economies

MDPI

Article

Development of Trade in Recyclable Raw Materials: Transition to a Circular Economy

Olga Lingaitiene and Aurelija Burinskiene *

Department of Business Technologies and Entrepreneurship, Faculty of Business Management, Vilnius Gediminas Technical University, Saulėtekio Av. 11, LT-10223 Vilnius, Lithuania; olga.lingaitiene@vilniustech.lt
* Correspondence: aurelija.burinskiene@vilniustech.lt

Abstract: Mechanisms for sectoral change in the economy are being used to move towards a circular economy. Trade in recycled raw materials could contribute to circular economy development and is treated as the main circular indicator used to monitor progress toward a circular economy. However, the research area surrounding the transition to a circular economy lacks adequate tools, as until now, the circular economy has been investigated from an evolutionary and ecological perspective. In the article, the authors conduct a study identifying important variables for trade in recycled raw materials as the main indicator of CE development. The authors propose a two-step methodology for researching the links between main trade in recyclables and circular economy indicators. The authors found correlations between trade in recyclables and private investments in circular economy sectors. The authors used panel data analysis, compiled a regression matrix, and formed a dynamic regression model. The statistical tests showed that the formed regression model has no significant autocorrelation and heteroscedasticity. The framework can be applied in practice to serve policymakers and the academic community interested in analyzing the move toward a circular economy and its main circular indicators.

Keywords: circular economy; trade; recyclables; EU

check for updates

Citation: Lingaitiene, Olga, and Aurelija Burinskiene. 2024. Development of Trade in Recyclable Raw Materials: Transition to a Circular Economy. *Economies* 12: 48. https://doi.org/10.3390/economies12020048

Academic Editor: António C. Marques

Received: 12 December 2023
Revised: 26 January 2024
Accepted: 31 January 2024
Published: 14 February 2024

1. Introduction

The trade in recyclable raw materials (TRRM) is the circular indicator helping to monitor the circular economy's (CE's) progress (Hanusa 2021; Mancini et al. 2019). In the CE sector, the purpose of residual materials is to be recycled and reintroduced into the economy as new raw materials. This can have several advantages as follows: reducing waste and increasing the security of the supply of raw materials (Pati et al. 2006). Furthermore, it is necessary to include the movements of raw materials derived from waste, i.e., secondary raw materials (Eurostat 2023; Risch 1978).

The TRRM contributes to positive economic and environmental benefits by reducing material inputs. Environmental benefits are mentioned by Sandin and Peters (2018) in the review of more than 40 scientific papers.

The proposed revision of the progress of circular trade is narrowed to monitoring the flow of material, and, using such an explanation, the authors focus on the flow of materials that contribute to a CE (Barrie and Schröder 2022). However, as long as circular trade activities (and CE) are pursued within the economic system driving continuous economic growth, the net contribution of trade in recyclables to national resource consumption reduction could be measured in a more precise way, helping to increase the impact of TRRM (Gregson and Crang 2015). Such an investigation is still on the priority list of the researchers.

Lieder and Rashid (2016) reviewed the literature on circularity and the practical application of the CE in many manufacturing industries. European Union (2020) suggests an action plan on circular economics, which offers new innovative opportunities for waste reduction (European Union 2020).

A recent report by BDO LLP (2022) shows that investment in the CE reached new heights in 2022, and 2022 remains the busiest year for CE investments, growing by 16%. Investors are focusing on companies that can be reduced to modify old raw materials with steady ones. According to the report by BDO LLP (2022), society's desire to consume more sustainable products has led to significant investments in brands that use circular and sustainable materials. This is reflected by its 35% contribution to materials recycling in the manufacturing and manufacturing sectors. This trend is also reflected in the retail, consumer, and entertainment sectors, where 40% of investments are focused on more circular raw materials.

The fact is that whereas the EU imports about half of these raw materials it consumes, Eurostat (2023), the development of TRRM is worthy of this topic but still gains little attention from researchers.

Materials are recycled to achieve the twin benefits of reuse as new materials or products in the economy and through circularity. However, some countries cannot deal with this waste and trade their recyclable waste. Equally, some countries cannot reuse, remanufacture, or recycle used goods and waste materials; such cases require investments. Also, TRRM supports initiatives that shift companies from a linear to a circular business model.

This paper focuses on developing the trade of recycling and secondary raw materials initiatives and indicates what stimulates an increase in such trade flows. The trade in waste not only solves the problems of resource scarcity, reduces the negative impact on our environment, and brings significant economic benefits but is also actively involved in expanding the CE (Morici et al. 2022). To create waste trading networks and identify their structural evolution and determinants, Xu et al. (2021) analyzed waste trade flows.

The authors analyzed the scientific literature and identified a gap from the fact that, in European research, there are not many studies related to the integrated processing of all types of recycled raw materials in the trade landscape and the presentation of how it responds to the CE's approach. Scientific research on this topic is, therefore, timely and relevant. The novelty of this article relates to the fact that it explains the development of TRRM, which indicates the transition to a CE.

The methodological framework proposed in this article is intended for EU countries seeking to help review the dynamics of TRRM. In this research, the authors set out to determine the interdependences of the mentioned phenomena and use statistical software related to the dynamic regression model, such as the Chow test and the breakdown of the variance of forecast errors. The listed tools establish causal links between CE-related private investments and an indicator defining the trade development in recycled raw materials. Adequately delayed values of the forecasted measures show how accurate the forecasts of recyclable trade volumes are (Mesjasz-Lech and Michelberger 2019).

Main idea: A transition towards more efficient resource usage and a CE has many links with trade. Such interactions are essential in helping ensure that global value chains via trade can improve resource usage efficiency. In this article, the authors conducted a study identifying important variables for trade in recycled raw materials as the main indicator of CE development.

Research gaps: The studies show that in the context of the EU, adequate tools and standards that ensure the quality of secondary raw materials to enhance their recovery and trade flows are missing (OECD 2018). Among the methods applied for the delivered research, the most popular methods for researching trade dynamics were causal effect modeling, single-objective and multiple-objective linear programming, analysis of hierarchical regression, fuzzy logic, rough neighborhood sets, and network modeling; however, the application of other methods is still under revision.

Practical implications: In this article, the researchers studied variables important to recycling, excluding other less significant ones. The authors revised and recommended a regression equation characterizing the variables impacting trade in recyclables. This system can be applied in practice and could serve and be useful for those interested in analyzing the trade in recyclables and CE development cases.

Originality/Value: the paper analyzes and investigates TRRM by applying the dynamic regression method, which is quite a new application in similar studies.

This article has five sections. After the introduction, the authors revise the connections between the CE and TRRM. In the first section, the authors present a variety of recycled raw materials. A literature review on TRRM focuses on the trade aspects of different raw materials. In the second section, quantitative methods that are used in other studies for researching TRRM are presented. Herein, the authors propose a two-stage methodology applied for empirical research. In the fourth section, the authors present the results of the research. Finally, the paper is finalized with concluding remarks.

2. Literature Review

Trade in recyclable raw materials facilitates the shift to a circular economy (CE). Processing raw materials reduces the need to recover and treat primary raw materials and protects natural ecosystems (Geisendorf and Pietrulla 2018), supporting the circular approach concept, whereby products and materials are reused and recycled rather than thrown away (Geisendorf and Pietrulla 2018). Introducing recyclable materials to the market fosters recycling technology innovation (Nicolli et al. 2012) and processes. International trade in recyclable materials promotes resource efficiency and reduces waste (De Sa and Korinek 2021). Reusing materials reduces energy consumption and greenhouse gas emissions associated with resource extraction. The process industry creates economic opportunities and jobs and contributes to sustainable economic growth (Hysa et al. 2020). A well-managed recycling market reduces the demand for single-use products and stimulates the production of durable products (Van Beukering and Bouman 2001).

In this way, valuable materials can be redistributed where needed, thus reducing waste in the supply chain (Xu et al. 2017). It supports developing recycling infrastructure and collection systems to make recycling more accessible. International recycling cooperation helps to ensure responsible and environmentally friendly waste management (Wath et al. 2010). Increasing recycling can reduce the environmental impact of landfills and incinerators. Recycling reduces pressure on ecosystems and helps protect biodiversity and natural habitats (Buchmann-Duck and Beazley 2020). The sale of recyclable materials encourages companies to develop products that can be recycled. Trade in recyclable materials can boost investment in cleaner production technologies (Nilsson 2007) and waste management systems.

A circular economy could be achieved If countries share recyclable materials. Trading in recyclable raw materials can help diversify a country's resources and reduce dependence on certain reserves (de Jong et al. 2016).

Circular economy theories. In this chapter, the authors describe six main theories of the circular economy: economic and environmental theory, theory of resource efficiency, waste hierarchy theory, environmental impact theory, green growth theory, and sustainable development theory.

Economic and environmental theories highlight the role of trading in recycled raw materials to transition to a CE (Ghisellini et al. 2016; Allwood 2014). The European Economic and Social Committee recommends that resources be protected for as long as possible and that they be easier to transport through trade to places where they would best be reused or recycled (Hönnige and Panke 2016). The CE theory is a transformational system that emphasizes moving from a linear "take, do, and move" model to one that prioritizes sustainability and resource conservation (Corona et al. 2019; Lang-Koetz et al. 2010). Essentially, the theory proposes to keep materials and products in a closed cycle for as long as possible, in which companies specialize in regions or countries for collecting and recovering recyclable materials and using their comparative advantages (de Oliveira et al. 2012). This theory emphasizes the importance of uncoupling resource usage from economic growth, and trade has a main role in reaching this goal by ensuring an efficient flow of recyclable materials (Ali et al. 2018).

According to the theory of resource efficiency, trade in recyclable raw materials contribute to resource efficiency by reducing the need to destroy and process primary resources, which is consistent with the theory that a sustainable economy requires the maximum use of resources (Farzin 2004). Trade makes it possible to redistribute materials where they can be recycled or reused most efficiently, thus reducing waste and facilitating the circulation of resources. Placing recyclable raw materials on the market directly contributes to resource efficiency, reducing the need to dispose of and recover internal resources (Ghisellini et al. 2016). Marketing recyclable materials contributes to developing recycling infrastructure and technologies, thereby improving efficiency in general recycling processes (Zhang et al. 2019). This theory recognizes that regions can have different processing capacities for each material, so marketing is a way to balance supply and demand (Franco 2017). The efficient use of resources in trade stimulates innovation by creating market incentives to improve recycling practices and product development (Shooshtarian et al. 2022).

According to the waste hierarchy theory, which establishes a hierarchy of waste management strategies (Awino and Apitz 2023), the best solutions are waste prevention and reduction, management, recycling, and reuse, which are at the top of waste management strategies (Ilankoon et al. 2018). By promoting recycling and reuse, retailers reduce waste generation Ilankoon, I.M.S.K. and the need to dispose of it, thereby contributing to the essential objectives of the CE. This theory recognizes that recycled materials should be preferred wherever possible over landfill or incineration. The marketing of recyclable products facilitates the efficient flow of materials from surplus areas to areas where they can be optimally recycled or reused, thus contributing to waste prevention and resource conservation (Zhang et al. 2022). This ensures that materials that would otherwise end up in the trash are used productively and sustainably. The theory of waste hierarchy emphasizes the importance of avoiding environmental damage, which is significantly reduced by the recycling and sale of recyclable raw materials (Loiseau et al. 2016). Finally, the waste hierarchy theory emphasizes that trade in recyclable raw materials is essential to implement the waste hierarchy (Gregson and Crang 2015) and promote the transition to a CE, with recycling and reuse taking precedence over disposal.

The environmental impact theory emphasizes the importance of reducing environmental impact. It promotes responsible waste management (Sáez-Martínez et al. 2016) and ensures that recyclable materials are recycled and reused environmentally. Trade in recyclable materials promotes responsible management (De Sa and Korinek 2021) and hazardous waste disposal, thereby reducing further environmental damage. This theory is based on reducing the unfavorable impact of economic activity on the environment, which fits perfectly into the goals of the CE. This theory recognizes that recycling (Culiberg and Bajde 2013), a core principle of the CE, reduces the emissions of greenhouse gas and energy consumption, thereby helping to mitigate climate change (Culiberg and Bajde 2013). Retailers divert waste from landfills and incinerators, thereby reducing the negative impact of such disposal practices on air, water, and soil quality (Joensuu et al. 2020). The environmental impact theory emphasizes that recycling and marketing reduce the depletion of economic resources (Awan 2013), such as minerals and metals, which are necessary to protect ecosystems (Awan 2013). Overall, the environmental impact theory emphasizes that trade in recyclable raw materials is a main factor in the shift to a CE (Yamaguchi 2018), as it directly contributes to protecting the environment, reducing waste, and reducing environmental damage (Yamaguchi 2018).

The green growth theory states that environmentally friendly practices can achieve sustainable economic growth (Fernandes et al. 2021). It highlights the importance of sustainable economic development (Loiseau et al. 2016), and trade in recycled raw materials is meaningful in the shift to a CE (Vazquez-Brust and Sarkis 2012). The green growth theory shows that economic growth and environmental sustainability are incompatible but can be achieved together (Ekins 2002). Recycling and marketing recyclable materials creates economic opportunities and stimulates the development of a green economy (Di Maio and Rem 2015). This theory recognizes that the circular economy, including trade, reduces pressure on ecosystems (Sehnem et al. 2019) and contributes to biodiversity conservation (Sehnem et al. 2019). It encourages companies to adopt sustainable practices, including developing environmentally friendly products and managing waste responsibly. The green growth theory recognizes the potential for innovation in recycling technologies (Kemp et al. 2013) and sustainable business models driven by the circular economy and trade in recycled materials. In short, trade in recycled raw materials is at the heart of the green growth theory (Ikram 2022), balancing the development of the economy with the sustainability of the environment, promoting resource efficiency and a prosperous green future.

According to the theory of sustainable development, trade in recyclable raw materials contributes to the sustainable use of resources, which is in line with the broader theory of combining social, economic, and environmental goals (Kryshtanovych et al. 2020). The sustainability theory emphasizes that long-term prosperity requires a balance of economic, social, and environmental goals and that trade in recyclable raw materials is essential for achieving sustainability in the shift to a CE (Hysa et al. 2020). The sustainability theory recognizes that economic systems must not harm the environment or waste economic resources that meet the goals of the CE (Ghisellini et al. 2016). Sustainable practices facilitate trade in recyclable raw materials, reducing the need for resource and waste extraction. These practices focus on conserving resources and reducing the impact of goods manufacturing on the environment (Hojnik et al. 2023). This theory states that marketing contributes to efficiently distributing secondary raw materials and ensures their full potential is exploited. The sustainability theory emphasizes that trading in recyclable raw materials helps reduce pollution and protect ecosystems (Joensuu et al. 2020). Finally, the sustainability theory emphasizes that trade in recyclable raw materials is key to a more sustainable and equitable future, promoting resource efficiency, reducing waste, and protecting natural ecosystems.

These six theories provide a solid basis for understanding why trading in recyclable raw materials is essential to the shift to a CE, helping optimize resource usage, reduce waste, and promote economic and environmental sustainability.

Circular economy and green growth. Bauwens (2021) looked at two paths linking the circular economy to economic growth: it is a tenacious attempt to align the circular economy with economic growth or shape attitudes towards the circular economy after growth. Combining the circular economy with economic growth requires the consideration of the circular strategy aspects of the business models proposed by Geissdoerfer et al. (2018) regarding material loops that narrow, slow, close, and use fewer resources to produce goods or services.

Kirchherr (2022) notes that a recent Ellen MacArthur Foundation report outlines the assumption that circularity can become problematic "after growth" because it is defined as economic reduction as it applies biophysical limit principles of circularity such as how to reduce, reuse, or recycle.

Schultz (2022) also contributes to the debate among scientists about whether CE is compatible with economic growth and what kind of mindset. The author highlights two strands of speeches about circularity, which stimulates growth. Post-growth circulation identifies four elements that facilitate the transition to a CE: the trajectory of intensive growth, the creation of markets through internalizing negative external influences, the institutional incentive to spread positive externalities, and dissemination. Schröder et al. (2019) also examined the CE and the jugs of growth and degrowth, highlighting the need to better understand the overlapping and contradictory sustainability principles underpinning the current concepts of CE and degrowth.

3. Participants in Circular Economy Activity and Trade in Recyclable Raw Materials

The CE model avoids waste and pollution (Lebreton and Andrady 2019) and stimulates the prolonged use of materials and products, thus creating a sustainable manufacturing and consumption cycle (Luo et al. 2019). CE refers to circularity with several components, including resource efficiency (Smol et al. 2020), waste reduction and recycling, avoiding the depletion of resources, and protecting the environment (Barford and Ahmad 2021). The trade In recycled materials (Sugeta and Shinkuma 2012) contributes to CE development (Circular Economy 2023). It involves the sale, purchase, and exchange of recycled or secondary production materials recycled from waste or end-of-life products to create a new product cycle (Heller et al. 2020). This avoids the output of new raw materials and reduces the amount of waste that could end up in landfills or as waste products (Costa et al. 2022).

The authors highlight participants In CE activity and their links with trade in recycled materials, which are presented in Table 1.

Table 1. Essential aspects of trade in recycled materials.

Essential	Description	References
Policymakers or regulators	Policymakers determine the regulation of the system. For example, a sustainable product policy program includes three main elements: product-design-dedicated actions, actions that empower consumers, and more sustainable production process-related actions.	(Ali et al. 2018; Lebreton and Andrady 2019)
Primary producers	Primary producers contribute to the legislative initiative initiated by the European Commission on sustainable products and transition from a linear production model to sustainable production.	(Corona et al. 2019; Lang-Koetz et al. 2010)
Recycling companies	These companies play a key role in transforming waste into secondary production materials that could be sold to manufacturers or used to develop new products.	(Barford and Ahmad 2021; Fuss et al. 2021)
Secondary raw material markets	These are markets where recycled or secondary raw materials are traded. Manufacturers can buy the raw materials needed to make products without using new resources.	(Van der Ven 2020; Glogic et al. 2021; Chen and Pao 2022)
Environmental and sustainability organizations	These organizations aim to promote recycling and the use of recycled materials in manufacturing and aim for the ecological design system to be applied to the broadest possible range of product spectrum and ensure circularity.	(Glogic et al. 2021; Siman et al. 2020; Walker et al. 2022)
Consumers	Consumers play an essential role in the CE. They support sustainable consumption patterns by buying products made from recycled materials and encouraging manufacturers to develop products made from recycled materials.	(Yeow and Loo 2018; Wagner et al. 2020; Paço et al. 2021; Rabiu and Jaeger-Erben 2022)

Trade in recycled materials in the CE promotes circularity, sustainability, responsible consumption, and the long-term conservation of natural resources (Paço et al. 2021; Rabiu and Jaeger-Erben 2022). This is essential for reducing pollution and resource depletion and promoting sustainable economic growth (Moslehpour et al. 2023).

Barford and Ahmad (2021), examining how circularity-minded companies address the challenges of waste collection for recycling, noted that waste pickers in countries with a low and average income are the backbone of the recycling cycle and that on purpose to increase circular activity, it is imperative to address the deep-rooted social issues at play (Fuss et al. 2021). Glogic et al. (2021) described circularity scenarios that aim to improve the use and recovery of resources, considering their potential environmental impacts and assessing their effectiveness using the material circularity index (MCI) and assessment of life cycle (LCA) approaches as well as their changes concerning secondary raw materials recycling (Glogic et al. 2021). Van der Ven (2020) looked at changes in international trade flows as global value chains move towards a CE and the trends expected to be most pronounced in developing countries as follows: increasing TRRM, waste, and secondhand products, increasing trade in services, and declining trade in primary raw materials (Van der Ven 2020). Chen and Pao (2022) noted that promoting floriculture is one of the essential tools for the global development of sustainability. Their study found a causal relationship between the following indicators: the municipal waste recycling rate, CE-related investment, per-inhabitant generation of municipal waste, CE rate, and TRRM. Walker et al. (2022) described the corporate adoption of circularity as new opportunities for businesses and environmental impact reduction and described the relationship between CE and sustainability (Walker et al. 2022). The scientific study showed that organizations applying the principles of the CE increase their value by using environmentally friendly resources and trading recycled raw materials. Siman et al. (2020) described waste collectors' organizations' management chain in urban solid waste (Siman et al. 2020). The core business of waste collectors is organizations interested in circular activities involving materials in a production cycle, recycling, and promoting trade (Barrie and Schröder 2022).

Trade in recycled raw materials is also influenced by consumers, their needs, habits, and purchasing power (Paço et al. 2021; Rabiu and Jaeger-Erben 2022), investigating the roles of users, the conditions of use, and the appropriation practices necessary for the repair, reuse, and recycling of circular products and services (Paço et al. 2021).

The Interface between TRRM and CE Is receiving more attention (Hanusa 2021). Although the main role of trade plays a role in the shift to a CE, the interface between these concepts is not well analyzed. To address such a research gap, this paper investigates the intersections between CE and trade in recycled and secondary raw materials (Mesjasz-Lech and Michelberger 2019).

Some of these papers focus on modeling the dynamics of trade flows to support the shift to a CE. One method proposed by the authors is multi-region input–output analysis, which helps model the dynamic changes in trade in recyclables after the performance of CE-related activity. The authors Aguilar-Hernandez et al. (2021), in their study presented in 2021, also used multi-region input–output analysis to estimate the impacts of the gross domestic product (GDP), employment level, and CO_2 changes towards the implementation of CE.

4. Recyclable Raw Materials

Recycling secondary raw materials is a key direction for the sustainable transition of primary product production sectors. Every phase of moving secondary raw materials for recycling creates workplaces and allows businesses to create values, such as collecting, sorting, transporting, and recycling. In most cases, recycling is used to move secondary raw materials to reproduction and create a new product. It could be a solution that orients managers toward sustainable business performance.

Another problem is that 70–80% of secondary raw materials containing potentially useful substances are wasted. This means the loss of economically valuable materials that can be recycled again. The aim is to find ways to reduce the release of valuable materials and reuse them (Risch 1978).

Society has difficulty ensuring the responsible collection and supply of such raw materials and expanding their recycling rates. Different secondary raw materials are collected, such as high-value base metals, plastics, glass, and rubber, which are the most important raw materials.

The most urgent environmental problems for which governments and scientists must constantly seek solutions are the excessive consumption of raw materials and plastic waste generation, which leads to uncontrolled plastic pollution (Lebreton and Andrady 2019). One of the most critical tasks is to improve recycling and minimize the depletion of fossil resources, which would reduce environmental pollution and simplify the collection of organic waste, reduce incineration and disposal in landfills, and provide an opportunity to reduce the consumption of carbon dioxide emissions and petroleum raw materials (Smol et al. 2020).

In many countries, the prevailing opinion is that too much municipal waste is disposed of in landfills (Ncube et al. 2021). Changing the approach to the sustainable management of waste based on the provisions of EAA could help to review the opportunities and challenges of waste management, develop strategies for reusing and recycling materials, diverting them to secondary markets, as well as composting, landfilling, energy production and incineration. A set of complex methods is applicable for developing sustainable approaches to waste management and providing, creating, and operating a sustainable waste management system.

The sustainable management of waste application promotes a CE in Europe by creating business models of waste as resources (Gregson and Crang 2015), which are necessary to develop secondary markets for raw materials and waste diversion strategies.

These strategies consist of subsidies, regulations, legal responsibilities for raw material extraction, appropriate taxes, including household and business efforts to recycle, and pricing based on the full (i.e., social) marginal cost of waste disposal.

The authors raise and examine the following topics in this article: the productivity and optimality of waste disposal, the efficiency of managing waste in landfills and added value (Lebreton and Andrady 2019), the selection of waste management methods and decisions about processing or incinerating waste to extract energy and/or change its physical state, and reducing the volume of waste or extracting useful materials (Gregson and Crang 2015); the authors also consider whether waste should be sent to landfills which are extracted from spent plant material that may contain biological compounds further used as secondary raw materials (Veličković et al. 2008). The authors also review how waste should be sorted before it is processed to extract the desirable or marketable properties of secondary raw materials. The strategy proposed by Morici et al. (2022) suggests increasing the supply of high-quality recycled plastic by increasing the efficiency of material production. Fu et al. (2021) propose a new attitude for glass waste recycling using low-cost glass waste powder as the raw material for preparation (Fu et al. 2021).

Recycling other materials, such as e-waste (Ilankoon et al. 2018), batteries, and textiles, is limited due to insufficient legal regulations to provide incentives for regulating pollution control during recycling, and more research is needed in these areas. Examining the circularity of different types of materials and their relationship with environmental sustainability processes, it is distinguished that metals are the most integrated into the CE's processes due to their wide recycling possibilities (Barford and Ahmad 2021).

Investments in circularity are very important. First, production will be increasingly focused on green materials and processes in the future, so it is important to use circular materials with better recyclability, recycling, and reuse (Dumée 2022). Circularity is important because of the possibility of having positive effects, which reduces raw material consumption and generates basic resources, creating new jobs (Skare et al. 2023).

The amount of secondary raw materials and their accumulation places, collection, sorting trends, distribution, and final locations in different waste streams in the city are insufficient. In Europe, no unified institution manages all primary and secondary raw material information. Such information is dispersed among various institutions, including government agencies, universities, NGOs, and industries. Unified solutions for managing primary and secondary raw materials in a one-stop trailer are required (Lucarini et al. 2020).

The research findings reveal that "ithi" the European Union (EU), there is a lack of adequate tools and standards ensuring the quality of secondary raw materials, hindering their recovery and trade flows, which are both needed for the circular economy's development.

5. Trade in Recyclable Raw Materials

Waste is a secondary resource for countries with lower incomes; its collection is a substantial economic activity, and the resulting recovery of resources is a major section of the CE (Gregson and Crang 2015).

The authors found that trade issues in recycled raw materials are not widely studied in the scientific literature. For example, in their article, Mesjasz-Lech and Michelberger (2019) propose a methodological framework for EU countries to determine the development impact of sustainable waste logistics TRRM. Liang et al. (2021) researched the generation, trade, management, and processing of waste plastic in Asia (Liang et al. 2021). To understand the nature of the waste from the plastic trade in different Asian countries, the authors examined the relationship between the trade in plastic waste and the waste of plastic. Morici et al. (2022) examined the recycling of various types and specifications of plastic, emphasizing that a system of waste management following the specificity of the materials increased the cleanliness and reduced the level of contamination in the collected materials as well as the possible recycling of plastics and bioplastic-based materials (Morici et al. 2022). D'Amato et al. (2019) describe how China's export restrictions have affected European countries, who have felt that the rapidly growing number of plastics harms the environment and climate. Yoshida (2022) conducted field research in China and Taiwan and reviewed China's import policy of recycled waste and its impact on the plastics recycling industry (Yoshida 2022). The investigation results showed that China switched from direct imports of plastic waste from countries of export to imports of recycled pellets through third countries, mainly from Southeast Asia.

The essential aspects of recycling are the impact on the environment of the trade of recycled materials and the possibility of promoting recycled materials as raw materials to produce a recyclable end product that can be sold. The authors distinguish the essential types of secondary raw materials generating volumes for trade.

Table 2 shows the most popular recyclable materials, which receive the highest attention from authors: metal, plastic, glass, and e-waste. The publications fit into time slots between 2003 and 2022. The selected revision of different secondary materials for generating trade volumes reflects this article's research novelty, as most papers focus on a single type of raw material.

Table 2. Trade in different types of recyclable materials.

Recyclable Material Type	References
metal	(Bergthorson 2018; Bertram et al. 2017; Hu et al. 2020; Shamsdini et al. 2020; Söderholm and Ekvall 2020; Sommerville et al. 2021; Sun et al. 2019; Van Ruijven et al. 2016; Wang et al. 2019)
glass	(Barfod et al. 2022; Ganio et al. 2012; Gliozzo et al. 2022; Henderson et al. 2020; Jackson and Paynter 2022; Koleini et al. 2019; Neri et al. 2019; Plank et al. 2022; Wiedenhofer et al. 2019)
plastic	(Morici et al. 2022; Barford and Ahmad 2021; Wagner et al. 2020; Liang et al. 2021; D'Amato et al. 2019; Yoshida 2022; Brooks et al. 2018; Hossain and Shams 2020; Huang et al. 2020; Leal Filho et al. 2019; Navarre et al. 2022; Schultz and Reinhardt 2023; Schultz and Pies 2023; Wang et al. 2020; Wen et al. 2021)
paper, cardboard	(Aytaç and Korkmaz 2022; Aravossis and Fountzoula 2014; Westmorland and Furness Council 2023; Yang et al. 2020; Yuan 2022; Zhou et al. 2021)
batteries	(Sommerville et al. 2021; Chen et al. 2019; Igogo et al. 2019; Mayyas et al. 2019; Song et al. 2019)
e-waste	(Ilankoon et al. 2018; Dias et al. 2022; Hijazi et al. 2021; Petridis et al. 2020; Rathore 2020; Shamim et al. 2015; Shinkuma and Huong 2009; Shittu et al. 2021; Theis 2021)
household appliances	(Luo et al. 2019; Yoshida 2022; Yoshida 2013; McCollough 2009; Sasaki 2021; Shigetomi et al. 2015)
textile	(DeVoy et al. 2021; Hawley 2006; Norris 2012; Norris 2019; Pensupa et al. 2017; Stone et al. 2020)

Lebreton and Andrady (2019) and Ncube et al. (2021) examined the accumulation of improperly managed waste in the environment, citing the suspension of imports of waste for recycling from China as one of the reasons for this; (Ncube et al. 2021). Brooks et al. (2018) observed that this ban could have two consequences as follows: in some countries, there will be vast amounts of plastic waste, or it will create a system of reliable waste management that has results in the future. It should be noted that the most impacted countries are East Asian and Pacific countries, all countries of Europe and Central Asia, and countries located in America. Gregson and Crang (2015) examined economic illegitimacy and the impact of importing illegally used goods on the domestic industry. Considering the 2018 China ban on importing plastic waste to other countries, Asian countries have severely restricted other countries' plastic waste imports (D'Amato et al. 2019; Yoshida 2022). Wang et al. (2019) assessed the direct and indirect import effects of China-generated plastic waste on the international trade networks of plastic waste.

Paletta (2019) looked at the possibility of reducing plastic consumption, increasing recycling, and accelerating the transition of plastic systems to circularity. Leal Filho et al. (2019), in their study on the use of plastics and bioplastics in Europe, point out that the conventional production of plastics is based on fossil fuels and is growing steadily and that this is making the release of plastics into the environment an increasingly important issue (Shamsdini et al. 2020). The plastic pollution of living organisms in soil, marine, and freshwater ecosystems is causing problems that pose risks to human health. It is, therefore, important to find new ways of collecting and properly managing plastic waste. Gong et al. (2023) also looked at the issue of waste management and the links between the role of CE and plastics and investigated the elimination of non-recyclable plastics, packaging innovation, in-store retailer programs, and label changes. The author stressed that the CE can stimulate economic growth and allow companies to save on waste management and reduce their environmental impact.

Schultz and Reinhardt (2023) conducted a study identifying the main CE barriers and drivers. They studied how certain factors hinder or promote systemic "eco-efficient" CE innovation in the European polyurethane plastic industry and proposed how to facilitate and further develop the management of systemic CE innovation activities. The authors Schultz and Reinhardt (2023) extended their study and, in the next article, described how to facilitate CE's ambitions by overcoming technological challenges and identifying opportunities in the European plastics industry. The authors found that the technological challenges in the plastics sector are mainly related to the contamination of secondary materials, recycling problems, production processing problems, the quality problems of production materials, and quality problems of final products, while opportunities are related to the effective management of secondary materials; chemical recycling innovations; production and processing innovations; and innovative materials and innovative final products.

Moving towards more effective resource utilization, the implementation of the CE is closely intertwined with trade. These connections play a crucial role in ensuring that global value chains, facilitated by trade, contribute to enhancing the efficiency of resource utilization. The authors undertook a study to identify key variables influencing the trade in recycled raw materials, serving as a primary indicator of circular economy development.

6. Materials and Methods

The authors analyzed the scientific literature, reviewed the quantitative methods used in the research of other authors, and constructed Table 3. Table 3 summarizes and provides a revision of the previous studies and research methods used in their studies. The authors found that among the quantitative methods listed above, the mathematical ones are occasionally mentioned in the research works of other scientists. In the meantime, time-series analysis allows us to identify variables, which help to trigger trade research for main recyclables.

Table 3. Hierarchy of quantitative methods and models for researching the trade of recyclable raw material.

Model	Modeling Technique	Method of Solution	Sources
Mathematical programming methods	Single objective	Linear programming	(Pati et al. 2006; Ohno et al. 2017)
	Multi-objective	Mixed-integer linear programming	(Rajak et al. 2022)
		Mixed-effect linear model	(Petridis et al. 2020)
		VAR model	(Mesjasz-Lech and Michelberger 2019)
		Multi-objective linear programming	(Govindan and Sivakumar 2016; Paksoy et al. 2010)
		Multiple regression	(Person 2011)
		Analysis of hierarchical regression	(Yeow and Loo 2018; Vedantam et al. 2022)
		Fuzzy programming	(Arora et al. 2021)
		Stochastic dynamic programming	(Mesjasz-Lech and Michelberger 2019)
		Non-linear causality	(Feng 2022)
	Time series	Dynamic regression analysis	In this paper
Causal models	Causality identification	Causal effect modeling	(Lessard et al. 2021; Pao and Chen 2022; Giljum et al. 2008)
		Diagram of causal systems	(Tong et al. 2021)
Heuristic methods	Simple heuristic	Simulated annealing heuristics	(Taheri and Moghaddam 2022)
	Artificial intelligence	Markov chain	(Eckelman et al. 2012)
		Object-oriented Petri nets	(Xu et al. 2021)
		Fuzzy logic	(Arora et al. 2021; Chen et al. 2018)
		Rough sets	(Amiri et al. 2022)
		Neighbourhood rough sets	(Furedy 1997; Benjamin 2000)
	Metaheuristic	Genetic algorithm	(Demirel et al. 2014)
		Particle swarm optimization	(Wang et al. 2015)
Analytical models	Multiple-criteria decision making	Analytical hierarchy process	(Handfield et al. 2002)
		DEMATEL	(Shih-Hsiung et al. 2018)
	Systematic models	Delphi method	(Al-Agele and Al-Kaabi 2016)
		Network model	(Bing et al. 2015)

The research results in Table 3 show that the most popular methods are causal effect modeling, single-objective and multiple-objective linear programming, the analysis of hierarchical regression, fuzzy logic, rough neighborhood sets, and network models. However, some other methods, including the dynamic regression method, do not receive attention or are rarely used in particular studies. Within this section, a detailed analysis and investigation into the trade of recyclables was conducted using the dynamic regression method, representing a relatively novel approach in similar studies, which is essential for circular economy development.

The authors of the CE might view this differently, including the dynamics of transitions. Considering such an approach, the authors proposed a methodology for researching the progress regarding a CE on the thematic area of 'recycled raw materials' using an indicator—trade in recyclable raw materials. The methodology is presented in Table 4.

Table 4. Two-stage methodology for researching trade in recyclable raw materials.

Step of applied methodology	Approach toward evaluation of trade	Technique to achieve results and implement validation	Assessment of compliance with the requirements important for the transition to a CE
First step			
Revision of variables	Identification of strong and weak connections with variables under the current situation.	Normalization, panel data analysis, and formation of the correlation matrix to identify critical variables.	Achievement of efficient use of environmental resources; achieving environment-oriented management and reduction in waste through recycling
Second step			
Identification of dynamics	Construction of equations among identified pairs of variables with significant relationships.	Dynamic regression analysis, formation of regression equations, and testing the statistical validity of formed equations by applying the Chow test.	Identification of means necessary for TRRM development, which policymakers could apply.

To review essential variables, the authors used several steps. The authors identified the relationships by applying the suggested two-stage methodology (Table 4) and constructing Equations (1)–(2) describing the dynamics of trade volumes in recyclable raw materials.

The authors collected panel data for this study and investigated the links among monthly data about trade in recyclable raw materials from the Eurostat (2023) database. This article uses a dynamic regression model, as stated in Table 3. Using a simple regression analysis procedure, the authors seek regression coefficients in a model reflecting a linear relationship between the dependent and the regressor.

The authors determined the variables affecting the trade amount in recyclable raw materials based on the dynamic regression equation. The process has the following four steps:

1. To accurately perceive new phenomena and systematize the variables important for phenomena, the authors formed a set of critical variables;
2. The data selection phase was based on analytical reliability, measurability, and phenomenon adequacy. The quality of the available data was checked by assessing the availability of the required data, checking data sources, and analyzing their strengths and weaknesses.
3. The authors performed a normalization step to compare variables regarding annual percentage differences. Compared to the historical period, the value differences showed a percentage change.
4. At the validation stage of the analysis, the regression equation was estimated based on the normalization scheme. The authors analyzed if the correlation between private investments in CE sectors and the trade regarding recyclables exists and answered this question.

By applying the four steps mentioned above, the authors of this paper designed (1) the Equations (1) and (2). For Equation (2), the authors selected the data following the correlation coefficients and probabilities based on a designed matrix of research variables, which are presented in the Appendix A. In a specific section, the researchers focused on variables essential to recycling, excluding those considered less significant; (3) furthermore, data were normalized using a logarithmic process; and (4) later, the authors showed the validation analysis presented in Appendix B.

The model of dynamic regression developed to estimate how recycling variables affect the amount of trade in recyclables:

$$trd\_rec_t = \beta_0 + \beta_1 trd\_rec_{(t-1)} + \beta_2 prinv\_circ_{(t)} + \beta_3 recov\_cnstr_{(t)} + u_t \quad (1)$$

Variables:
trd_rec_t—dependent variable of TRRM in year t;
β_0—intercept;
trd_rec_{t-1}—TRRM i—year $t-1$;
$prinv\_circ_t$—private investments, jobs, and gross value added in relation to circular economy sectors in year t;
$recov\_cnstr_t$—recovery rate of construction and demolition-generated wastes (CDWs) in year t;
u_t—random model error,
$\beta_1, \beta_2, \beta_3$—coefficients of elasticity reflect the influence of independent variables on TRRM.

The variables included in the research are presented in Equation (1). The values of these variables are connected with period t.

This analysis reveals trend dynamics and provides insights into relationships in pairs. For the revision of dependent variables, the authors collected monthly information about trade in recyclable raw materials from the Eurostat (2023) database between 2000 and 2019.

7. Results

The trade volumes in recyclables are researched following a two-stage methodology. Following the first step, the authors must prove that the suggested equation is possible and matches statistical validity. The formula of the dynamic regression model is presented herein (see Equation (2)), where information from Table 5 is used. The authors included the coefficients of the formula and standard error values:

$$\begin{aligned} trd_{rec\,t} = \underset{(81698.4)}{190461.7} + \underset{(0.07)}{0.36} trd_{rec\,(t-1)} + \underset{(5.64)}{17.92} prinv_{circ\,(t)} + \underset{(384.3)}{915.17} recov_{cnstr\,(t)} \end{aligned} \quad (2)$$

Variables from Equation (1):
trd_rec_t—dependent variable of TRRM in year t;
trd_rec_{t-1}—TRRM i—year $t-1$;
$prinv\_circ_t$—private investments, jobs, and gross value added in relation to circular economy sectors in year t;
$recov\_cnstr_t$—recovery rate of construction and demolition-generated wastes (CDWs) in year t.

The strongest link is between private investments, jobs, and the gross value added in relation to circular economy sectors (PRINV_CIRC) and trade in recyclables (TRD_REC), which is presented in Figure 1.

Aiming to summarize the concrete values of the regression analysis (2), the authors incorporate the results of the correlation tests conducted for this empirical study, following identified correlation coefficients and probabilities among the pairs of variables normalized for this test's performance. Later, the authors selected the pairs of variables with significant relationships (see Appendix A) and applied the panel least squares method to obtain the outputs provided below (see Table 5 and Appendix B).

Table 5 shows the following statistics: coefficients, which are used in Equation (2); standard error values, which are placed under each variable of Equation (2); and the probability, which shows that the coefficients mentioned above are valid when the probability is lower than 0.05.

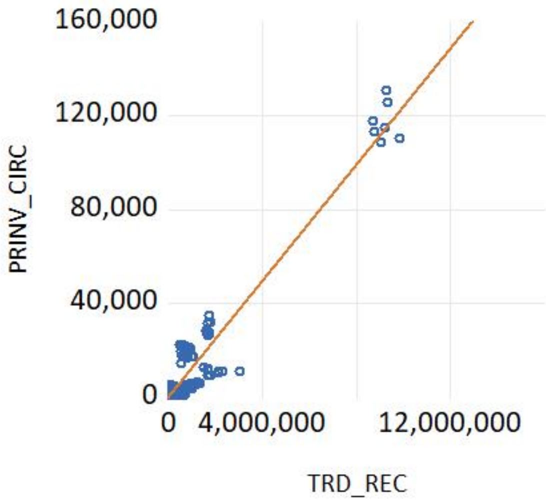

Figure 1. The link between variables.

Table 5. Coefficients for forming Equation (2) applying the panel least squares revision method.

Variable	Coefficient	Standard Error	t-Statistic	Probability
C	190,461.7	81,698.4	2.33	0.021
trd_rec_{t-1}	0.36	0.07	4.95	0
$prinv\_circ_t$	17.92	5.64	3.17	0.001
$recov\_cnstr_t$	915.17	384.3	2.38	0.018

Variables from Equation (1):

trd_rec_{t-1}—TRRM *i*—year $t-1$;

$prinv\_circ_t$—private investments, jobs, and gross value added in relation to circular economy sectors in year *t*;

$recov\_cnstr_t$—recovery rate of construction and demolition-generated wastes (CDWs) in year *t*;

The table above shows the relationship between trade for recyclable raw materials and other variables. Table 5 shows that the trade in recyclable raw materials has links with the following two indicators: the recovery rate of CDW and private investments into circularity. According to Equation (2), if the recovery rate of CDW and private investments into circularity increase, then the trade for the recycling amount also increases.

The authors Identified that R-squared equals 0.994, and the Durbin–Watson statistic equals 1.84. In addition, the statistical validity is tested using the Chow test, which presents the correct statistical validity.

The results show that the constructed residuals of the equation are spread by following normal distribution (see Figure 2). The statistics demonstrate that the mean is close to zero. Figure 2 shows that the average of residuals is close to zero.

The results show that the authors formed a correlation matrix and dynamic regression model, which was used to determine the amount of trade in recyclable raw materials.

The dynamic regression model is formed following the two-stage methodology suggested by this paper's authors. The suggested model can be used to predict the use of trade in recyclable raw materials in the EU-27 countries.

The authors revised and proposed a regression equation that characterizes the variables influencing the trade in recyclables. This system can be practically applied and proves valuable for individuals interested in analyzing cases related to the trade of recyclables and circular economy development.

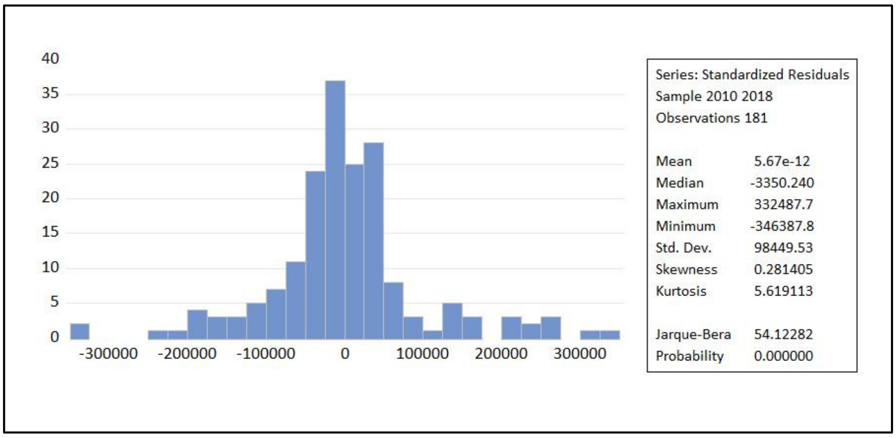

Figure 2. Spread of equation residuals.

8. Discussion

The CE has become one of the newest solutions to environmental sustainability problems. Also, CE is gaining increasing attention as a way of transforming current production and consumption patterns, which are based on continuous economic growth and increasing resource scarcity. The shift towards CE and the drive for more resource efficiency drives the economic system towards closed-loop production models, with a particular focus on waste reduction, recycling, and a strong link to trade.

These interactions are key to ensuring that global value chains can increase resource efficiency through trade while ensuring the best possible balance between the economy, environment, and society.

This paper contributes to the theoretical understanding of circular economy principles by exploring trade dynamics in recyclable raw materials. It may lead to refining and expanding existing circular economy frameworks, offering insights into how trade practices can be integrated into theoretical models.

Research gaps have been identified in the EU's lack of adequate tools and standards to ensure the quality of secondary raw materials to increase their use and trade flows. Causal modeling, single-objective and multi-objective linear programming, hierarchical regression analysis, fuzzy logic, fuzzy neighborhood sets, and network modeling were found to be the most popular methods used to investigate the dynamics of trade. However, the use of other methods is still being refined. The authors revised six economic and environmental theories to cover the research gap, highlighting trade's role in recyclables.

Such trade is a specific phenomenon and highly depends on the contribution of industry sectors.

This topic must receive more attention in the context of sustainability, circularity, the CE, and their interaction with the economy. In the shift to a CE, it is important to quantify the contribution of the circularity of services and products to the CE and look at circularity indicators while minimizing the environmental impact and considering economic and social aspects.

The theoretical implications of this paper contribute to an academic understanding of circular economy dynamics, while its practical implications guide businesses, policymakers, and practitioners in implementing sustainable practices and navigating the evolving landscape of global trade in recyclable raw materials.

Countries engaged in international trade can practically consider this paper's implications for collaboration. These findings may influence trade agreements and partnerships, fostering a more coordinated global approach to circular economy practices and the trade of recyclable materials and interactions with the economy.

In addition, the formed equation shows that private investments, jobs, and the gross value added in relation to CE sectors are the most important factors affecting the trade volumes of recyclable raw materials. This phenomenon could argue that investments into circularity have positive effects and help the EU-27 to reduce the consumption of raw materials and basic resources. According to research, the private investments, jobs, and gross value added in relation to circularity and CE sectors have the highest correlation coefficient in pair with the trade of recyclable raw materials.

The study's design is quite new and highlights the potential of the dynamic regression model, whose application showed fairly good results in this study.

In this article, the authors studied variables important for recycling, excluding other less significant aspects. The authors plan to conduct a study that includes more variables and a more in-depth examination of the economic impact in future research.

9. Conclusions

The research shows the links between the CE's development and trade in recycled raw materials. Such links are seen in two ways: first, the trade in recyclable raw materials is the main indicator for CE development; on the other hand, private investments in CE sectors show trade growth in recycled raw materials. Understanding such links is important for the transition process toward a CE and gives valuable insights for policy formers and decision makers.

The authors researched how the Increase in secondary waste could influence the change in trade volumes. The authors identified many quantitative methods generally used to analyze trade volumes' dependency on recyclable raw materials. Among these quantitative methods, the most popular methods applied in the research of other authors are causal effect modeling, single-objective and multiple-objective linear programming, the analysis of hierarchical regression, fuzzy logic, rough neighborhood sets, and network models.

Using the dynamic regression model, the authors propose a two-step methodology for researching trade in recyclable raw materials. Such a model could be used for notified investigations in this area. The authors applied panel data analysis in the EU-27, constructed the equation, and tested its statistical validity. The model follows several trends: the recovery rate of CDW, private investments, jobs, and the gross value added in relation to circularity and CE sectors. It analyzes how these trends influence the trade volumes in recyclable raw materials. The authors determined the direct relationship and statistical significance of the mathematical description of researched phenomena.

The development of trade In recyclable raw materials could have far-reaching effects, influencing political decisions, societal behavior, and the practices of practitioners in businesses and industries. The development of trade in recyclable raw materials has the potential to drive positive change by fostering sustainability, resource efficiency, and economic resilience.

This research has some limitations. Not all the types of secondary waste (i.e., plastic metal, e-waste, etc.) were analyzed in this paper, including trade's evolution toward them. Such investigations could be the future direction for further studies. Also, the authors could analyze the development of trade volumes when more types of waste are included. The research is delivered over a ten-year time frame. As the research cycle continues, this study could cover other periods. This research has geographical territory limitations as the research was delivered in the EU-27.

Author Contributions: Conceptualization, A.B.; methodology, A.B.; investigation, O.L.; writing—original draft preparation O.L.; writing—review and editing, A.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data is available at Eurostat database.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Variables		MUNW	CIRC_U	PATNTS_DL	PRINV_CIRC	REC_BIOW	REC_EW	REC_MU	REC_PCW	REC_R	RECOV_CNSTR	TRD_REC
Generation of municipal waste per capita (MUNW)	Coeff.	1										
	Probability	-----										
Circular material use rate (CIRC_U)	Coeff.	-0.030	1									
	Probability	0.830	-----									
Patents related to recycling and secondary raw materials (PATNTS_DL)	Coeff.	0.325	0.002	1								
	Probability	0.017	0.985	-----								
Private investments, jobs and gross value added related to circular economy sectors (PRINV_CIRC)	Coeff.	0.015	0.982	-0.037	1							
	Probability	0.915	0	0.790	-----							
Recycling of biowaste (REC_BIOW)	Coeff.	0.489	-0.002	-0.152	0.042	1						
	Probability	0.000	0.983	0.274	0.763	-----						
Recycling rate of e-waste (REC_EW)	Coeff.	0.367	-0.119	-0.080	-0.118	0.213	1					
	Probability	0.006	0.395	0.566	0.399	0.125	-----					
Recycling rate of municipal waste (REC_MU)	Coeff.	0.449	0.088	-0.170	0.129	0.820	0.439	1				
	Probability	0.000	0.529	0.223	0.354	0	0.00	-----				
Recycling rate of packaging waste by type of packaging (REC_PCW)	Coeff.	0.203	0.033	-0.164	0.088	0.572	0.267	0.728	1			
	Probability	0.143	0.809	0.239	0.527	0	0.053	0	-----			
Recycling rate of municipal waste (REC_R)	Coeff.	0.165	0.041	-0.177	0.060	0.578	0.129	0.693	0.623	1		
	Probability	0.237	0.766	0.204	0.667	0	0.356	0	0	-----		
Recovery rate of construction and demolition waste (RECOV_CNSTR)	Coeff.	0.236	0.032	-0.101	0.038	0.170	0.220	0.202	0.055	0.272	1	
	Probability	0.088	0.819	0.471	0.784	0.221	0.112	0.146	0.694	0.048	-----	
Trade in recyclable raw materials (TRD_REC)	Coeff.	-0.002	0.949	-0.049	0.956	0.051	-0.087	0.144	0.155	0.064	0.020	1
	Probability	0.983	0	0.723	0	0.714	0.532	0.301	0.267	0.645	0.886	-----

Figure A1. Correlation matrix.

Appendix B

Table A1. The statistics used for Equation (2)'s formation.

Testing Variables	Values	Testing Variables	Values
Root MSE	98,177.1	R-squared	0.995
Mean dependent var	648,001.6	Adjusted R-squared	0.994
S.D. dependent var	1,516,512	S.E. of regression	109,313.4
Akaike info criterion	26.2	Sum squared resid	1.74×10^{12}
Schwarz criterion	26.8	Log likelihood	−2337.3
Hannan–Quinn criteria	26.4	F-statistic	1014.6
Durbin–Watson stat	1.84	Prob(F-statistic)	0

References

Aguilar-Hernandez, Glenn A., João Dias Rodrigues, and Arnold Tukker. 2021. Macroeconomic, social and environmental impacts of a circular economy up to 2050: A meta-analysis of prospective studies. *Journal of Cleaner Production* 278: 15–35. [CrossRef]

Al-Agele, Hatem Kh. B., and Sajjad A. M. Al-Kaabi. 2016. Identification of Key Factors Affecting Waste Management in Life Cycle of the Construction Project by Using Delphi Technique. *Journal of Engineering* 22: 19–34. [CrossRef]

Ali, Mustafa, Christina M. Kennedy, Joe Kiesecker, and Yong Geng. 2018. Integrating biodiversity offsets within Circular Economy policy in China. *Journal of Cleaner Production* 185: 32–43. [CrossRef]

Allwood, Julian M. 2014. Squaring the circular economy: The role of recycling within a hierarchy of material management strategies. In *Handbook of Recycling*. Amsterdam: Elsevier, pp. 445–77.

Amiri, Maghsoud, Mohammad Hashemi-Tabatabaei, Masoud Ghahremanloo, Mehdi Keshavarz-Ghorabaee, Edmundas Kazimieras Zavadskas, and Sali Salimi-Zavieh. 2022. Evaluating barriers and challenges of circular supply chains using a decision-making model based on rough sets. *International Journal of Environmental Science and Technology* 19: 7275–96. [CrossRef]

Aravossis, Konstantinos, and Christina Fountzoula. 2014. An analysis of an innovative concept regarding exchanging recyclable with agri-cultural products. *Fresenius Environmental Bulletin* 23: 2890–94.

Arora, Ritu, Anubhav Pratap Singh, Renu Sharma, and Anand Chauhan. 2021. A remanufacturing inventory model to control the carbon emission using cap-and-trade regulation with the hexagonal fuzzy number. *Benchmarking: An International Journal* 29: 2202–30. [CrossRef]

Awan, Abdul Ghafoor. 2013. Relationship between environment and sustainable economic development: A theoretical approach to environmental problems. *International Journal of Asian Social Science* 3: 741–61.

Awino, Florence Barbara, and Sabine E. Apitz. 2023. Solid Waste Management in the Context of the Waste Hierarchy and Circular Economy Frameworks: An International Critical Review. *Integrated Environmental Assessment and Management* 20: 9–35. [CrossRef] [PubMed]

Aytaç, Ayhan, and Murat Korkmaz. 2022. An Analysis of the World Paper Industry with a Focus on Europe and Trade Perspective. *Seria Științe Economice* 32: 24–40. [CrossRef]

Barfod, Gry H., Ian C. Freestone, Ruth E. Jackson-Tal, Achim Lichtenberger, and Rabina Raja. 2022. Exotic glass types and the intensity of recycling in the northwest Quarter of Gerasa. *Journal of Archaeological Science* 140: 105546. [CrossRef]

Barford, Anna, and Saffy Rose Ahmad. 2021. A call for a socially restorative circular economy: Waste pickers in the recycled plastics supply chain. *Circular Economy and Sustainability* 1: 761–82. [CrossRef]

Barrie, Jack, and Patrick Schröder. 2022. Circular economy and international trade: A systematic literature review. *Circular Economy and Sustainability* 2: 447–71. [CrossRef]

Bauwens, Thomas. 2021. Are the circular economy and economic growth compatible? a case for post-growth circularity. *Resources, Conservation and Recycling* 175: 105852. [CrossRef]

BDO LLP. 2022. Circular Economy Series—Investment Into The UK Circular Economy 2022. Available online: https://www.bdo.co.uk/en-gb/insights/advisory/mergers-and-acquisitions/circular-economy-series-waste-management-and-recycling/download (accessed on 23 January 2023).

Benjamin, Solomon. 2000. Governance, economic settings and poverty in Bangalore. *Environment and Urbanization* 12: 35–56. [CrossRef]

Bergthorson, Jeffrey M. 2018. Recyclable metal fuels for clean and compact zero-carbon power. *Progress in Energy and Combustion Science* 68: 169–96. [CrossRef]

Bertram, Martin, S. Ramkumar, Helmut Rechberger, Georg Rombach, Chris Bayliss, Kenneth J. Martchek, and Gang Liu. 2017. A regionally-linked, dynamic material flow modelling tool for rolled, extruded and cast aluminium products. *Resources, Conservation and Recycling* 125: 48–69. [CrossRef]

Bing, Xiaoyun, Jacqueline Bloemhof-Ruwaard, Amin Chaabane, and Jack Van Der Vorst. 2015. Global reverse supply chain redesign for household plastic waste under the emission trading scheme. *Journal of Cleaner Production* 103: 28–39. [CrossRef]

Brooks, Amy L., Shunli Wang, and Jenna R. Jambeck. 2018. The Chinese import ban and its impact on global plastic waste trade. *Science Advances* 4: eaat0131. [CrossRef] [PubMed]

Buchmann-Duck, Johanna, and Karen F. Beazley. 2020. An urgent call for circular economy advocates to acknowledge its limitations in conserving biodiversity. *Science of the Total Environment* 727: 138602. [CrossRef]

Chen, Chun-Chih, and Hsiao-Tien Pao. 2022. The causal link between circular economy and economic growth in EU-25. *Environmental Science and Pollution Research* 29: 76352–64. [CrossRef] [PubMed]

Chen, Yountong, Felix T.S. Chan, S. H. Chung, and Woo-Yong Park. 2018. Optimization of product refurbishment in closed-loop supply chain using multi-period model integrated with fuzzy controller under uncertainties. *Robotics and Computer-Integrated Manufacturing* 50: 1–12. [CrossRef]

Chen, Zhenyang, Lingen Zhang, and Zhenming Xu. 2019. Tracking and quantifying the cobalt flows in mainland China during 1994–2016: Insights into use, trade and prospective demand. *Science of the Total Environment* 672: 752–62. [CrossRef]

Circular Economy. 2023. Available online: https://circulareconomy.earth/publications/trade-and-circular-economy (accessed on 5 April 2023).

Corona, Blanca, Li Shen, Denise Reike, Jesús Rosales Carreón, and Ernst Worrell. 2019. Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. *Resources, Conservation and Recycling* 151: 104498. [CrossRef]

Costa, Catarina, André Viana, Carla Silva, Eduardo F. Marques, and N. G. Azoia. 2022. Recycling of textile wastes, by acid hydrolysis, into new cellulosic raw materials. *Waste Management* 153: 99–109. [CrossRef] [PubMed]

Culiberg, Barbara, and Domen Bajde. 2013. Consumer recycling: An ethical decision-making process. *Journal of Consumer Behaviour* 12: 449–59. [CrossRef]

D'Amato, Alessio, Susanna Paleari, Maij Pohjakallio, Ive Vanderreydt, and Roberto Zoboli. 2019. *Plastics Waste Trade and the Environment*. Boeretang: The European Environment Information and Observation Network (Eionet).

de Jong, Sijbren, Myrthe van der Gaast, Joost Kraak, Reinier Bergema, and Artur Usanov. 2016. *The Circular Economy and Developing Countries: A Data Analysis of the Impact of a Circular Economy on Resource-Dependent Developing Nations*. The Hague: The Hague Centre for Strategic Studies.

de Oliveira, Camilla Reis, Andréa Moura Bernardes, and Annelise Engel Gerbase. 2012. Collection and recycling of electronic scrap: A worldwide overview and comparison with the Brazilian situation. *Waste Management* 32: 1592–610. [CrossRef] [PubMed]

De Sa, Paulo, and Jane Korinek. 2021. *Resource Efficiency, the Circular Economy, Sustainable Materials Management and Trade in Metals and Minerals*. Paris: OECD Publishing.

Demirel, Neslihan, Eren Özceylan, Turan Paksoy, and Hadi Gökçen. 2014. A genetic algorithm approach for optimizing a closed-loop supply chain network with crisp and fuzzy objectives. *International Journal of Production Research* 52: 3637–64. [CrossRef]

DeVoy, Julia E., Elizabeth Congiusta, Dielle J. Lundberg, Sarah Findeisen, and Sunand Bhattacharya. 2021. Post-Consumer textile waste and disposal: Differences by socioeconomic, demographic, and retail factors. *Waste Management* 136: 303–9. [CrossRef]

Di Maio, Francesco, and Peter Carlo Rem. 2015. A robust indicator for promoting circular economy through recycling. *Journal of Environmental Protection* 6: 1095. [CrossRef]

Dias, Pablo, Aandréa M. Bernardes, and Nazmul Huda. 2022. e-Waste Management and Practices in Developed and Developing Countries. *Electronic Waste: Recycling and Reprocessing for a Sustainable Future* 15–32.

Dumée, Ludovic F. 2022. Circular materials and circular design—Review on challenges towards sustainable manufacturing and recycling. *Circular Economy and Sustainability* 2: 9–23.

Eckelman, Mattehew J., Barbara K. Reck, and T. E. Graedel. 2012. Exploring the global journey of nickel with Markov chain models. *Journal of Industrial Ecology* 16: 334–42. [CrossRef]

Ekins, Paul. 2002. *Economic Growth and Environmental Sustainability: The Prospects for Green Growth*. London: Routledge.

European Union. 2020. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions a New Circular Economy Action Plan for a Cleaner and More Competitive Europe. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN (accessed on 5 June 2023).

Eurostat. 2023. Waste Streams. Available online: https://ec.europa.eu/eurostat/web/waste/data/database (accessed on 12 February 2023).

Farzin, Y. Hossein. 2004. Is an exhaustible resource economy sustainable? *Review of Development Economics* 8: 33–46. [CrossRef]

Feng, Chen. 2022. Granger Causality Analysis of Foreign Trade in Cement Products and Ecological Impact in China. *Mathematical Problems in Engineering* 2022: 3467483. [CrossRef]

Fernandes, Christina I., Pedro Mota Veiga, João J. M. Ferreira, and Mathew Hughes. 2021. Green growth versus economic growth: Do sustainable technology transfer and innovations lead to an imperfect choice? *Business Strategy and the Environment* 30: 2021–37. [CrossRef]

Franco, Maria A. 2017. Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *Journal of Cleaner Production* 168: 833–45. [CrossRef]

Fu, Chong, Jianwei Liang, Gao Yang, Abd Alwahed Dagestani, Wei Liu, Xudong Luo, Baobao Zeng, Haidong Wu, Meipeng Huang, Lifu Lin, and et al. 2021. Recycling of waste glass as raw materials for the preparation of self-cleaning, lightweight and high-strength porous ceramics. *Journal of Cleaner Production* 317: 128395. [CrossRef]

Furedy, Christine. 1997. *Household-Level and Community Actions for Solid Waste Management and Recycling in Asian Cities: Recent Research and Projects*. Nagoya: United Nations Centre for Regional Development.

Fuss, Maryegli, Raphael T. V. Barros, and Witold-Roger Poganietz. 2021. The role of a socio-integrated recycling system in implementing a circular economy–The case of Belo Horizonte, Brazil. *Waste Management* 121: 215–25. [CrossRef]

Ganio, Monica, Sara Boyen, David Brems, Rebecca B. Scott, Denis Foy, Kris Latruwe, and Patrick Degryse. 2012. Trade routes across the Mediterranean: A Sr/Nd isotopic investigation on Roman colourless glass. *Glass Technology-European Journal of Glass Science and Technology* 53: 217–24.

Geisendorf, Sylvie, and Felicitas Pietrulla. 2018. The circular economy and circular economic concepts—A literature analysis and redefinition. *Thunderbird International Business Review* 60: 771–82. [CrossRef]

Geissdoerfer, Martin, Sandra Naomi Morioka, Marly Monteiro de Carvalho, and Steve Evans. 2018. Business models and supply chains for the circular economy. *Journal of Cleaner Production* 190: 712–21. [CrossRef]

Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. 2016. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production* 114: 11–32. [CrossRef]

Giljum, Stefan, Arno Behrens, Friedrich Hinterberger, Christian Lutz, and Bernd Meyer. 2008. Modelling scenarios towards a sustainable use of natural resources in Europe. *Environmental Science & Policy* 11: 204–16.

Gliozzo, Elisabetta, Francesca Giannetti, Roberto Goffredo, and Darian Marie Totten. 2022. Late antique glass from Salapia: Tracking production and trading networks. *Archaeometry* 65: 118–35. [CrossRef]

Glogic, Edis, Guido Sonnemann, and Steven B. Young. 2021. Environmental trade-offs of downcycling in circular economy: Combining life cycle assessment and material circularity indicator to inform circularity strategies for alkaline batteries. *Sustainability* 13: 1040. [CrossRef]

Gong, Yuanchao, Yang Li, and Yan Sun. 2023. Waste sorting behaviors promote subjective well-being: A perspective of the self-nature association. *Waste Management* 157: 249–55. [CrossRef]

Govindan, Kannan, and Ramu Sivakumar. 2016. Green supplier selection and order allocation in a low-carbon paper industry: Integrated multi-criteria heterogeneous decision-making and multi-objective linear programming approaches. *Annals of Operations Research* 238: 243–76. [CrossRef]

Gregson, Nicky, and Mike Crang. 2015. From waste to resource: The trade in wastes and global recycling economies. *Annual Review of Environment and Resources* 40: 151–76. [CrossRef]

Handfield, Robert, Steven V. Walton, Robert Sroufe, and Steven A. Melnyk. 2002. Applying environmental criteria to supplier assessment: A study in the application of the Analytical Hierarchy Process. *European journal of Operational Research* 141: 70–87. [CrossRef]

Hanusa, Isabel. 2021. *Opportunities and Challenges for a B2B Trading Platform of Secondary Raw Material: An Exploratory Analysis based on the Sourcing Process of Sustainable SMEs in the Fashion and Textile Industry*. Borås: Högskolan i Borås.

Hawley, Jana M. 2006. Textile recycling: A systems perspective. In *Recycling in Textiles*. Cambridge: Woodhead Publishing Limited.

Heller, Martin C., Michael H. Mazor, and Gregory A. Keoleian. 2020. Plastics in the US: Toward a material flow characterization of production, markets and end of life. *Environmental Research Letters* 15: 094034.

Henderson, Julian, Hongjiao Ma, and Jane A. Evans. 2020. Glass production for the Silk Road? Provenance and trade of Islamic glasses using isotopic and chemical analyses in a geological context. *Journal of Archaeological Science* 119: 105164. [CrossRef]

Hijazi, Omar, Aikins Okyere, and Heinz Bernhardt. 2021. Environmental impacts of E-Waste recycling in Africa. In *2021 ASABE Annual International Virtual Meeting*. St. Joseph: American Society of Agricultural and Biological Engineers, p. 1.

Hojnik, Jana, Mitja Ruzzier, Maja Konečnik Ruzzier, Boris Sučić, and Brandon Soltwisch. 2023. Challenges of demographic changes and digitalization on eco-innovation and the circular economy: Qualitative insights from companies. *Journal of Cleaner Production* 396: 136439. [CrossRef]

Hönnige, Christoph, and Diana Panke. 2016. Is anybody listening? The Committee of the Regions and the European Economic and Social Committee and their quest for awareness. *Journal of European Public Policy* 23: 624–42. [CrossRef]

Hossain, Mehnaz, and Aditi Shams. 2020. Export potential of recycled plastic: A study on Bangladesh. *Asian Social Science* 16: 1–17. [CrossRef]

Hu, Xiaoquian, Chao Wang, Ming K. Lim, and S. C. Lenny Koh. 2020. Characteristics and community evolution patterns of the international scrap metal trade. *Journal of Cleaner Production* 243: 118576. [CrossRef]

Huang, Qiao, Guangwu Chen, Yafei Wang, Shaoging Chen, Lixiao Xu, and Rui Wang. 2020. Modelling the global impact of China's ban on plastic waste imports. *Resources, Conservation and Recycling* 154: 104607. [CrossRef]

Hysa, Eglantina, Alba Kruja, Naqeeb Ur Rehman, and Rafael Laurenti. 2020. Circular economy innovation and environmental sustainability impact on economic growth: An integrated model for sustainable development. *Sustainability* 12: 4831. [CrossRef]

Igogo, Tsisilile A., Debra L. Sandor, Ahmad T. Mayyas, and Jill Engel-Cox. 2019. *Supply Chain of Raw Materials Used in The manufacturing of light-Duty Vehicle Lithiumion Batteries*. Golden: National Renewable Energy Lab.

Ikram, Muhammad. 2022. Transition toward green economy: Technological Innovation's role in the fashion industry. *Current Opinion in Green and Sustainable Chemistry* 37: 100657. [CrossRef]

Ilankoon, I. M. S. K., Yousef Ghorbani, Meng Nan Chong, Gamini Herath, Thandazile Moyo, and Jochen Petersen. 2018. E-waste in the international context–A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. *Waste Management* 82: 258–75. [CrossRef]

Jackson, Caroline, and Sarah Paynter. 2022. Baubles, bangles and beads: Recycling colored glasses in the British Iron Age and Roman periods. *Archaeometry* 64: 150–67. [CrossRef]

Joensuu, Tuomo, Harry Edelman, and Arto Saari. 2020. Circular economy practices in the built environment. *Journal of Cleaner Production* 276: 124215. [CrossRef]

Kemp, René, Fernando J. Diaz Lopez, and Raimund Bleischwitz. 2013. *Report on Green Growth and Eco-Innovation*. Wuppertal: Wupertal Institute for Climate, Environment and Energy.

Kirchherr, Julian. 2022. Circular economy and growth: A critical review of "post-growth" circularity and a plea for a circular economy that grows. *Resources, Conservation and Recycling* 179: 106033. [CrossRef]

Koleini, Farahnaz, Philippe Colomban, Innocent Pikirayi, and Linda C. Prinsloo. 2019. Glass beads, markers of ancient trade in Sub-Saharan Africa: Methodology, state of the art and perspectives. *Heritage* 2: 2343–69. [CrossRef]

Kryshtanovych, Myroslav, Viktorija Filippova, Marina Huba, Olga Kartashova, and Oleksandar Molnar. 2020. Evaluation of the implementation of the circular economy in EU countries in the context of sustainable development. *Business: Theory and Practice* 21: 704–12. [CrossRef]

Lang-Koetz, Claus, Nico Pastewski, and Holger Rohn. 2010. Identifiyng new technologies, products and strategies for resource efficiency. *Chemical Engineering & Technology: Industrial Chemistry-Plant Equipment-Process Engineering-Biotechnology* 33: 559–66.

Leal Filho, Walter, Dawn Ellams, Sara Han, David Tyler, Valérie Julie Boiten, A. Paço, Harri Moora, and A. L. Balogun. 2019. A review of the socio-economic advantages of textile recycling. *Journal of Cleaner Production* 218: 10–20. [CrossRef]

Lebreton, Laurent, and Anthony Andrady. 2019. Future scenarios of global plastic waste generation and disposal. *Palgrave Communications* 5: 1–11. [CrossRef]

Lessard, Jean-Martin, Guillaume Habert, Arezki Tagnit-Hamou, and Ben Amor. 2021. Tracking the Environmental Consequences of Circular Economy over Space and Time: The Case of Close-and Open-Loop Recovery of Postconsumer Glass. *Environmental Science & Technology* 55: 11521–32.

Liang, Yangyang, Quanyin Tan, Qingbin Song, and Jinhui Li. 2021. An analysis of the plastic waste trade and management in Asia. *Waste Management* 119: 242–53. [CrossRef]

Lieder, Michael, and Amir Rashid. 2016. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production* 115: 36–51. [CrossRef]

Loiseau, Eleonore, Laura Saikku, Riina Antikainen, Nils Droste, Bernd Hansjürgens, Kati Pitkänen, Pekka Leskinen, Peter Kuikman, and Marianne Thomsen. 2016. Green economy and related concepts: An overview. *Journal of Cleaner Production* 139: 361–71. [CrossRef]

Lucarini, Massimo, Antonio Zuorro, Gabriella Di Lena, Roberto Lavecchia, Alessandra Durazzo, Barbara Benedetti, and Ginevra Lombardi-Boccia. 2020. Sustainable management of secondary raw materials from the marine food-chain: A case-study perspective. *Sustainability* 12: 8997. [CrossRef]

Luo, Minxin, Xiaoxu Song, Shanuing Hu, and Dingjiang Chen. 2019. Towards the sustainable development of waste household appliance recovery systems in China: An agent-based modeling approach. *Journal of Cleaner Production* 220: 431–44. [CrossRef]

Mancini, Lucia, Beatriz Vidal Legaz, Matteo Vizzarri, Dominic Wittmer, Giacomo Grassi, and David Pennington. 2019. Mapping the role of raw materials in sustainable development goals. *A Preliminary Analysis of Links, Monitoring Indicators, and Related Policy Initiatives* 3: 1–9.

Mayyas, Ahmad, Darlene Steward, and Margaret Mann. 2019. The case for recycling: Overview and challenges in the material supply chain for automotive li-ion batteries. *Sustainable Materials and Technologies* 19: e00087. [CrossRef]

McCollough, John. 2009. Factors impacting the demand for repair services of household products: The disappearing repair trades and the throwaway society. *International Journal of Consumer Studies* 33: 619–26. [CrossRef]

Mesjasz-Lech, Agata, and Pál Michelberger. 2019. Sustainable waste logistics and the development of trade in recyclable raw materials in Poland and Hungary. *Sustainability* 11: 4159. [CrossRef]

Morici, Elisabetta, Sabrina Carola Carroccio, Elena Bruno, Paola Scarfato, Giovanni Filippone, and Nadka Tz. Dintcheva. 2022. Recycled (Bio) Plastics and (Bio) Plastic Composites: A Trade Opportunity in a Green Future. *Polymers* 14: 2038. [CrossRef] [PubMed]

Moslehpour, Massoud, Afrizal Firman, Chen-Hsien Lin, İsmail Bilgiçli, Trung Kien Tran, and Tran Thai Ha Nguyen. 2023. The moderating impact of government support on the relationship between tourism development and growth, natural resources depletion, sociocultural degradation, economic environment, and pollution reduction: Case of Indonesian economy. *Environmental Science and Pollution Research* 30: 56863–78. [CrossRef]

Navarre, Nicolas, José M. Mogollón, Arnold Tukker, and Valerio Barbarossa. 2022. Recycled plastic packaging from the Dutch food sector pollutes Asian oceans. *Resources, Conservation and Recycling* 185: 106508. [CrossRef]

Ncube, Lindani Koketso, Albert Uchenna Ude, Enoch Nifise Ogunmuyiwa, Rozli Zulkifli, and Isaac Nongwe Beas. 2021. An overview of plastic waste generation and management in food packaging industries. *Recycling* 6: 12. [CrossRef]

Neri, Elisabetta, Bernard Gratuze, and Nadine Schibille. 2019. The trade of glass beads in early medieval Illyricum: Towards an Islamic monopoly. *Archaeological and Anthropological Sciences* 11: 1107–22. [CrossRef]

Nicolli, Francesco, Nick Johnstone, and Patrik Söderholm. 2012. Resolving failures in recycling markets: The role of technological innovation. *Environmental Economics and Policy Studies* 14: 261–88. [CrossRef]

Nilsson, Lennart. 2007. *Cleaner Production: Technologies and Tools for Resource Efficient Production*. Uppsala: Baltic University Press, vol. 2.

Norris, Lucy. 2012. Trade and transformations of secondhand clothing: Introduction. *Textile* 10: 128–43. [CrossRef]

Norris, Lucy. 2019. Waste, dirt and desire: Fashioning narratives of material regeneration. *The Sociological Review* 67: 886–907. [CrossRef]

OECD. 2018. *International Trade and the Transition to a Circular Economy*. Paris: OECD Publishing.

Ohno, Hajime, Kazuyo Matsubae, Kenichi Nakajima, Yasushi Kondo, Shinichiro Nakamura, Yasuhiro Fukushima, and Tetsuya Nagasaka. 2017. Optimal recycling of steel scrap and alloying elements: Input-output based linear programming method with its application to end-of-life vehicles in Japan. *Environmental Science & Technology* 51: 13086–94.

Paço, Arminda, Walter Leal Filho, Lucas V. Ávila, and Karen Dennis. 2021. Fostering sustainable consumer behavior regarding clothing: Assessing trends on purchases, recycling and disposal. *Textile Research Journal* 91: 373–84. [CrossRef]

Paksoy, Turan, Eren Özceylan, and Gerhard-Wilhelm Weber. 2010. A multi objective model for optimization of a green supply chain network. *AIP Conference Proceedings* 1239: 12.

Paletta, Angelo. 2019. Rethinking Economics in a Circular Way in the Light of Encyclical "Laudato Sì". In *Sustainability and the Humanities*. Cham: Springer, pp. 339–57.

Pao, Hsiao-Tien, and Chun-Chih Chen. 2022. The dynamic interaction between circular economy and the environment: Evidence on EU countries. *Waste Management & Research* 40: 969–79.

Pati, Rupesh Kumar, Prem Vrat, and Pradeep Kumar. 2006. Economic analysis of paper recyclingIs wood as raw material. *International Journal of Production Economics* 103: 489–508. [CrossRef]

Pensupa, Nattha, Shao-Yuan Leu, Yunzi Hu, Chenyu Du, Hao Liu, Houde Jing, Huaimin Wang, and Carlos Sze Ki Lin. 2017. Recent trends in sustainable textile waste recycling methods: Current situation and future prospects. *Chemistry and Chemical Technologies in Waste Valorization* 189–228.

Person, Caroline. 2011. *Predicting Recycling Efficiency-Multiple Regression Modeling of the Recycling Rates of Tetra Pak's Beverage Cartons*. Lund: Lund University Publications.

Petridis, Nikolaos E., Konstantinos Petridis, and Emmanouil Stiakakis. 2020. Global e-waste trade network analysis. *Resources, Conservation and Recycling* 158: 104742. [CrossRef]

Plank, Barbara, Jan Streeck, Doris Virág, Fridolin Krausmann, Helmut Haberl, and Dominik Wiedenhofer. 2022. Compilation of an economy-wide material flow database for 14 stock-building materials in 177 countries from 1900 to 2016. *MethodsX* 9: 101654. [CrossRef] [PubMed]

Rabiu, Mubarik K., and Melanie Jaeger-Erben. 2022. Appropriation and routinization of circular consumer practices: A review of current knowledge in the circular economy literature. *Cleaner and Responsible Consumption* 7: 100081. [CrossRef]

Rajak, Sonu, K. E. K. Vimal, Sricharan Arumugam, Jagadesan Parthiban, Swesh Kannan Sivaraman, Jayakrishna Kandasamy, and Angel Acevedo Duque. 2022. Multi-objective mixed-integer linear optimization model for sustainable closed-loop supply chain network. *Environment, Development and Sustainability* 24: 6481–507. [CrossRef]

Rathore, Gayatri Jai Singh. 2020. Circulating waste, circulating bodies? A critical review of E-waste trade. *Geoforum* 110: 180–82. [CrossRef]

Risch, Benno W. K. 1978. The raw material supply of the European Community: The importance of secondary raw materials. *Resources Policy* 4: 181–88. [CrossRef]

Sáez-Martínez, Francisco J., Cristina Díaz-García, and Ángela González-Moreno. 2016. Factors promoting environmental responsibility in European SMEs: The effect on performance. *Sustainability* 8: 898. [CrossRef]

Sandin, Gustav, and Greg M. Peters. 2018. Environmental impact of textile reuse and recycling—A review. *Journal of Cleaner Production* 184: 353–65. [CrossRef]

Sasaki, So. 2021. Controlling an Invisible Flow of Product Reuse: The Current State of International Reuse of Used Household Appliances in Thailand and Japan. In *International Trade of Secondhand Goods*. Cham: Palgrave Macmillan, pp. 173–94.

Schröder, Patrick, Magnus Bengtsson, Maurie Cohen, Paul Dewick, Joerg Hofstetter, and Joseph Sarkis. 2019. Degrowth within: Aligning circular economy and strong sustainability narratives. *Resources, Conservation and Recycling* 146: 190–91. [CrossRef]

Schultz, Felix Carl. 2022. The circular economy and economic growth–An irreconcilable tradeoff? *Resources, Conservation and Recycling* 183: 106351. [CrossRef]

Schultz, Felix Carl, and Ingo Pies. 2023. The circular economy growth machine—A critical perspective on "post-growth" and "pro-growth" circularity approaches. *Journal of Industrial Ecology* 2023: 1–8. [CrossRef]

Schultz, Felix Carl, and Robert Jaroslav Reinhardt. 2023. Technological Challenges and Opportunities to Plastics Valorization in the Context of a Circular Economy in Europe. *Sustainability* 15: 3741. [CrossRef]

Sehnem, Simone, Diego Vazquez-Brust, Susana Carla Farias Pereira, and Lucila M. Campos. 2019. Circular economy: Benefits, impacts and overlapping. *Supply Chain Management: An International Journal* 24: 784–804. [CrossRef]

Shamim, Ahsan, Ali K. Mursheda, and Islam Rafiq. 2015. E-waste trading impact on public health and ecosystem services in developing countries. *Journal Waste Resources* 5: 1–18. [CrossRef]

Shamsdini, Seyed Amir Reza, Sajad Shakerin, Amir Hadadzadeh, Babak Shalchi Amirkhiz, and Mohsen Mohammadi. 2020. A trade-off between powder layer thickness and mechanical properties in additively manufactured maraging steels. *Materials Science and Engineering* 776: 139041. [CrossRef]

Shigetomi, Yosuke, Keisuke Nansai, Shigemi Kagawa, and Susumu Tohno. 2015. Trends in Japanese households' critical-metals material footprints. *Ecological Economics* 119: 118–26. [CrossRef]

Shih-Hsiung, Cheng, Shih Ming Ou, and Su-Mei Lin. 2018. Using decision-making trial and evaluation laboratory (DEMATEL) to explore the key success factors for green logistics manufacturers. *African Journal of Business Management* 12: 58–65.

Shinkuma, Takayoushi, and Nguyen Thi Minh Huong. 2009. The flow of E-waste material in the Asian region and a reconsideration of international trade policies on E-waste. *Environmental Impact Assessment Review* 29: 25–31. [CrossRef]

Shittu, Olanrewaju S., Ian D. Williams, and Peter J. Shaw. 2021. Global E-waste management: Can WEEE make a difference? *Waste Management* 120: 549–63. [CrossRef]

Shooshtarian, Salman, Savindi Caldera, Tayyab Maqsood, Tim Ryley, Peter S. P. Wong, and Atiq Zaman. 2022. Analysis of factors influencing the creation and stimulation of the Australian market for recycled construction and demolition waste products. *Sustainable Production and Consumption* 34: 163–76. [CrossRef]

Siman, Renato Ribeiro, Liuciana Harue Yamane, Roquemar de Lima Baldam, Juliana Pardinho Tackla, Sarina Francisca de Assis Lessa, and Piscila Mendonça de Britto. 2020. Governance tools: Improving the circular economy through the promotion of the economic sustainability of waste picker organizations. *Waste Management*, 148–69. [CrossRef]

Skare, Marinko, Beata Gavurova, and Martin Rigelsky. 2023. Income inequality and circular materials use: An analysis of European Union economies and implications for circular economy development. *Management Decision*, *ahead-of-print*.

Smol, Marzena, Paulina Marcinek, Joanna Duda, and Dominika Szołdrowska. 2020. Importance of sustainable mineral resource management in implementing the circular economy (CE) model and the european green deal strategy. *Resources* 9: 55. [CrossRef]

Söderholm, Patrik, and Tomas Ekvall. 2020. Metal markets and recycling policies: Impacts and challenges. *Mineral Economics* 33: 257–72. [CrossRef]

Sommerville, Roberto, Pengcheng Zhu, Mohammad Ali Rajaeifar, Oliver Heidrich, Vanessa Goodship, and Emma Kendrick. 2021. A qualitative assessment of lithium-ion battery recycling processes. *Resources, Conservation and Recycling* 165: 105219. [CrossRef]

Song, Jiali, Wenyi Yan, Hongbin Cao, Qingbin Song, He Ding, Zheng Lv, Yi Zhang, and Zhi Sun. 2019. Material flow analysis on critical raw materials of lithium-ion batteries in China. *Journal of Cleaner Production* 215: 570–81. [CrossRef]

Stone, Catherine, Fredric M. Windsor, Max Munday, and Isabelle Durance. 2020. Natural or synthetic–how global trends in textile usage threaten freshwater environments. *Science of the Total Environment* 718: 134689. [CrossRef] [PubMed]

Sugeta, Hajime, and Takayoshi Shinkuma. 2012. International trade in recycled materials in vertically related markets. *Environmental Economics and Policy Studies* 14: 357–82. [CrossRef]

Sun, Xin, Han Hao, Zongwei Liu, Fuquan Zhao, and Junnan Song. 2019. Tracing global cobalt flow: 1995–2015. *Resources, Conservation and Recycling* 149: 45–55. [CrossRef]

Taheri, Farid, and Babak Farhang Moghaddam. 2022. A heuristic-based hybrid algorithm to configure a sustainable supply chain network for medical devices considering information-sharing systems. *Environmental Science and Pollution Research* 29: 91105–26. [CrossRef]

Theis, Nicholas. 2021. The global trade in e-waste: A network approach. *Environmental Sociology* 7: 76–89. [CrossRef]

Tong, Yen Dan, Thi Dan Xuan Huynh, and Tien Dung Khong. 2021. Understanding the role of informal sector for sustainable development of municipal solid waste management system: A case study in Vietnam. *Waste Management* 124: 118–27. [CrossRef] [PubMed]

Van Beukering, Pieter J. H., and Mathijs N. Bouman. 2001. Empirical evidence on recycling and trade of paper and lead in developed and developing countries. *World Development* 29: 1717–37. [CrossRef]

Van der Ven, Colette Marie Anne. 2020. The Circular Economy, Trade, and Development: Addressing Spillovers and Leveraging Opportunities. Paper presented at Trade, and Development: Addressing Spillovers and Leveraging Opportunities, Geneva, Switzerland, July 8.

Van Ruijven, Bas J., Detlef P. Van Vuuren, Willem Boskaljon, Maarten L. Neelis, Degen Saygin, and Martin K. Patel. 2016. Long-term model-based projections of energy use and CO_2 emissions from the global steel and cement industries. *Resources, Conservation and Recycling* 112: 15–36. [CrossRef]

Vazquez-Brust, Diego A., and Joseph Sarkis. 2012. *Green Growth: Managing the Transition to Sustainable Economies*. Dordrecht: Springer, pp. 1–25.

Vedantam, Aditya, Nallan C. Suresh, Khadija Ajmal, and Michael Shelly. 2022. Impact of China's National Sword Policy on the US Landfill and Plastics Recycling Industry. *Sustainability* 14: 2456. [CrossRef]

Veličković, Dragan T., Dragan M. Milenović, Mihailo S. Ristić, and Vlada B. Veljković. 2008. Ultrasonic extraction of waste solid residues from the *Salvia* sp. Essential oil hydrodistillation. *Biochemical Engineering Journal* 42: 97–104. [CrossRef]

Wagner, Florian, Ellen Bracquene, Eduard Wagner, Jozefien De Keyzer, Joost Duflou, Wim Dewulf, and Jeff R. Peeters. 2020. Grading system for post-consumer recycled plastics from WEEE. Paper presented at Proceedings Electronics Goes Green Congress, Online, September 1.

Walker, Anna M., Katelin Opferkuch, Erik Roos Lindgreen, Andrea Raggi, Alberto Simboli, Walter J. V. Vermeulen, Sandra Caeiro, and Roberta Salomone. 2022. What is the relation between circular economy and sustainability? Answers from frontrunner companies engaged with circular economy practices. *Circular Economy and Sustainability* 2: 731–58. [CrossRef] [PubMed]

Wang, Allen, Li-Chih Wang, and Yi-Wen Chen. 2015. A Particle Swarm Optimization Approach for Solar Cell Industry Multi-Stage Closed-Loop Supply Chain Model. In *Toward Sustainable Operations of Supply Chain and Logistics Systems*. Cham: Springer, pp. 445–59.

Wang, Junbo, Yiyi Ju, Minxi Wang, and Xin Li. 2019. Scenario analysis of the recycled copper supply in China considering the recycling efficiency rate and waste import regulations. *Resources, Conservation and Recycling* 146: 580–89. [CrossRef]

Wang, Chao, Langfeng Zhao, Ming K. Lim, Wei-Qiang Chen, and John W. Sutherland. 2020. Structure of the global plastic waste trade network and the impact of China's import Ban. *Resources, Conservation and Recycling* 153: 104591. [CrossRef]

Wath, Sushant B., Atul N. Vaidya, P. S. Dutt, and Tapan Chakrabarti. 2010. A roadmap for development of sustainable E-waste management system in India. *Science of the Total Environment* 409: 19–32. [CrossRef]

Wen, Zongguo, Yiling Xie, Muhan Chen, and Christian Doh Dinga. 2021. China's plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide. *Nature Communications* 12: 1–9. [CrossRef]

Westmorland and Furness Council. 2023. Trade Waste and Recycling. Available online: https://www.southlakeland.gov.uk/bins-and-recycling/trade-waste-and-recycling/ (accessed on 7 April 2023).

Wiedenhofer, Dominik, Tomer Fishman, Christian Lauk, Willi Haas, and Fridolin Krausmann. 2019. Integrating material stock dynamics into economy-wide material flow accounting: Concepts, modelling, and global application for 1900–2050. *Ecological Economics* 156: 121–33. [CrossRef]

Xu, Zhitao, Adel Elomri, Shaligram Pokharel, Qin Zhang, X. G. Ming, and Wenjie Liu. 2017. Global reverse supply chain design for solid waste recycling under uncertainties and carbon emission constraint. *Waste Management* 64: 358–70. [CrossRef]

Xu, Helian, Lianyue Feng, Gang Wu, and Qi Zhang. 2021. Evolution of structural properties and its determinants of global wastepaper trade network based on temporal exponential random graph models. *Renewable and Sustainable Energy Reviews* 149: 111402. [CrossRef]

Yamaguchi, Shunta. 2018. *International Trade and the Transition to a More Resource Efficient and Circular Economy: A Concept Paper*. Paris: OECD Publishing.

Yang, Guang, Chuanbin Zhou, Wenlai Wang, Shijun Ma, Hongju Liu, Yijie Liu, and Zhilan Zhao. 2020. Recycling sustainability of wastepaper industry in Beijing City: An analysis based on value chain and GIS model. *Waste Management* 106: 62–70. [CrossRef]

Yeow, Paul H. P., and Wee Hong Loo. 2018. Determinants of Consumer Behavior Regarding Reusing, Refurbishing, and Recycling Computer Waste: An Exploratory Study in Malaysia. *International Journal of Business & Information* 13: 201022973.

Yoshida, Aya. 2013. Recyclable waste trade of mainland China. In *International Trade in Recyclable and Hazardous Waste in Asia*. Cheltenham: Edward Elgar Publishing.

Yoshida, Aya. 2022. China's ban of imported recyclable waste and its impact on the waste plastic recycling industry in China and Taiwan. *Journal of Material Cycles and Waste Management* 24: 73–82. [CrossRef]

Yuan, Qing-Song. 2022. The current status, problems, and development strategies of country's wood forest products trade under the double cycle pattern. Paper presented at 2nd International Conference on New Computational Social Science, Suzhou, China, October 15–17; p. 248.

Zhang, Chunbo, Mingming Hu, Liang Dong, Abraham Gebremariam, Brenda Miranda-Xicotencatl, Francesco Di Maio, and Arnold Tukker. 2019. Eco-efficiency assessment of technological innovations in high-grade concrete recycling. *Resources, Conservation and Recycling* 149: 649–63. [CrossRef]

Zhang, Chunbo, Mingming Hu, Francesco Di Maio, Benjamin Sprecher, Xining Yang, and Arnold Tukker. 2022. An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. *Science of the Total Environment* 803: 149892. [CrossRef] [PubMed]

Zhou, Jieyu, Peng Jiang, Jin Yang, and Xiao Liu. 2021. Designing a smart incentive-based recycling system for household recyclable waste. *Waste Management* 123: 142–53. [CrossRef] [PubMed]