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DEVELOPMENT OF THE CIRCULAR ECONOMY IN POLAND AND THE CZECH REPUBLIC – A COMPARATIVE ANALYSIS *

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Abstract. The Circular Economy (CE) concept has gained significant traction in recent years, both in the academic and industrial sectors. Recognised as a potential game-changer in addressing the escalating environmental challenges posed by the linear economic model, the CE proposes a sustainable alternative that maximises the value of resources while minimising waste. Despite its increasing relevance, there needs to be more consensus on the definition and appropriate indicators for assessing the CE. This paper addresses these gaps by presenting an integrated analysis of various definitions of the CE and proposing a set of indicators. Five common elements across definitions of the CE were identified, and ten key indicators associated with these five elements were selected. Based on these indicators, the development of the Circular Economy in the Czech Republic and Poland was analysed. The findings show that Poland needs to concentrate its initiatives on streamlining waste management and preserving stability in dependency on imports of raw materials. Simultaneously, the Czech Republic should mitigate its burgeoning dependency on imports of raw materials and augment its resource efficiency. The research methods utilised in this study include literature review, content analysis, comparative analysis, and statistical analysis. The findings reveal significant insights into CE practices in the countries studied, leading to an improved understanding of CE from a theoretical and practical perspective.

Keywords: circular economy; resource efficiency; sustainable development; green economy; economic development

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JEL Classifications: Q56, O44, Q01

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1. Introduction

The Circular Economy (CE) concept has emerged as a pivotal paradigm shift in recent years, attracting the attention of the academic and industrial sectors. With the linear economic model increasingly becoming unsustainable in the face of increasing environmental challenges, the CE offers a promising alternative framework that not only seeks to reduce waste but also strives to optimise the value of resources. This shift towards circularity underscores the urgency to transition from a 'take-make-waste' approach to a more sustainable and regenerative system. However, as the CE gains in prominence, there is reason for critical concern arising due to the lack of consensus regarding its precise definition and the appropriate indicators for

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evaluating its implementation (Korhonen, 2018; Corvellec, 2021; Koval et al., 2023). The vagueness surrounding the definition of the Circular Economy has given rise to a multiplicity of interpretations, adding complexity to both academic discourse and practical implementation (Blomsman, 2020). While the fundamental principles of the CE emphasise resource efficiency, waste reduction, and closed-loop systems, variations in interpretation have created ambiguity in its operationalisation.

This paper aims to fill these gaps by presenting a comprehensive analysis of various definitions of the CE and proposing a set of indicators that can holistically assess initiatives in the area of the CE. Additionally, this study introduces a novel approach by conducting a comparative analysis using quantitative methods to explore the implementation of the CE in Poland and the Czech Republic. By combining data from expert interviews and extensive secondary sources, this research provides insights into sustainable practices. It is further supported by a systematic literature review that highlights its academic relevance and identifies research gaps. This methodology ensures a nuanced understanding of the CE's challenges and advancements toward more sustainable practices, emphasising the importance of this comparative study.

These elements serve as a foundation for constructing a unified understanding of CE and facilitate the subsequent development of a set of key indicators for evaluating its progress in two distinct countries, Poland and the Czech Republic. By applying the developed indicators, we aim to shed light on the challenges and opportunities facing each nation on its journey towards a more Circular Economy. Through a meticulous blend of literature review, content analysis, comparative analysis, and statistical examination, this study endeavours to contribute theoretically and practically to the discourse on the CE, offering valuable insights into its implementation and implications within these unique contexts.

Despite the comprehensive approach, this study is limited by its reliance on quantitative data, which may not capture the full scope of socio-cultural factors influencing CE practices. Focusing solely on Poland and the Czech Republic may also limit the applicability of our findings to other contexts. Furthermore, the temporal scope of the data may not reflect ongoing or future developments.

In the next part of this paper, we review existing theoretical definitions of the Circular Economy. Based on this overview, we then develop a set of five key elements of the Circular Economy and 10 indicators of implementation of the Circular Economy at a national level. The empirical study presented in the third part of the paper conducts a comparative analysis to identify the differences between Poland and the Czech Republic in the approach to and level of implementation of principles of the Circular Economy. The paper concludes with a discussion of the main results.

2. Theoretical background

Corvellec (2021) observed that the Circular Economy (CE) frequently demonstrates conceptual fragmentation due to varied interpretations and applications (Korhonen, 2018; Blomsma, 2020), potentially leading to a perceived deficiency in paradigmatic coherence (Inigo, 2019). As documented, over a hundred interpretations of circularity have surfaced, indicating that the term possesses a range of meanings contingent on individual perspectives. This variation in interpretation leads to different conceptions of the Circular Economy across various theoretical settings (Kirchherr, 2017; Andronicean et al., 2021). From a practical point of view, the concept focuses on the minimisation of waste, where the end of a product's lifecycle requires retaining its constituent materials within the economic system, as much as possible, through recycling (Parliament, 2023). The concept of a Circular Economy (CE) has gained significant attention in both the academic and practical spheres. Previous reviews of the concept of the Circular Economy have been undertaken by many authors, such as Ghisellini et al. (2016), Lieder and Rashid (2016), Sauvé et al. (2016), Murray et al. (2017) and Lewandowski (2016). CE is a departure from the traditional linear economic model and is increasingly embraced as a viable alternative.

One can conceptualise a Circular Economy as an economic system that champions the prudent utilisation of resources through waste reduction, preservation of value over the long term, minimising the use of primary

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resources, and the promotion of closed-loop products, components and materials, with a keen focus on environmental protection and socio-economic benefits (Morseletto, 2020). In such an economy, emphasis is placed on creating products engineered for longevity, reusability, and recyclability and sourcing raw materials from pre-existing products. In essence, this model promotes reuse, remanufacturing, recycling, and energy recovery and treats disposal as a last resort. The realisation of a Circular Economy pivots on the adherence to the principles of the 3Rs - reduction, reuse, and recycling of materials. It manifests in production and consumption activities due to the interpenetration of material and energy flows within these sectors (Heshmati, 2015). A significant proliferation can be observed around the "Rs" framework, leading certain investigators to expand the waste hierarchy to encompass up to 10Rs (Charef et al., 2022). Currently, the Circular Economy concept is garnering widespread popularity as a potential framework for sustainable future development, and is being championed by the European Union, as well as several national governments. In a report from 2014, the European Commission posited that transitioning towards a Circular Economy in EU countries could yield up to 600 billion euros in annual economic benefits for the EU manufacturing sector alone (European Commission, 2014). Moreover, the European Circular Economy Stakeholder Platform showcases more than 150 significant practices, innovative processes, and experiential learnings related to the implementation of the Circular Economy concept across Europe (European Circular Economy Stakeholder Platform, 2018). Academic interest in the Circular Economy has also surged, with a notable uptick in articles and journals focusing on this topic in the past decade (Geissdoerfer, 2017; Zecca et al., 2023).

However, the definition of the Circular Economy is not fixed. Still, it encompasses a wide range of principles and proposals that have been articulated over the years, including 'regenerative design', 'performance economy', 'Cradle-to-Cradle' and 'industrial ecology'. In Table 1, selected definitions of the Circular Economy are presented.

Table 1. Selected definitions of the Circular Economy

Author	Definition
Preston (2012), p. 1	A 'circular economy' (CE) is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process – and products could be repaired, reused or upgraded instead of thrown away.
Ellen MacArthur Foundation (2013), p. 7	A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models (Foundation, Towards the circular economy. Economic and business rationale for an accelerated transition., 2013)
Chinese National People's Congress, (2013)	*The term "circular economy" […] is a general term for the activity of reducing, reusing and recycling in production, circulation and consumption* (China, 2013)
European Environment Agency (2014)	Circular economy "refers mainly to physical and material resource aspects of the economy […] it focuses on recycling, limiting and reusing the physical inputs to the economy, and using waste as a resource, leading to reduced primary resource consumption (Agency, 2014).
European Commission (2015)	An economy *where "the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised"* (Commission, Circular Economy, 2015)
Kirchherr et al., p. 221-232 (2017)	A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations (Kirchherr, 2017).
Figge et al., (2023), p. 2	The circular economy is a multi-level resource use system that stipulates the complete closure of all resource loops. Recycling and other means that optimise the scale and direction of resource flows contribute to the circular economy as supporting practices and activities. In its conceptual perfect form, all resource loops will be fully closed. In its realistic, imperfect form, some use of virgin resources is inevitable (Figge et al., 2023)

Source: Own elaboration

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Although there are numerous proposals for defining a Circular Economy in the literature, most definitions share some common elements. Firstly, **systemic nature**: the Circular Economy is described as a system operating at multiple levels – micro, meso, and macro, encompassing all stages of the economic process, from production to consumption. Secondly, the **3R principle**: reduction, reuse, and recycling are key components of the concept, emphasising waste minimisation and optimisation of resource utilisation. Thirdly, **resource loop closure**: the overarching idea is to close the resource loops, aiming to maintain the value of products, materials, and resources in the economy for as long as possible while minimising waste generation. Fourthly, **transformation**: the Circular Economy is presented as an approach intended to transform how resources function in the economy, moving from an "end-of-life" concept towards business models and strategies enabling continuous value utilisation and recovery. Fifthly, **sustainable development**: all definitions underscore the goal of a Circular Economy to promote environmental quality, economic prosperity, and social equity, contributing to sustainable development for current and future generations (Fig. 1).

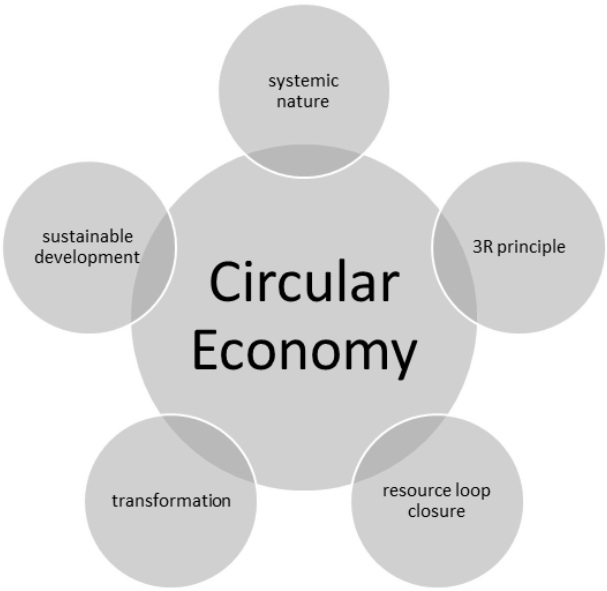

Figure 1. Key components of the Circular Economy
Source: Own elaboration

Based on the verified five components of CE, ten indicators were selected that are connected with them:

- **Systemic nature**: this aspect speaks to the integrated and holistic nature of the Circular Economy. It relates to indicators such as "Greenhouse gas emissions from production activities" and "Share of renewable energy in gross final energy consumption", which signify the interconnectedness of production, consumption, and energy use within the system. "Material import dependency" also falls into this category, showing the extent to which the system relies on external inputs.
- The **3R principle** (Reduce, Reuse, Recycle): this principle encapsulates the essence of the Circular Economy and directly connects to the “Recycling rate of municipal waste” indicator. This principle also relates to “Generation of plastic packaging waste per capita”, measuring the success of reducing and recycling initiatives specifically related to plastic waste.
- **Transformation**: this element corresponds to the transition from a linear to a Circular Economy. The “Circular material use rate” indicator reflects this transition, quantifying the percentage of material usage following circular practices.
- **Sustainable development**: indicators such as “Resource productivity”, “Consumption footprint”, and “Material footprint” pertain to this principle. They evaluate whether economic activities are sustainable and resource-efficient. The indicator 'Waste generation per capita' also relates to sustainable development, gauging the degree to which waste reduction is achieved.

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By connecting these indicators to the common elements of a Circular Economy, we can evaluate the implementation and effectiveness of a Circular Economy in the Czech Republic and in Poland in a more comprehensive and systematic manner. The crucial issue is monitoring the implementation of the Circular Economy. Many sets of indicators have been proposed for this purpose in the literature. For instance, The OECD Inventory of Circular Economy Indicators proposed 474 circular-economy-related indicators (OECD, 2020), UNECE categorised 17 indicators into four groups (UNECE, 2021), the European Commission proposes 26 indicators (Commission, Measuring progress towards circular economy in the European Union – Key indicators for a monitoring framework, 2018) and the French Minister for the Ecological Transition proposes 11 indicators (Transition, 2021). The indicators used to measure the CE also are based on the developments of sustainable development indicators (e.g., Sustainable Development Indicators by UNEP, Sustainable Development Goals by UNDP or Little Green Data Book by the World Bank (EASAC, 2016), as well as green economy indicators (Green Growth Indicators by the OECD, Green Economy Indicators by UNEP or Global Green Economy Index by Dual Citizen (Daniek, 2020).

Ten indicators were selected for the analyses (Table 2), and based on these, the development of the CE in the Czech Republic and Poland was examined. The indicators were selected based on a literature review. They are also proposed in the EUROSTAT Circular Economy indicators category.

Table 2. Selected indicators to compare the Circular Economy in the Czech Republic and Poland

Recycling rate of municipal waste	This metric quantifies the percentage of municipal waste that is recycled. It is calculated by dividing the total weight of recycled municipal waste by the overall amount of municipal waste produced. Recycling in this context includes the processes of material recycling, composting, preparation for reuse, and anaerobic digestion. Municipal waste primarily originates from residential sources but can also encompass waste from small businesses and public institutions that is collected by municipal services. The composition of this waste can differ significantly across various municipalities and countries, reflecting local variations in waste management practices. For regions lacking municipal waste collection services, the generated waste quantity is typically estimated.
Resource productivity	This indicator calculates the efficiency of material use in relation to economic output, expressed as the ratio of Gross Domestic Product (GDP) to Domestic Material Consumption (DMC). DMC measures the total amount of materials an economy utilises directly. It encompasses the total of raw materials mined or harvested within the country, added to all physical imports, and subtracted by all physical exports. In this context, 'consumption' within DMC denotes apparent consumption, which does not include final consumption, and it does not account for the upstream processes related to the international trade of raw materials and products.
Circular material use rate	The metric assesses the proportion of reclaimed material reintegrated into the economy, thereby curbing the necessity for extracting new primary resources. Known as circular material use (CMU) or circularity rate, it denotes the ratio of recycled materials to total material consumption. Total material consumption is derived from aggregating domestic material consumption (DMC) and recycled materials, with DMC delineated in economy-wide material flow records. The circular use of materials is estimated by subtracting imported recyclable waste from domestically recycled waste and adding exported recyclable waste. A heightened circularity rate implies greater utilisation of secondary materials over primary ones, consequently mitigating the environmental repercussions of primary resource extraction.
Greenhouse gas emissions from production activities	This metric presents the greenhouse gas emissions stemming from all production operations within the EU economy. It notably encompasses emissions from international air travel by EU-based airlines while excluding emissions from individual households. Quantified in kilograms of CO2 equivalents per capita, it provides insight into the environmental impact of economic activities within the EU.
Share of renewable energy in gross final energy consumption by sector	The indicator measures the share of renewable energy consumption in gross final energy consumption according to the Renewable Energy Directive. The gross final energy consumption is the energy used by end-consumers (final energy consumption) plus grid losses and self-consumption of power plants.
Consumption footprint	The consumption footprint indicator assesses the ecological impact of consumption within the EU and its member states. It achieves this by amalgamating data on consumption levels and the environmental impacts of representative products. This indicator covers five key consumption areas: food, transportation, housing, appliances, and household goods. Consumption intensities are determined based on statistics related to consumer behaviour.

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Material import dependency	The dataset furnishes the percentage ratio of imports (IMP) to direct material inputs (DMI). Described as 'material import dependency,' it quantifies the degree to which an economy depends on imports to fulfil its material requirements. Material import dependency values cannot be negative or exceed 100%. A 100% value signifies that no domestic extractions occurred during the reference year.
Material footprint	The indicator quantifies the global demand for raw material extraction resulting from EU consumption and investment. Known as Raw Material Consumption (RMC), this metric illustrates the volume of raw materials necessary to manufacture consumed goods, accounting for both direct and indirect extractions worldwide. It is calculated by subtracting exports (measured in raw material equivalents, RME) from the total raw material input. The RMC provides valuable insights into the quantity and nature of materials required to satisfy the EU's demand for products.
Waste generation per capita	The indicator is formulated as the quotient of total waste, including major mineral wastes, produced within a country (encompassing all NACE activities and residential waste) and the country's average population.
Generation of plastic packaging waste per capita	This indicator concerns plastic packaging waste, where 'packaging' encompasses all items made of any materials intended for the containment, protection, and transportation of goods from producers to consumers. It includes non-returnable items serving the same purposes as packaging. 'Packaging waste' refers to any packaging or packaging material classified as waste according to the Waste Framework Directive 2008/98/EC, excluding production residues..

Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database, accessed: 01/07/2023).

3. Research objective and methodology

The aim of this research is to conduct a comparative analysis of the development and implementation of the circular economy in Poland and the Czech Republic. This study seeks to identify key drivers, challenges, and progress towards achieving a sustainable economic model that emphasises resource reduction, reuse, and recycling.

This research adopts a mixed-methods approach, combining quantitative data analysis with an in-depth examination of policy, cultural, and technological aspects to provide a comprehensive overview of the circular economy's status in both countries. This methodology was chosen for its ability to capture the complexity of economic systems and the multifaceted nature of the circular economy.

Primary data were collected through interviews with experts in the field of circular economy from both Poland and the Czech Republic, including policymakers, business leaders, and academics. Secondary data were sourced from government reports, industry analyses, scholarly articles, and international databases on recycling rates, waste management, and sustainability indicators.

The analysis involves comparing these data sets to identify trends, patterns, and disparities in the implementation of circular economy practices. Statistical tools and content analysis methods are employed to analyse quantitative data and qualitative information, respectively.

A systematic literature review was conducted as part of the methodology to understand the current state of research on the circular economy in Poland and the Czech Republic and globally. This review helped to frame the research within the broader academic discourse, identify gaps in the current literature, and justify the need for a comparative study. The literature review focuses on studies that examine policy frameworks, economic impacts, societal attitudes, and technological innovations related to the circular economy.

4. Results and discussion

This section presents the results of the comparative analysis concerning the development and implementation of circular economy practices in Poland and the Czech Republic. By examining a range of indicators, such as recycling rates, waste management efficiency, and material consumption patterns, the study sheds light on the achievements and challenges faced by each country in its transition towards a circular economy. The findings highlight the nuances of policy effectiveness, societal engagement, and the environmental impacts of current practices, offering a comprehensive overview of the progress and areas needing further action. Through this analysis, we aim to contribute valuable insights to the ongoing discourse on sustainable development and

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provide actionable recommendations for enhancing circular economy initiatives in the context of Poland and the Czech Republic.

4.1 Recycling rate of municipal waste

One of the pivotal indicators to assess the progress of a Circular Economy is the recycling rate of municipal waste, as it reflects how effectively an economy is capable of reclaiming and reutilising resources. Data analysis for the "Recycling rate of municipal waste" indicator for Poland and the Czech Republic from 2008 to 2021 reveals that both countries have made significant strides in municipal waste recycling, yet the pace and trajectory of progress varied somewhat.

In Poland, the rate of municipal waste recycling initially stood at 10.5% in 2008 but increased to 16.3% by 2010. However, in 2011, this figure dipped to 11.4%, possibly due to changes in waste management policies or fluctuations in the volume of waste generated. From 2012 onward, the rate began to rise steadily, reaching 26.5% in 2014. This could suggest that during this period, effective measures were implemented to promote recycling. Since then, the rate remained stable until 2019, subsequently increasing to 38.7% in 2020 and 40.3% in 2021.

In the Czech Republic, the municipal waste recycling rate consistently rose from 10.4% in 2008 to 43.3% in 2021. This rate experienced a particularly strong increase between 2011 and 2012, hinting at the introduction of effective policies or recycling-related technologies during this period. Aside from a slight drop to 32.1% in 2017, the Czech Republic displayed a steady increase in municipal waste recycling rate over the years analysed.

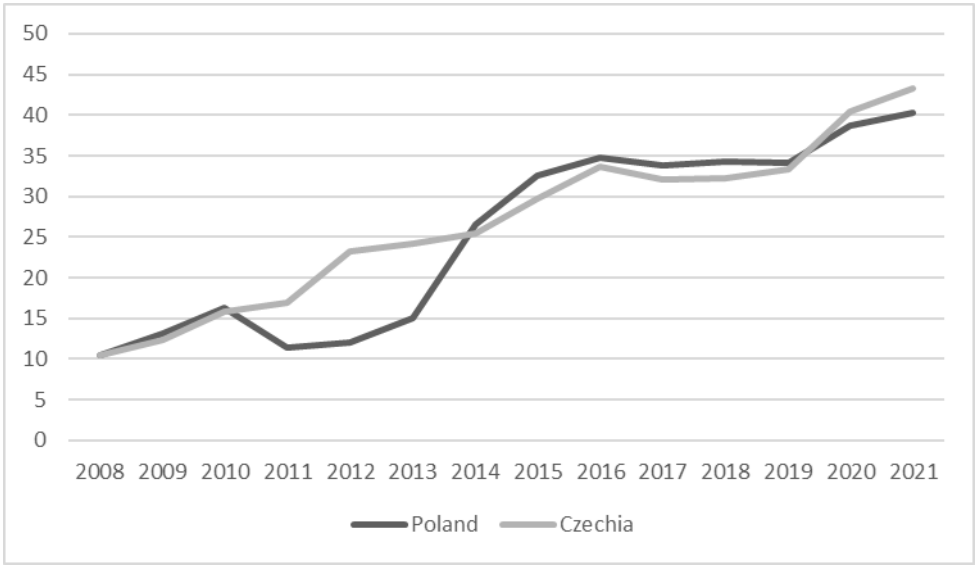

Figure 2. Recycling rate of municipal waste (%) in Poland and the Czech Republic, 2008-2021
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database, accessed: 01/07/2023).

In summary, while both countries demonstrated significant advancements in municipal waste recycling, the Czech Republic exhibited a slightly more stable and linear growth trend. Nonetheless, both countries have made considerable progress in this realm, a vital element of transitioning to a Circular Economy. Still, there remains room for improvement to achieve the European Union's goal of recycling 65% of municipal waste by 2035 (Commission, Circular Economy: New rules will make EU the global front-runner in waste management and recycling. Press release., 2018).

These outcomes may be associated with various factors, including differences in public policies, economic conditions, infrastructure, and societal awareness regarding recycling and the Circular Economy. For instance, the more stable growth trend in the Czech Republic could stem from earlier and more consistent implementation of policies promoting recycling and waste minimisation. Despite the initial variability in recycling rates, Poland

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has shown significant progress in recent years, potentially reflecting the effects of introduced reforms and growing societal awareness.

4.2 Resource productivity

In the context of a Circular Economy, resource productivity is a key indicator that measures how effectively an economy can generate value from available resources. Specifically, this indicator is defined as the ratio of Gross Value Added (GVA) to Domestic Material Consumption (DMC), and is expressed in euro/kg. Analysing data from 2008 to 2021 shows an upward trend observed in resource productivity for both Poland and the Czech Republic. This is an encouraging sign, suggesting that both countries are becoming increasingly efficient at deriving value from their resources.

Despite this general upward trend, differences in the pace and level of resource productivity between these two countries are also observed. Throughout the period under review, resource productivity in the Czech Republic consistently outperformed Poland, suggesting that the Czech economy was more efficient in generating value from its resources. The uncertainty observed in the data for Poland, particularly visible in 2010-2011, could point to certain structural issues that impacted resource productivity during this period. Despite this, the upward trend for Poland is sustained and has become more stable in recent years.

For the Czech Republic, while a generally stable upward trend is observed, data from 2021 shows a slight decline in resource productivity compared to the previous year. This could signal potential challenges or changes in resource management that may warrant further investigation. Resource productivity, as a measure of an economy's efficiency in utilising raw materials, is a crucial indicator within the context of a Circular Economy. Economies with higher resource productivity are capable of generating more value with less resource consumption, which aligns with the fundamental principles of a Circular Economy – minimisation of consumption of resources and maximisation of their utilisation.

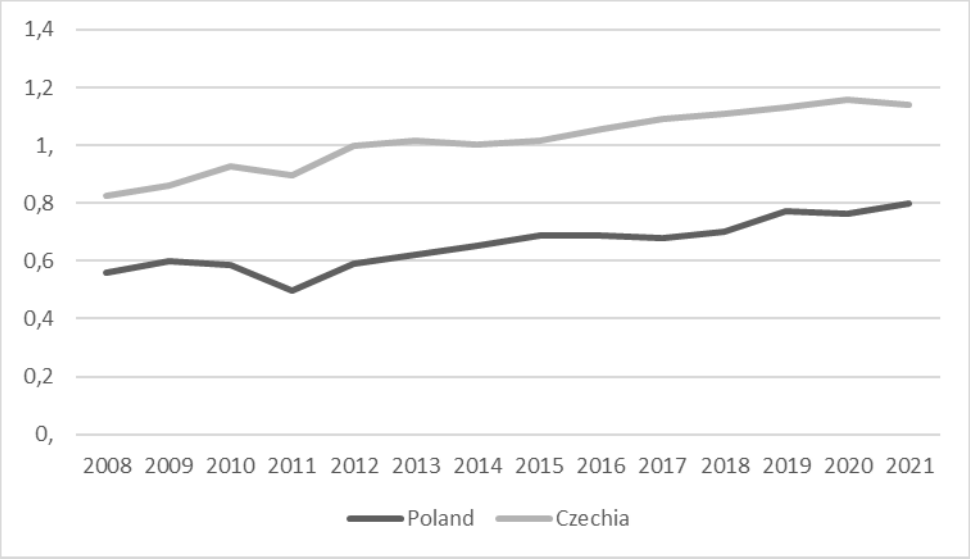

Figure 3. Resource productivity (euro per kg) in Poland and the Czech Republic, 2008-2021
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database, accessed: 01/07/2023).

The increasing resource productivity indices for Poland and the Czech Republic indicate positive changes in these economies' efficiency in using raw materials. This could suggest heightened innovation through support for the creation of start-ups (Redlichová and Chmelíková, 2012), the introduction of technologies providing greater efficiency, as well as effective resource management strategies.

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4.3 Circular material use rate

The Circular Material Use (CMU) rate is a significant indicator in the context of a Circular Economy. It measures the extent to which recycled materials are reintroduced into the economy, instead of procuring new resources, which is crucial for minimising resource consumption and waste.

An analysis of the data for the years 2010-2021 shows that both Poland and the Czech Republic demonstrate variability in terms of CMU.

For Poland, the CMU rate initially rises, peaking in 2014 (12.6%), after which a downward trend is observed until 2021 (9.1%). This variability could be attributed to several factors such as changes in economic policy, waste and recycling regulations, as well as changes in economic and market practices. The decline in the CMU rate in recent years could indicate challenges in maintaining the level of recycling and reintroduction of materials into the economy, which might require further analysis and policy interventions.

In the case of the Czech Republic, despite an initially lower level of CMU compared to Poland, a general upward trend is observed. In 2021, the CMU rate of the Czech Republic was 11.4%, which is higher than the result for Poland in the same year. This could suggest that the Czech Republic is more effective in reintroducing recycled materials into the economy.

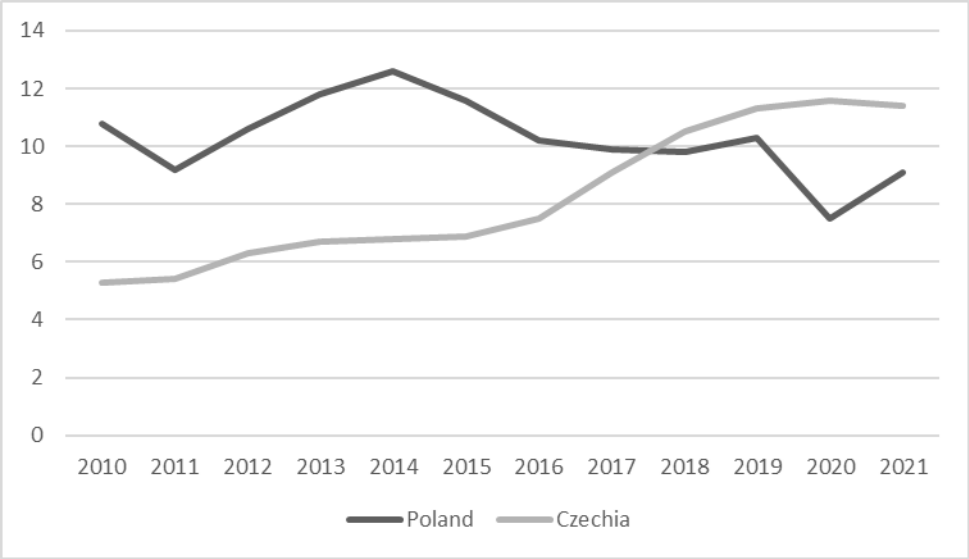

Figure 4. Circular material use rate (%) in Poland and the Czech Republic, 2010-2021
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database, accessed: 02/07/2023).

These results could have significant implications for the further development of a Circular Economy in both countries. In Poland, the decline in the CMU rate indicates the need for further actions to increase the reintroduction of recycled materials into the economy. In the Czech Republic, the continuation of the upward trend could yield further benefits in terms of reducing resource consumption and waste. In both cases, an effective Circular Economy policy promoting recycling and the reintroduction of materials will be key to further development.

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4.4 Greenhouse gases emissions from production activities

This indicator presents the emission of greenhouse gases from all production activities carried out in the EU economy. Data for Poland and the Czech Republic from 2008-2021 indicates certain trends and differences between these two countries.

In Poland, greenhouse gas emissions per capita from 2008 to 2021 show some degree of variability, but generally remain at a similar level. The highest indicator values are observed in 2008, 2010, 2017, and 2021, while the lowest value of the indicator is recorded in 2020. This trend may suggest that, despite the evolution in the economy and industry, greenhouse gas emissions per capita in Poland still remain at a relatively stable level.

Similarly, in the Czech Republic, some variability can also be seen in greenhouse gas emissions per capita for the years 2008-2021, but there is a clear general downward trend. The highest indicator values are observed in 2008, 2010, and 2011, while the lowest indicator value is recorded in 2020 (likely due to the outbreak of the pandemic and implemented restrictions). As for Poland, the trend of stability, despite some variability, suggests that the Polish economy, although experiencing changes over the period from 2008 to 2021, may not have made significant progress in reducing greenhouse gas emissions from production activities per capita. This situation may reflect Poland's maintaining of an intensive industrial sector based on traditional energy sources such as coal, which is known for high greenhouse gas emissions. Although Poland has made some efforts to diversify its energy sources and increase energy efficiency, these results suggest that these efforts may not have been sufficient to decisively change the emissions trend. The downward trend in the Czech Republic may suggest that this country is making more progress in reducing greenhouse gas emissions per capita, probably due to the implementation of more efficient technologies and production practices and a greater emphasis on ecological energy sources.

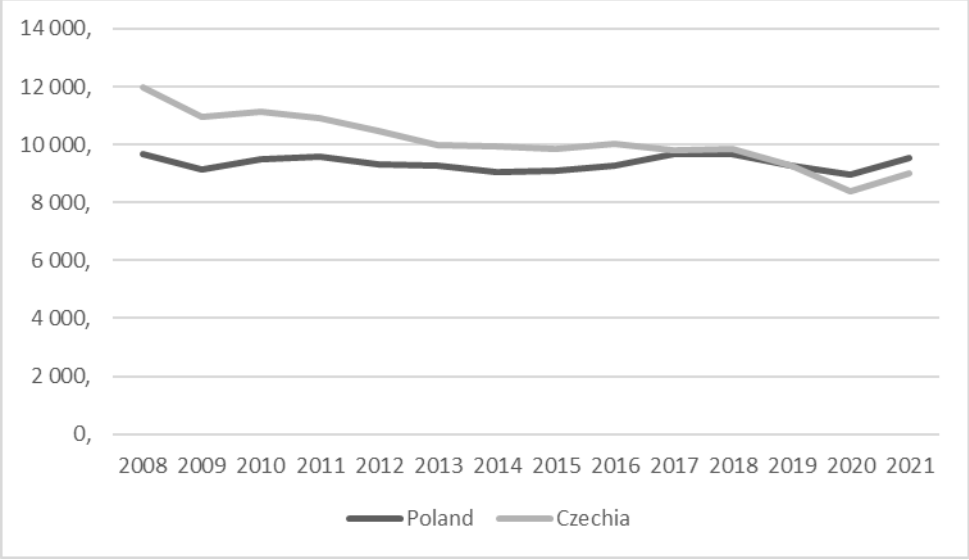

Figure 5. Greenhouse gases emissions from production activities (kg per capita) in Poland and the Czech Republic, 2008-2021
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database, accessed: 02/07/2023).

In general, these results indicate that both countries have different dynamics and effects in managing greenhouse gas emissions from production activities. This indicator is particularly significant in the context of a Circular Economy, where the aim is to minimise greenhouse gas emissions through efficient resource and waste management, recycling and reuse of raw materials, and promoting ecological energy sources.

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4.5 Share of renewable energy in gross final energy consumption

From the data, both Poland and the Czech Republic have significantly increased the share of renewable energy in their final energy consumption from 2008-2021. In 2008, the share of renewable energy was 7.686% in Poland and 8.674% in the Czech Republic. By 2021, these figures had increased to 15.624% and 17.667% respectively. This suggests that both countries have made substantial progress in replacing fossil fuels with renewable energy.

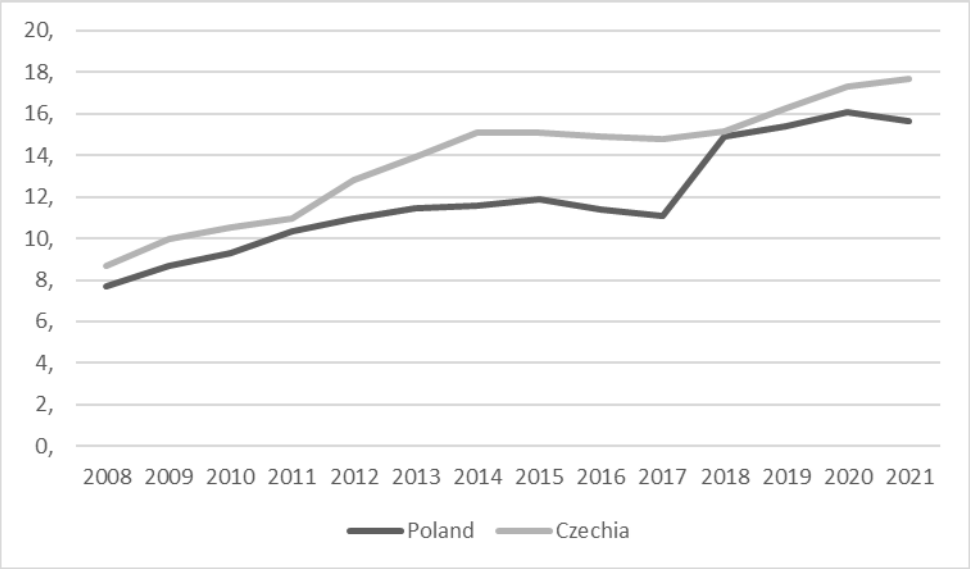

Figure 6. Share of renewable energy in gross final energy consumption (%) in Poland and the Czech Republic, 2008-2021
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database, accessed: 08/07/2023).

The differences between Poland and the Czech Republic may stem from various factors such as energy policy, the availability of renewable resources, and the technological and economic capabilities to exploit them. The Czech Republic shows a slightly higher level of renewable energy use, which may result from better infrastructure, more investment in renewable technologies, or differences in energy policy.

From the perspective of a Circular Economy, an increased share of renewable energy is beneficial as it allows for a reduction in dependency on fossil fuels, which are a non-renewable resource and cause the emission of greenhouse gases. Renewable energy sources such as wind, solar, or biogas allow for the 'closing of the loop' of energy where energy is not only consumed but also regenerated.

Despite the positive trend in both countries, it is worth noting that the average share of renewable energy in final energy consumption in the European Union was 22.4% in 2020, indicating that both countries still have some catching up to do compared to some other EU countries.

4.6 Consumption footprint

The Consumption footprint indicator, which measures the ecological footprint associated with consumption, shows that both Poland and the Czech Republic experienced an increase in this index from 2012-2021, indicating an increase in the environmental impact of consumption. This is consistent with the global trend related to the growing influence of human activity on the environment.

In Poland, this index increased from 100 in 2012 to 120 in 2021, indicating a 20% increase in consumption intensity over these years. In the Czech Republic, this increase was slightly lower, from 95 in 2012 to 108 in 2021, indicating a 13.7% increase. This increase is mainly due to a rising level of consumption in both countries,

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which could be the result of income growth, changes in consumption preferences, or a growing population. This indicator takes into account five areas of consumption: food, mobility, housing, household appliances, and household goods.

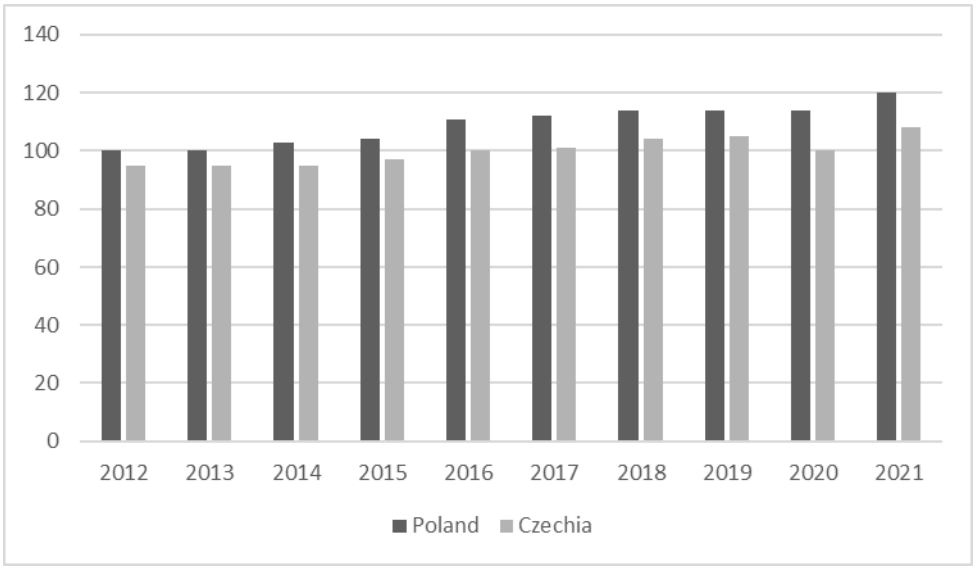

Figure 7. Consumption footprint (Index, 2010=100) in Poland and the Czech Republic, 2012-2021
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database , accessed: 10/07/2023).

However, it is worth noting that a Circular Economy aims to reduce the impact of consumption on the environment by promoting sustainable consumption and production, minimising waste, and maximising reuse and recycling. In the context of this indicator, strategies such as eco-design of products, extended producer responsibility, or encouraging changes in consumption patterns can contribute to reducing Consumption footprint.

Comparing these results with other EU countries, it's important to note that the average Consumption footprint for the EU in 2019 was 101.7, indicating that both Poland and the Czech Republic show a higher level of consumption impact on the environment than the EU average. This suggests that both countries could benefit from further investments and policies supporting sustainable consumption and production.

4.7 Material import dependency

The "Material import dependency" indicator measures the extent to which a country's economy depends on imported raw materials to meet its material needs. It is a key indicator for the Circular Economy, where the principle is to minimise resource consumption and maximise their reuse.

Over the years 2008-2021, we observe that Poland maintained a relatively stable level of dependence on imported materials, with a slight increase from 17.3% in 2008 to 19.7% in 2021. This indicates that despite ongoing economic development, Poland is able to maintain its dependence on imported materials at a comparable level, which may result from a relatively large amount of materials available domestically. In the Czech Republic, in contrast, we see an increase in dependence on imported materials from 26.3% in 2008 to 33% in 2021. This indicates an increase in the Czech Republic's dependence on imported materials, which could result from a limited amount of materials available domestically, increased consumption, or changes in the structure of the economy.

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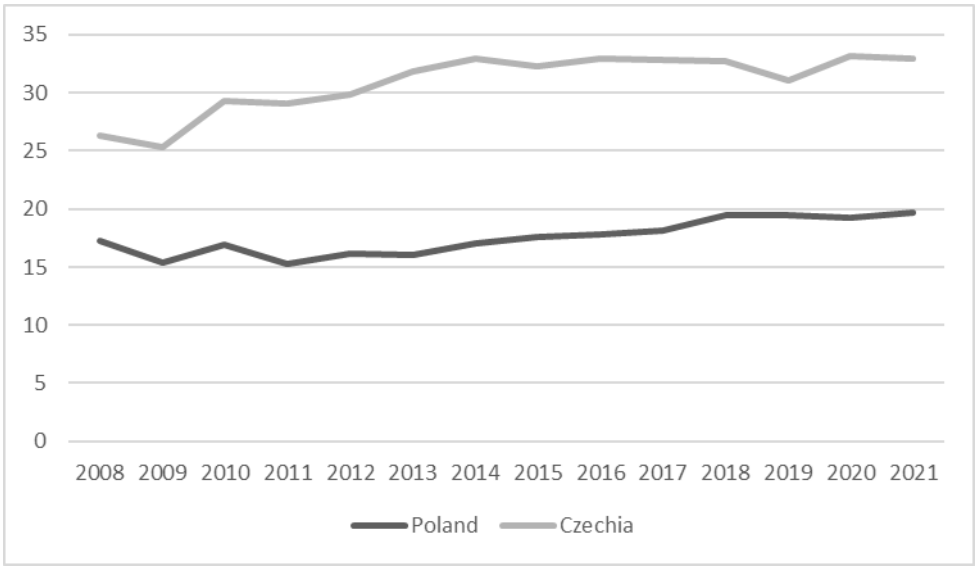

Figure 8. Material import dependency (%) in Poland and the Czech Republic, 2008-2021
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database , accessed: 10/07/2023).

From the perspective of the Circular Economy, a lower dependence on imported materials is preferred, as it indicates a country's greater ability to meet its material needs through recycling and reuse of materials. Therefore, both countries should aim to further increase resource efficiency and promote recycling to reduce their dependence on imported materials. In the context of previous studies, according to a 2020 Eurostat report, the average dependence on imported materials in the EU was 18.6%, suggesting that the Czech Republic is above and Poland is close to the EU average (Eurostat, 2020, "Material flow accounts and resource productivity").

4.8 Material footprint

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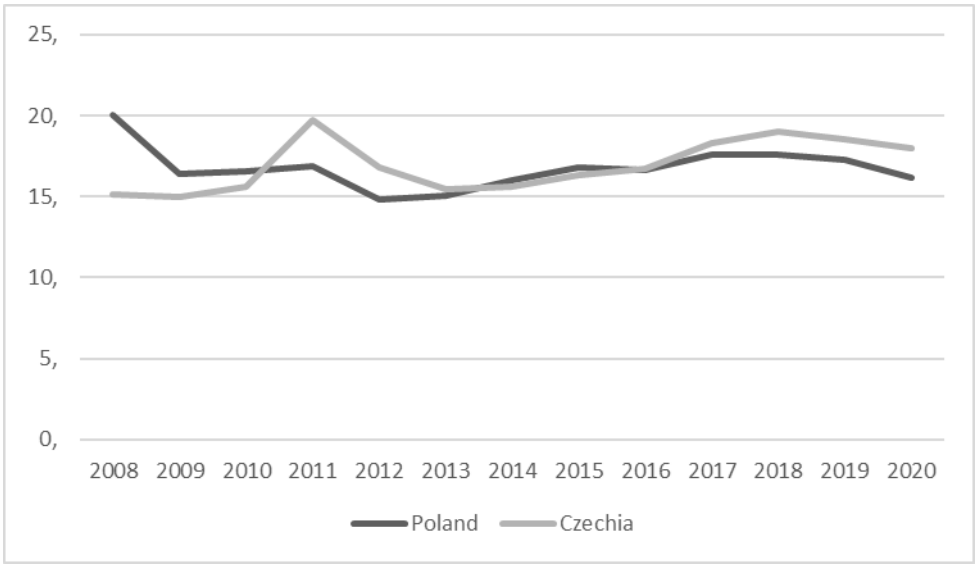

Figure 9. Material footprint (tonnes per capita) in Poland and the Czech Republic, 2008-2020
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database , accessed: 12/07/2023).

This indicates an increase in the Czech Republic's dependence on imported materials, which could result from a limited amount of materials available domestically, increased consumption, or changes in the structure of the economy.

4.9 Waste generation per capita

Waste generation indicators are instrumental in evaluating the progression towards a Circular Economy. They reflect resource efficiency, indicating how optimally an economy uses its resources, with an ideal Circular Economy minimising waste through efficient use and recycling. These indicators also highlight a commitment to sustainability, with reduced waste generation alleviating pressure on natural resources and potentially mitigating climate change. Furthermore, they illuminate potential environmental challenges, including waste management and pollution. Crucially, they aid in crafting economic strategies and environmental policies by identifying areas in need of intervention and measuring policy effectiveness, thereby guiding a sustainable economic trajectory in a Circular Economy.

This indicator shows the total waste generated per capita, inclusive of major mineral waste, in a specific country, emanating from all NACE activities and households, and is calculated as a quotient of the total waste produced and the average population of the country.

From 2008 through 2020, Poland manifested an increasing trajectory in waste generation per capita, rising from 3,645 kilograms per inhabitant in 2008 to 4,492 kilograms per inhabitant in 2020. This indicates an escalation in the intensity of waste generation per capita, potentially attributable to a plethora of factors such as increased consumption, shifts in economic structure, or an evolution in production technologies.

By contrast, the Czech Republic, albeit subject to certain fluctuations, maintained a predominantly stable level of waste generation per capita until 2016, starting from 2,448 kilograms per inhabitant in 2008 and achieving a slight reduction to 2,402 kilograms per inhabitant in 2016. Nevertheless, a substantial rise has been observed from 2016 onward, reaching 3,598 kilograms per inhabitant in 2020. This recent surge may indicate shifts in economic structure, amplified consumption, or other determinants influencing waste generation.

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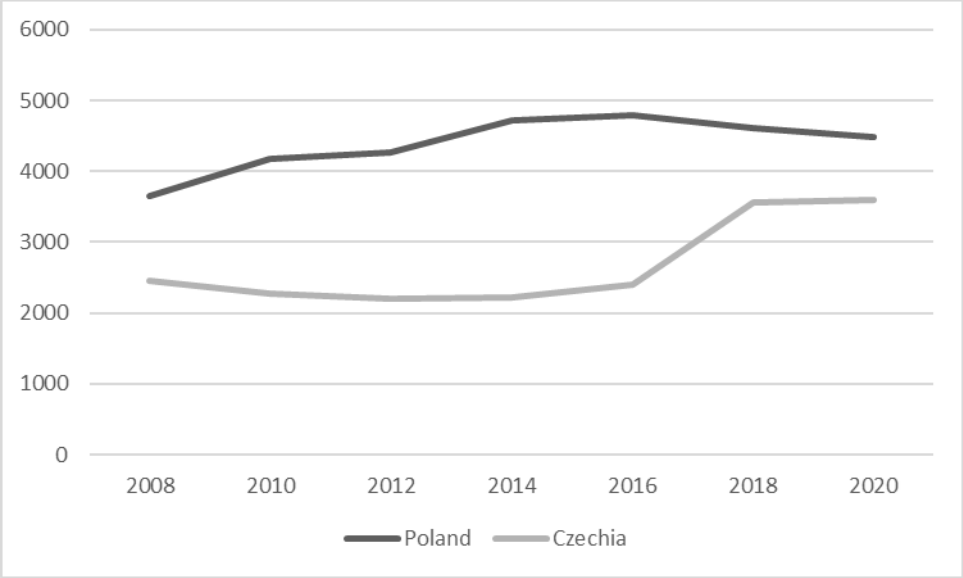

Figure 10. Waste generation (kg per capita) in Poland and the Czech Republic, 2008-2020
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database , accessed: 12/07/2023).

Comparatively, Poland evidently generates a significantly higher volume of waste per capita than the Czech Republic, potentially resulting from variations in economic structure, waste management strategies, or levels of consumption. In 2020, Poland generated approximately 25% more waste per inhabitant compared to the Czech Republic. Nonetheless, the rapid growth of waste generation observed in the Czech Republic in recent years suggests that additional measures may be necessary to manage this expansion.

4.10 Generation of plastic packaging waste

The "Generation of plastic packaging waste per capita" indicator, encompassing all non-returnable items and packaging waste as defined by the Waste Framework Directive 2008/98/EC, provides an important metric to gauge plastic waste output at an individual level.

A deep dive into the presented data reveals intriguing patterns and significant increases in the generation of plastic packaging waste in both Poland and the Czech Republic from 2008 to 2019.

In Poland, the figures reveal a persistent increase in per capita plastic packaging waste generation, rising from 17.57 kg in 2008 to a notably higher 34.19 kg in 2019. This represents almost a doubling in plastic packaging waste generation per capita over this 12-year period. This marked increase may indicate several underlying phenomena, such as a rise in consumption of consumer goods, an increase in the use of plastic packaging in commercial activities, or possibly less efficient waste management practices.

In the Czech Republic, while the increase is not as stark, there is still a discernible upward trend from 20.82 kg per capita in 2008 to 24.76 kg in 2019. The somewhat steadier progression in the Czech Republic suggests that the country may have different consumption patterns, possibly better waste reduction strategies, or more widespread use of alternative packaging materials.

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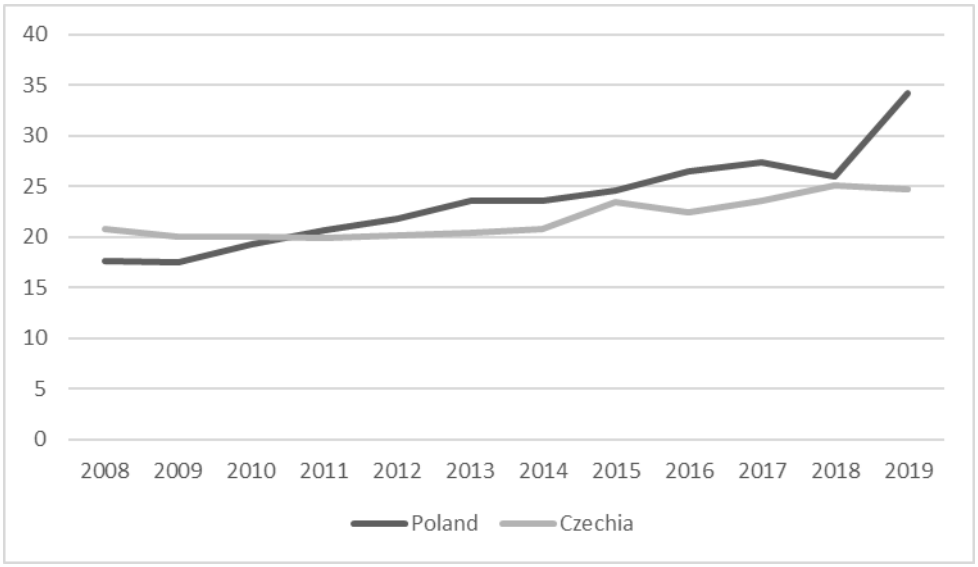

Figure 10. Generation of plastic packaging waste (kg per capita) in Poland and the Czech Republic, 2008-2019
Source: Own elaboration based on Eurostat (https://ec.europa.eu/eurostat/web/main/data/database , accessed: 14/07/2023).

These significant increases underscore the need for comprehensive strategies to address the proliferation of plastic packaging waste. These could include stringent waste management policies, initiatives to promote sustainable consumption habits, technological innovation in packaging, and a broader transition towards a Circular Economy where resources are used more efficiently and waste is minimised. Furthermore, this data provides critical input for policymakers to benchmark progress and adjust policies accordingly.

Conclusions

The comprehensive evaluation of material and waste metrics reveals significant insights into progressing towards a Circular Economy within Poland and the Czech Republic. Poland exhibits relative stability concerning its material import dependency, which suggests an enduring and balanced management of raw material resources despite its escalating economic development. Conversely, the Czech Republic displays an escalating trend in this respect, indicating potential constraints of domestic resource availability or a modification in its economic structure necessitating greater raw material imports. An examination of the 'material footprint' measure reveals an overall persistent trend with minor fluctuations in Poland, proposing a relationship between resource consumption and economic output that remains relatively consistent over time. The Czech Republic presents an upward trajectory with sporadic declines, which may indicate opportunities for amplifying resource efficiency. The generation of plastic packaging waste per capita reveals divergent trends in both countries. A significant upward trend is observed in Poland, underscoring the urgency of improving waste management strategies and bolstering recycling efforts.

In contrast, the Czech Republic shows a more moderate increase in this respect. The waste generation per capita, a consequential metric for the Circular Economy, suggests that Poland exhibits significantly higher waste generation per individual than the Czech Republic. This difference allows one to conclude that there is a greater requirement for efficient waste management strategies, such as recycling and resource recovery, in Poland.

Taken together, these data metrics show that the developmental trajectories of Circular Economies in Poland and the Czech Republic are characterised by unique challenges and opportunities. The evidence suggests that Poland needs to concentrate its initiatives on streamlining waste management and preserving stability in dependency on imports of raw materials. Simultaneously, the Czech Republic should aim to mitigate its burgeoning dependency on imports of raw materials and augment its resource efficiency.

Projecting these trends into the future, it is envisaged that additional targeted strategies will be required in order for these countries to continue to make progress in the area of the Circular Economy. For Poland, this might necessitate increased investments in recycling infrastructure and improving societal awareness of the benefits of recycling. The Czech Republic, in contrast, might need to focus on enhancing technological efficiency of resource usage and diversification of raw material sources.

Cooperation between Poland and the Czech Republic could stimulate their progress towards a Circular Economy. For instance, Poland could adopt strategies from the Czech Republic's expertise in managing raw materials, while the latter could benefit from Poland's proficiency in stabilising dependency on imports of raw materials. Collaborative endeavours in domains such as research, education, and policy development could substantially expedite their journey towards sustainable development.

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