG4	SG5	C1	C2	C3
CE1	0.320	0.033	-0.207	-0.205	-0.101	-0.132	-0.267	-0.418
CE2	0.755	0.845	-0.719	-0.303	0.785	0.087	0.633	-0.245
CE3	-0.014	-0.150	0.042	0.212	-0.056	-0.044	-0.040	0.201
CE4	0.791	0.901	-0.938	-0.015	0.542	-0.203	0.739	-0.077
CE5	0.289	0.499	-0.160	-0.674	0.594	-0.383	0.425	-0.049

Source: own design

Table 1 clearly illustrates that the circular economy indicators analysed are not connected to sustainable development to the same degree. Although all indicators grasp different aspects of circular transition, resource productivity (CE2) has the most consistent and strongest relationship with the economic, energetics and productivity dimensions of sustainable development. This indicates that the long-term sustainability performance of the Hungarian economy can mainly be improved by a more effective utilisation of resources rather than through the reduction of resource consumption in absolute terms.

Resource productivity has strong, positive correlation with GDP per capita ($r = -0.755$), the rate of renewable energy ($r = 0.845$) and labour productivity ($r = 0.785$), while its connection with energy intensity ($r = 0.719$) is strongly negative. The correlation illustrates well one of the basic mechanisms of sustainable growth: in periods when the economy is capable of producing higher added value using the same resources the indicators of both economic performance, energy efficiency and productivity improve at the same time. All that indicates, based on the indicators examined, that energy efficiency can be interpreted as an indicator connected to the modernisation of the economic structure and technological development.

The findings are particularly important from the aspect of economic theory. The goal of a circular economy is not simply to mitigate the consumption of materials, but to achieve increased economic value produced from the resources. Accordingly, improved resource productivity indicates that an economy is able to provide higher output from the same inputs, which improves competitiveness and, at the same time, mitigates environmental pressure. This dual effect is particularly important for such open economies as Hungary, where the improvement of productivity is a key factor of competitiveness.

The findings are closely aligned with statements by Geissdoerfer et al. (2017). They believe the primary economic advantage of a circular economy is not simply the reduction of waste production but also the creation of higher economic value as a result of the more effective use of resources. Ghisellini et al. (2017) have come to a similar conclusion. They have pointed out the success of a circular economy can be best measured through the improvement of resource efficiency. The findings from Hungary support that approach at macroeconomic level too since resource productivity has the strongest and most consistent relationship with the indicators of sustainability development.

A strong negative correlation observed with energy intensity calls for special attention. Since energy intensity is an indicator of negative direction, its reduction is a sign that the energy efficiency of an economy is improving. The findings support that increased energy productivity goes hand in hand with reduced energy needs, which suggests the technological modernisation of production processes offers both economic and environmental benefits. This also supports the opinion of D’Orazio–Popoyan (2019), who believe one of the most important outcomes of sustainable investments is the gradual improvement of energy efficiency and more effective use of resources.

The connections with the supplementary macroeconomic variables also affect the interpretation of the results. The positive relationship with trade openness (C2) ($r=0.633$) suggests that international economic integration can contribute to the improvement of productivity and the quick spread of state-of-the-art technologies. On the other hand, the correlations with inflation and direct foreign capital investment are significantly weaker, which allows for the conclusion that the long-term trends in resource productivity are mainly affected by structural rather than short-term macroeconomic factors. The findings suggest resource efficiency may be a priority area of future policy analyses.

4.2.2 Recycling performance and restructuring

In addition to resource productivity, recycling performance, which reflects the degree of development in the circulation of materials and how effectively resources can be kept in circulation, is the other defining factor of a circular economy. Resource productivity mainly refers to the efficiency of economic value creation, while recycling indicators illustrate the structural transformation of production and consumption. Accordingly, the long-term analysis of recycling allows one to assess how much the Hungarian economy had come closer to the basic principles of a circular economy in the period from 2000 to 2025.

You can see on *Figure 2* presented above that the recycling ratio of communal waste (CE4) and that of packaging waste (CE5) were both increasing in the pe-

riod studied while the dynamism of their improvement was different. While the recycling of communal waste was gradual and relatively stable, the recycling of packaging waste increased faster, which can be partly explained by the introduction of the waste management directives of the European Union and partly by the gradual introduction of enhanced manufacturer responsibility systems. Such measures greatly contributed to the higher rate of reuse of secondary raw materials as well as to the development of waste management infrastructures.

Long-term correlations (*Table 1*) illustrate the two recycling indicators are connected to the variable of sustainable development in different ways. The recycling rate of communal waste (CE4) has a particularly strong connection with the rate of renewable energy and labour productivity, while its connection is negative with energy intensity. This suggests the development of recycling does not only reflect an improvement in waste management, but it is also part of a more complex economic modernisation process where energy efficiency, innovation and technological development amplify each other.

On the other hand, the recycling rate of packaging waste (CE5) is more modest, but it typically has a positive connection with the indicators of sustainable development except for SG3 and SG4. This suggests the management of packaging waste has mainly improved due to regulatory and institutional developments while its direct macroeconomic impact is less marked. The difference between the two indicators illustrate that certain elements of a circular economy exert their impact on economic performance on different time horizons and via different mechanisms.

The findings are closely related to the findings of Kirchherr et al. (2017), who stated a circular economy is not simply the recycling of waste; it also requires a comprehensive structural transformation of production and consumption systems. Bocken et al. (2016) have come to a similar conclusion. They pointed out recycling, in itself, is not sufficient to ensure sustainable economic development, while it is a necessary component in business models and innovation improving resource efficiency and reducing environmental pressure in the long run.

The findings in Hungary, however, call attention to another special feature. The positive relationship between the indicators of recycling and sustainable development suggests the development of recycling should not be interpreted as an independent process. On the contrary, it is intricately connected to the technological modernisation of the economy, the improvement of energy efficiency and the gradual implementation of the EU's environmental targets. Accordingly, recycling is not only a means of environmental protection. It can also be defined as a structural factor supporting economic competitiveness and sustainable development.

Thus, recycling performance can be interpreted as an important indicator of circular economic transition in Hungary. Its impact is mainly exerted indirectly, through improved energy efficiency and innovation. This suggests future policy measures will not only have to make efforts to increase the rate of recycling but also to support integrated circular economic solutions that promote secondary raw materials to be used at a higher added value. They will also have to strengthen industrial symbiosis and the spread of sustainable production systems.

Recycling indicators mostly reflect the effectiveness of material circulation. Understanding a circular economic transition fully also requires analysing what the relationship of material consumption with the different dimensions of sustainable development is. The next chapter analyses the question with respect to the indicator of domestic material consumption.

4.2.3. Domestic material consumption and sustainable development

Resource productivity and recycling performance have a more favourable and unambiguous relationship with the indicators of sustainable development. Domestic material consumption (CE₃), on the other hand, requires a different interpretation. CE₃ is an indicator of negative direction, i.e., a lower value suggests better sustainability performance. The reason for that is the indicator shows the quantity of materials used by the economy internally for its production and consumption processes. Therefore, from the aspect of circular economic transition, the reduction of domestic material consumption may theoretically indicate material intensity is mitigated and the structure of the economy becomes more resource effective.

Long-term correlations, however, show the connections of domestic material consumption with sustainable development indicators to be weak and less consistent. CE₃, in effect, shows no clear relationship with GDP per capita, the use of renewable energy, energy intensity or labour productivity. This suggests the trends of domestic material consumption in Hungary fail to follow a clear sustainability growth path unlike resource productivity or the rate of recycling communal waste.

The result is not necessarily a weakness of the analysis, but it is an important empirical lesson. Domestic material consumption may be rather sensitive to the structure of the industry, the cycles of the construction industry, to investment activity or to import and export processes. In a small open economy such as Hungary, the trends of material consumption will not exclusively reflect circular economic performance but also the impact of economic booms and the embeddedness of the structure of production and foreign trade. Therefore, domestic material consumption in itself is unsuitable to be interpreted as an indicator of sustainability performance.

In this sense, the findings in Hungary are consistent with criticism by Korhonen et al., (2018). They state a circular economy cannot be considered automatically sustainable by examining material flow alone. The authors emphasise system boundaries need to be considered to assess a circular economy, as well as energy consumption, rebound effects and the characteristics of the economic structure. Current findings suggest that the connections between material consumption in absolute terms and sustainable development are more complex than those between resource productivity and energy efficiency.

The weak correlation pattern of domestic material consumption also underlines that a circular economic transition in Hungary did not probably proceed via the absolute reduction of material consumption but along a more efficient economic utilisation of the resources and improved recycling performance. It is an important difference. It can occur in an early or intermediate stage of sustainability transition that an economy becomes more productive and more energy efficient, while material consumption cannot be reduced in absolute terms. It is typically the case when economic growth is linked to investment, infrastructure, or export-oriented industries.

The findings call for caution when assessing circular economy. If the absolute level of material consumption were examined only, the sustainability transition could seem poor in Hungary. The findings of resource productivity, recycling indicators, and energy intensity results, on the other hand, suggest the economy has become more effective in certain dimensions. This confirms the methodological statement according to which an empirical analysis of circular economy requires several indicators to be used jointly.

To sum up, the analysis of domestic material consumption adds to the interpretation of long-term results. While resource productivity and recycling presents a rosier image of circular economic transition, domestic material consumption warns that restructuring material flows is a slower and less linear process. Therefore, taking the aspect of sustainable development, analysing economic performance and efficiency is not enough; you also need to assess whether an economy is able to mitigate its material needs in absolute terms in the long run.

4.3 Short-term connections between green finance and circular economy

Following the analysis of long-term structural connections, you need to examine the relationship between the development of green finance and the indicators of circular economy on a shorter time horizon. While the indicators of circular economy reflect several decades of structural changes, green finance indicators mainly illustrate the result of post-2020 financial innovation and regulatory changes. *Table 2* is a summary of the results of short-term Pearson correlations.

Table 2

Values of short-term Pearson correlations between indicators of green finance and circular economy

Green finance	CE1	CE2	CE3	CE4	CE5
GF1	0.824	0.985	−0.949	0.198	0.291
GF2	0.856	0.868	−0.877	0.201	0.542
GF3	0.811	0.958	−0.907	0.454	0.330

Source: own design

The findings of *Table 2* reveal the connections between the indicators of green finance and those of circular economy are positive on the whole while they differ in strength. The findings suggest that co-movements are consistent with the assumption that the improvement of a green financial market may create more advantageous conditions for investments that can improve resource efficiency in the long run and can promote a circular economic transition.

The strongest link can be observed between green corporate lending (GF1) and resource productivity (CE2) ($r=0.985$). Green housing loans (GF2) and the green bonds portfolio (GF3) also have a positively strong co-movement with resource productivity. Considering the time series are based on six observations and contain common trends, the values cannot be regarded to present a causal relationship; they are indications that the enhancement of green finance and the improvement of resource efficiency moved side by side in the short period studied.

There is positive co-movement in the case of green housing loans (GF2) and the green bonds portfolio (GF3) with several indicators of circular economy. A possible interpretation of the connections is that green financial instruments can support investments into energy efficiency, technology, and infrastructure. Because of the limitations of sample, the common trend of time series and potential delayed effects, however, the stability of correlational coefficients cannot be properly checked.

The findings are exploratory, but they are consistent with statements made by Schoenmaker–Schramade (2019), D’Orazio–Popoyan (2019) and Taghizadeh–Hesary–Yoshino (2019) who stated green financial instruments can mostly improve the funding conditions of sustainable and resource effective investments. Finally, the short-term analysis suggests green finance in the period analysed cannot be interpreted to be a direct decisive factor of sustainable development. At the same time, the findings are consistent with the assumption that green financial instruments can contribute to the improvement of the funding conditions of invest-

ments into circular economy. Therefore, the development of a green financial market can be interpreted as a supplementary factor for long term restructuring.

5 CONCLUSIONS

The objective of this study was to conduct an empirical analysis to reveal the connections between circular economy, green finance, and sustainable development in Hungary. The research sets out from the academic approach according to which the relationship of green finance and sustainable development can partly be interpreted through processes of the real economy, such as the improvement of resource efficiency, the evolution of recycling and a stronger circular economic operation. Accordingly, the study looked at the indicators of green finance, circular economy, and sustainable development in a uniform analytical framework.

The contribution of the study to the topic is that it interprets the three areas studied in an interconnected system of theoretical and empirical relationships rather than individual phenomena separated from each other. In such a framework circular economy is not a formally verified mediator but a potential theoretical linking mechanism through which green finance can connect to sustainable development. The study in this way uses the example of a Central and Eastern European country to contribute to the interpretation of the relationships between green finance and circular economic transition, which have been little explored so far.

Based on the empirical results, the three dimensions studied have different dynamics. The indicators of green finance showed a quick expansion after 2020, which is an indication of the development of sustainable funding instruments and institutional solutions in Hungary. On the other hand, the indicators of circular economy reflect gradual structural changes gaining momentum on a longer timescale, while the indicators of sustainable growth indicate slower macroeconomic processes of adaptation. The diverse time dynamism is consistent with the assumption according to which changes in the real economy linked to green finance cannot be immediately observed but require longer time.

The most important finding of the long-term analysis is that out of the indicators of circular economy, resource productivity had the strongest and most consistent connection with the dimensions of sustainable development studied. There was a positive co-movement with GDP per capita, the proportion of renewable energy and labour productivity, while it was negative with energy intensity. The findings suggest a more effective economic utilisation of resources may have a strong connection with the sustainability performance of the Hungarian economy.

Recycling indicators also reflect favourable connections with several indicators of sustainable development. Those co-movements, however, can only be interpreted

as part of a larger technological and institutional modernisation. The improvement of recycling performance moved hand-in-hand with the changes of energy efficiency, the use of renewable energy and some productivity indicators. Contrary to the above, material consumption did not have a direct and consistent connection with the indicators of sustainable growth. This suggests that material consumption in the absolute sense is significantly affected by investment cycles and foreign trade processes side by side with the performance of the circular economy. Therefore, the progress of circular economy cannot be assessed using one indicator alone; it requires the joint analysis of several indicators supplementing each other.

In our short-term analysis several indicators of green finance and circular economy reflected positive co-movements. The correlations calculated with resource productivity were particularly strong. The findings are consistent with the theoretical assumption according to which green financial instruments can support funding resource efficient and environmentally sustainable investments. Nevertheless, six years of common observation and the trends of the time series only support the interpretation of the findings as exploratory co-movements; they do not prove that green finance is the cause of changes in circular economic performance.

5.1 Interpretation of hypotheses

The findings are consistent with hypothesis H1. There is strong positive connection between resource productivity and the GDP per capita ($r=0.755$), the ratio of renewable energy ($r=0.845$) and labour productivity ($r=0.785$), while its relationship with energy intensity is negative ($r=-0.719$). Of all the indicators of circular economy studied resource productivity has the most consistent link with the indicators of sustainable growth.

The findings are partially consistent with hypothesis H2. The ratio of recycling communal waste has strong relationship with several indicators of sustainable growth, while packaging waste recycling indicates a more moderate but mostly favourable co-movement. On the other hand, the correlations of domestic material consumption are weak and inconsistent. The deviation suggests recycling may be connected to sustainability as part of technological and institutional modernisation, while economic structure and prosperity can exert a strong impact on the evolution of material consumption in absolute terms.

Short term findings are of an exploratory nature with respect to hypothesis H3. All three indicators of green finance have strong positive correlation with resource productivity ($r=0.868-0.985$) and the relationship with the ratio of circu-

lar material consumption is also positive. Because of only six observations and trend-like time series, the findings cannot be considered to be causal proof. They suggest that certain dimensions of green finance and some dimensions of circular economic performance moved hand-in-hand in the period studied.

5.2 Policy implications

From a policy aspect, the findings call attention to the fact that sustainable economic transition cannot be supported by applying financial incentives alone. Green finance is expected to contribute substantially to the achievement of sustainability goals if it drives sources towards investments that improve resource productivity, promote technological innovation, develop recycling infrastructure, and pave the way for the spread of circular business models.

Thus, it is particularly important in the institutional environment of Hungary that green financial incentives, the strategy of circular economy and industrial, innovational, and environmental policy measures are coordinated. To improve the profitability of funding in environmental policy, you need to clearly identify sustainable activities, monitor the actual environmental performance of the investments funded and strengthen the reliability of information regarding corporate sustainability. In that way, if financial incentives and real economic development policy are applied in a coordinated manner, you can achieve that the enhancement of green finance is coupled with measurable improvement in resource productivity and environmental performance.

5.3 Limitations and further directions of research

Certain methodological limitations must be considered when interpreting the findings of the study. The short time series of green finance indicators, the six years of their common observation forming the basis of the correlations and the trends of macroeconomic variables limit the statistically probative power of the findings. Pearson and Spearman correlations indicate co-movements, but they are not suitable to prove causal relations, delayed effects, or the presence of formal mediating mechanisms. Lacking stationarity and co-integration research, long term correlations cannot be interpreted to prove a stable equilibrium.

The analysis covers Hungary only, so its findings can only be applied to other countries with limitations. In addition, the study approaches the complexity of circular economy using a limited number of macro-level indicators, so it cannot fully cover, for instance, circular business models, industrial symbiosis, or corporate technological adaptation.

Longer time series of green finance, delayed relationships and panel-econometric or structural equation models with improved time series should be used in future research. Expanding the research to cover a number of countries in Central and Eastern Europe and including corporate or industrial data can provide a better image of the investments and changes in environmental performance green financial sources are connected to.

To sum up, our findings suggest green finance, in itself, cannot be considered a factor explicitly defining sustainable development. On the other hand, the co-movements revealed are consistent with the theoretical approach according to which the instruments of green finance can contribute to an improvement of the funding conditions supporting circular economic transition. Financial innovation, investments improving resource effectiveness and a coordinated application of policy measures in the areas of environment, industry and innovation can support a sustainability transition. Our findings are of an exploratory nature to generate hypotheses, at the same time, they provide a starting point for further research.

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