Article

Core elements towards circularity: evidence from the European countries

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Abstract: In this paper, the authors identified key elements important for circularity: (1) Background: The primary goal of circularity is to eliminate waste and to prove the constant use of resources. In the paper, we classify studies according to circular approaches. The authors identified main elements and classified them into categories important for circularity, starting with the managing and reducing waste and the recovery of resources; and ending with the circularity of material, and general circularity-related topics and presented scientific works dedicated to each of the above-mentioned categories. The authors analyzed several core elements from the first category aiming to investigate and connect different waste streams and provided a regression model; (2) Methods: The authors used a dynamic regression model to identify relationships among variables and selected the ones, which has an impact on the increase of biowaste. The research was delivered for the 27 European Union countries during the period between 2020 and 2019; (3) Conclusions: The authors indicated that the recycling rate of wasted electrical equipment in the previous year has an impact on the increase of recycling biowaste next year. This is explained as non-metallic spare parts of electronic equipment are used as biowaste for fuel production. And the separation process of the composites of electric equipment takes some time, on average the effect is evident in one year period.

Keywords: circularity; waste streams; circular approaches; regression equation

1. Introduction

Excessive use of natural resources, which are essential for economic growth and development, has harmed the environment while making these resources rarer and more expensive [1, 2]. Therefore, it is not difficult to see why the idea of a circularity, which offers new ways to create a more sustainable model of economic growth, is taking hold around the world.

An early approach towards practical sustainability was envisioned and demonstrated as the saving of resources, the prevention of waste and the extension of product shelf life [3–6]. The recycling agenda requires the industry to restructure its processes towards sustainability. Case examples are proving the interlink between recycling and sustainability [7–10]. These examples are summarizing and demonstrating successful implementation by some companies from the production industry, like Hewlett Packard and Low carbon industrial manufacturing park (LOCI-MAP), etc. and study, which investigates the effect on environmental and socio-economic conditions, to investigate sustainable development [11–13].

A perfect circularity with 100% efficient material use cannot exist due to physical and practical limitations in material recycling [14–17]:

- Material turnover requires energy costs and impacts on the environment. These effects can sometimes outweigh the effects of primary production. In any case, the impact of energy use should not go beyond environmental protection.

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- Materials cannot be required to be recycled or reused in the long term. For example, steel in buildings cannot be reused for many years. Therefore, material demand cannot be met.
- Demand for most products is growing as the economy grows. Even the perfect material turnover is not enough to meet the growing demand.
- Material turnover includes inherent processing losses. Materials can also lose quality or be contaminated. Even with stable demand, additional raw materials are needed.
- The supply of recycled raw materials is not in line with demand. Due to technological changes or lack thereof, substances that can only be obtained from pure extraction may be preferred.

These constraints mean that recycling and recycling efficiency alone is not enough to achieve sustainable yields. The more efficient use of materials can also have repercussions, as cheaper raw materials could lead to lower prices and stimulate higher consumption [13,18]. Where higher consumption requires energy, production has an impact on the environment [19, 20].

The efficient use of resources could help to protect the environment but may hamper economic growth or vice versa. So, the modelling will help to define these boundaries [21].

Compared to the linear scheme, the circularity is a more complex system [22–24] Complexity arises from material stocks, return flows and their management in different countries, as well as resource planning, logistics and recycling management, coordination of multi-level network activities, physical and information flow between network partners [25–28].

The study consists of three parts—the review of scientific studies and the identification of main elements important for circularity are presented at the beginning of the study. Further on, the authors presented methodology. Following the methodology, the authors revised core elements actual for circularity by applying regression analysis. Seeking practical investigations, the authors revised the data of European countries. Based on the analysis, the authors constructed a set of regression equations to describe circularity. Finally, discussion and conclusion sections are provided.

2. Literature review on circularity

The changing economic environment (the program of the European Commission's Communication "Creating a circular economy. A Europe without waste") and changes in the business organization processes themselves lead to changes in the fields of materials extraction, production, marketing, and recycling [29, 30]. Keeping this in mind, many companies are modernizing and reorganizing traditional supply chains and moving from "linear" to "circular", thus reducing the consumption of material resources and energy, as well as the amount of waste generated [31–33].

The emergence of the circularity is a natural evolutionary process, but new challenges are now being encountered, such as the seamless (no-fragmented) arrangement and aggregation of relevant functional activities over time to ensure a continuous and closed cycle of "raw material-product-waste" movements [34]. In the long run, circularity protects the world dependence on natural resources and delivers benefits to society by absorbing emissions and waste through increased material circulation and stayed limits of the natural environment [35–37].

The cycles of extraction, production and consumption of products are shortened, which results in a faster cycle of material flows, including the collection, sorting, and recycling of used products [38, 39]. The research theme responds to the European Union (EU) research priorities in Horizon 2020, which emphasizes the need to increase the lifespan of goods, the re-use of materials, the recovery of resources using harmful technologies and the need to focus on the duration of resources over-exploitation [40]. The private sector and industry, which have a public commitment to ensure that recycled materials account for a certain proportion of products placed on the market, will play a key role in shaping demand. The private sector will have to implement the solutions that are most appropriate given the extended life cycle of the product [41–43].

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The circular scheme links traditional linear processes with product return processes involving product recovery, product recycling, dismantling, and reuse of recycled products [44]. The statement "recyclable" means that the materials can be reused. However, this reuse can be applied to just about anything, from converting used plastics to new containers we see on the roadside or burning. Thus, "recycling" is a very broad term covering less desirable forms of re-use, such as substandard standards and even incineration [4, 45, 46]. The components and materials are used for enhancing maintenance, reuse, remanufacture and recycle.

Manufacturers talking about tank design say something more specific. They say that new containers can be used from used container materials or that the material is suitable for similar purposes [47]. Incineration and low-quality adaptation are not possible. These manufacturers are paving the way to circularity. According to the authors [48-51], the optimised use of resources is reached by having the circularity of products.

Therefore, increasing recycling rates is vital to reach a circularity. European Commission is setting new targets on waste management - to increase the share of municipal waste for recycling to 70% and prepare packaging waste for recycling up to 80%. In this context, the European Commission (EC) has set a 50% recycling target for all the plastic packaging waste collected by 2025 and 55% by 2030 [5, 52]. The waste management hierarchy indicates the order of priority for waste reduction and management. The goal of the waste management hierarchy is to maximize the practical benefits of the products and to generate as little waste as possible. This delivers some benefits, it can help prevent greenhouse gas emissions, reduce pollution, save energy, save resources, create jobs and encourage the development of green technologies.

When products are recycled, repaired, or reused, employment is generated, and when waste from one process is used as an input into others, efficiency and productivity gains are achieved [53].

Savings of resources depend on how quickly products are collected from consumers, reach recycling sites, and how quickly they are processed. The shorter duration of the processes also leads to a lower need for material (and natural) resources [19, 21, 54].

Products and services are rethought in the implementation of circular solutions based on durability, recyclability, reusability, repair, replacement, renewal, upgrading and reduced use of materials [6, 31]. To avoid waste, increase resource productivity and decouple growth from natural resource consumption, companies need to apply these principles [37, 42].

Circularity contributes by increasing resource efficiency and reducing environmental impact [55–57]. This can be achieved by applying or enabling one or more in line with the main circular approaches, which were first mentioned by the European Commission in 2006 and consisted reuse (R3), recycle (R8) and recover (R9). Later on, due to high critics, more circular approaches were presented [54].

The authors revised the literature and classified the studies according to these approaches (R0-R9) and mentioned them in Table 1. The authors indicated 22 different combinations covering different circular approaches in 65 studies. The most of authors focus on the 8th combination, which includes 7R: reduce (R2), reuse (R3), repair (R4), refurbish (R5), remanufacture (R6), recycle (R8), and recover (R9). All circular approaches are indicated under the 2nd combination, which is provided by seven studies.

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Table 1. The classification of studies according to circular approaches

No	Authors	Circular approaches									
		Smarter production			End of life extend					Application of materials	
		R0 Refuse	R1 Rethink	R2 Reduce	R3 Reuse	R4 Repair	R5 Refurbish	R6 Remanufacture	R7 Repurpose	R8 Recycle	R9 Recover
1.	[3, 6, 14, 29, 36, 43, 51, 64, 65, 69, 79]			x	x					x	x
2.	[9, 20, 24, 35, 58, 66, 70]	x	x	x	x	x	x	x	x	x	x
3.	[17, 57, 67]			x	x	x	x	x	x	x	x
4.	[22, 48, 50, 56, 61, 68]			x	x			x		x	x
5.	[21, 58]			x	x	x	x			x	x
6.	[60, 63]			x	x	x		x		x	x
7.	[10, 13, 16]			x	x	x				x	x
8.	[7, 12, 15, 18, 34, 40, 41, 42, 44, 48, 53, 59, 73, 74]			x	x	x	x	x		x	x
9.	[19]		x	x	x	x	x			x	
10.	[55]			x	x		x		x	x	x
11.	[26]			x		x		x		x	x
12.	[27]			x	x	x			x	x	x
13.	[37, 75]			x	x		x	x		x	x
14.	[23]		x	x	x	x				x	x
15.	[38]		x	x		x				x	x
16.	[39]			x						x	x
17.	[28]		x	x	x		x			x	x
18.	[25, 76]		x	x	x	x	x	x		x	x
19.	[72]			x	x	x				x	
20.	[77, 78]				x					x	x
21.	[45]		x	x			x			x	x
22.	[79]			x						x	

According to the study, some circular approaches get higher attention and some of them – lower attention. Most of the authors focus on recycling (R8), reduce (R2), and recover (R9) in their studies. However, the lowest attention among authors gets rethink (R1), re-purpose (R7), and refuse (R0) circular approaches. To achieve circularity higher focus is required to R7, which belongs to the end-of-life extend approach.

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3. Core elements important for circularity

To develop a literature review of circularity, we will review the dominant elements. The academic literature provides a comprehensive overview [58–60]. The authors indicated key elements mentioned under literature review and grouped them into four main categories: managing and reducing waste, resource recovery, material circularity, general circular. These categories are selected as representing a high circularity level. General circular covers best practices for delivering value following environmental and social aspects and new business models supporting circularity. The other three categories (i.e., managing and reducing waste, resource recovery, material circularity) represent circularity with efficient material use, which is a longer period could help to reach a faster circulation cycle for materials from consumption back to production.

The first type - waste management is examined by different authors according to the types of the policy package. It is particularly important that packagers are aligned with strategic ones economic and industrial policy, as the industrial waste sector is one of those who dictate change from linearity to circularity [61, 62].

The 48 authors examine basic waste management, with applies typical policy measures such as basic provision for public service management of wastes through landfilling or burning. The 14 authors describe the characteristic of waste hierarchy apply to typical policy instruments, a fast link between waste management and resource use, as the implementation of it. In many areas, progress has been noted mainly in the recycling of industrial and organic waste [63, 64]. The authors emphasize that companies that want to reduce municipal waste must focus on consumers and forms of consumption [65, 66]. For example, reuse, reduce and recycle, we must effectively promote the need to change certain consumer behaviour [19] and to have a substantial waste reduction, through prevention, reduction, recycling [27, 34, 54, 67].

The second type - resource recovery is promoted by the United Nations and the Organization for Economic Co-operation and Development [71]. Alhawari et al. performed a literature review of a double loop regeneration system that focus is on the efficient and effective use of ecosystem resources, which is beneficial optimization of environmental and economic activities.

The third type - the material circularity considers recycled content in the product together with the waste (linear flow) and usefulness of the product (expressed over a lifetime) [24, 68, 69]. Garcés-Ayerbe et al. and Moraga et al., [23, 35] make a point of change in the concept of end-of-life by the life cycle of restoration and closed-loop products and want to eliminate waste, maintain the value of products and materials, promote their use of renewable energy and remove toxic chemicals. In current production and consumption practices, the "end of life" is being replaced by reducing, reusing, and recycling processes in the production, distribution and consumption of products and materials.

The fourth type – topics under general circular revise circular business models and value creation. A circular business model revises the logic of how a company generates value for its customers by reducing the environmental effect. The circular business model is different from a linear one and follows the logic of designing products without waste and pollution, storing used products and materials, and restoring natural systems.

Following the above-stated studies, the authors identified main categories closely interlinked with circularity (Table 2). Each category includes elements identified in studies and significant for circularity. The first category focuses on waste, waste streams, and waste reduction. The second category concentrates on the resources and their recovery; the third category - on the circularity of materials; and the last category - on very general topics. These categories are the key for circularity, which begins from waste-related questions that discuss the treatment of waste indicated as a resource. Later, the resource is recovered and used to its full potential. After its usage, product and package should be separately collected keeping the circulation of high-quality materials.

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Table 2. The classification of studies into elements and categories describing circularity.

Categories	Elements	Authors
1. Managing and reducing waste	Municipal waste	[2, 10, 13, 16, 18, 19, 22, 25, 27, 28, 29, 35, 45, 62, 65, 70, 77, 80]
	Waste reduction	[18, 20, 24, 27, 38, 40, 41, 55, 67, 76, 78, 79, 80]
	Waste recycling	[8, 10, 13, 18, 25, 27, 29, 35, 36, 37, 41, 51, 53, 53, 63, 66, 69, 75, 78]
	Impact of waste emission	[13, 24, 26, 40, 42, 48, 58]
	Waste hierarchy	[2, 14, 24, 28, 29, 45, 49, 53, 55, 57, 67, 80]
	Waste management	[2, 9, 10, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 25, 28, 29, 34, 35, 36, 37, 39, 40, 41, 42, 43, 45, 52, 53, 57, 59, 61, 62, 66, 68, 69, 70, 73, 76, 77, 78, 80]
	Industrial level waste	[10, 13, 18, 20, 21, 37, 57, 62, 66, 69, 76]
	Zero waste concept	[6, 9, 17, 18, 20, 21, 25, 34, 39, 48, 5763, 68, 77, 78]
2. Resource recovery	Resource-centred dimension	[6, 9, 15, 17, 20, 24, 25, 27, 28, 34, 38, 39, 40, 43, 48, 52, 58, 60, 69, 72, 74, 76]
	Scale/levels (micro, meso, macro)	[6, 7, 9, 10, 12, 13, 14, 17, 18, 27, 35, 53, 58, 61, 63, 67, 74]
	Resource productivity	[6, 9, 13, 17, 19, 25, 37, 39, 57, 60, 69]
	Resource recovery	[2, 3, 9, 14, 16, 18, 20, 22, 27, 29, 43, 45, 48, 51, 52, 53, 57, 63, 75, 77, 78]
	Savings of natural resources	[9, 10, 15, 17, 23, 27, 34, 39, 40, 48, 55, 57, 58, 60, 61, 62, 63, 67, 68]
3. Material circularity and its indicators	Resource/material circularity,	[3, 6, 9,13, 15, 18, 22, 25, 34, 37, 40, 43, 44, 57, 62, 67, 72]
	End-of-life concept	[3, 6, 9, 10,13, 17, 18, 20, 23, 24, 25, 28, 34, 35, 40, 42, 44, 53, 55, 62, 67, 68, 77]
	Material reutilization score	[6, 63, 72]
	Remanufacturing product	[8, 9, 15, 20, 22, 25, 40, 44, 51, 53]
	Recycling indices	[8, 17, 18, 20, 28, 29, 35, 45, 51, 52, 53, 73]
	Recycling rate of final products	[2, 7, 8, 9, 18, 19, 22, 28, 29, 35, 42, 45, 48, 51, 52, 53, 57, 66, 69, 73, 77, 79, 80]
	Recyclable raw materials	[2, 8, 13, 16, 17, 21, 27, 35, 37, 51, 63, 69, 73, 74]
	Recycling rate of industry	[3, 22, 73, 77, 78]
	Industry-specific indicator	[9, 20, 36, 55]
	Technical and biological cycles	[9, 28, 35, 37, 68]
4. General circular	Circular business model	[6, 7, 9, 10, 13, 15, 17, 19, 20, 24, 25, 34, 35, 36, 44, 56, 58, 62, 63, 73, 76]
	Value chains	[2, 3, 6, 9, 16, 17, 18, 21, 25, 27, 38, 44, 48, 53, 56, 58, 61, 72, 74, 75, 76, 77, 80]
	Sustainability approach	[9, 10, 17, 21, 24, 34, 36, 39, 41, 43, 55, 60, 62, 66, 67, 69, 73]
	Environmental efficiency	[9, 18, 24, 25 26, 34, 36, 42, 68, 69]

Table 2, indicate that authors are less concerned with the evaluation of recycling and composting options to manage waste, and the assessment of waste quality, which play an important role in circularity.

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4. Materials and Methods

The circularity is quite a complex and developing process [72]. This complexity is evident also in Table 2. The study aims to identify priorities and managerial aspects important for circularity and revise real situations, helping to figure out the effective actions important for decision making.

Decisions are made by applying different factors, such as:

- The infrastructure important for circularity;
- The revision of management priorities;
- The analysis of current situations and correction of actions.

The authors divided the review of circularity options into two layers and provided theoretical and practical revision under Table 3.

Table 3. The two-layer methodology supporting the review of circularity options.

The layers for review	Relation with circularity	Description of elements by stages	Methodological background	Output
The background of circularity [73, 74]	The cycle is covering stages from (1) the production of products, (2) consumption by households and industries, (3) to the management of waste, (4) the distribution of raw materials to the secondary market, (5) provision of high-quality materials to primary market	• Smarter production • End of life extension • Management of waste • Resource recovery • Application and circulation of materials	• Literature review • Classification of studies into the categories and the review of key elements	Supporting and indicating conditions that are different from linearity and focus on environmental sustainability
The review of recycling aspect in waste management [75–80]	The basic waste hierarchy prioritises the most effective solutions for waste management. There are many alternatives identified which are combined with recycling, such as re-usage, re-production, repairment, etc.	• Avoid surplus • Re-use surplus • Recycle different waste streams • Recover resources • Use disposal	• The revision of recycling trends and evaluation of variables having an impact on recycling rate and the construction of dynamic regression equation	The single way to reduce waste levels is the increase of recycling guaranteeing the recovery of resources

Below the authors provided practical research of real situations covering the revision of two elements from the first category (municipal waste and waste recycling) and waste streams, which could be separated into:

- municipal waste;
- mineral waste;
- package waste;
- biowaste;
- electronic waste (e-waste);
- construction waste.

The waste streams of mineral and construction waste were not revised during empirical research due to the low amount of provided data sets for EU countries.

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4.1 The revision of variables

The authors seek to revise the main factors for constructing a new regression model. The authors selected data from the Eurostat database for a period 2000-2019 for 27 EU countries. To identify main relationships the authors revised 13 variables and identifies the significance of defined correlation. Later, variables that were statistically not significant were taken away, and the construction of the regression equation step was used only for the ones that detected as significant.

The authors of this paper applied the dynamic regression model, which was the first time applied by Petris et al. [81]**.** The first step under the model construction procedure was the transformations of time series helping to identify the dependent variable and its links with the regressors. The constructed model meets the requirements important for the construction of a simple regression model but presents dynamic interlinks.

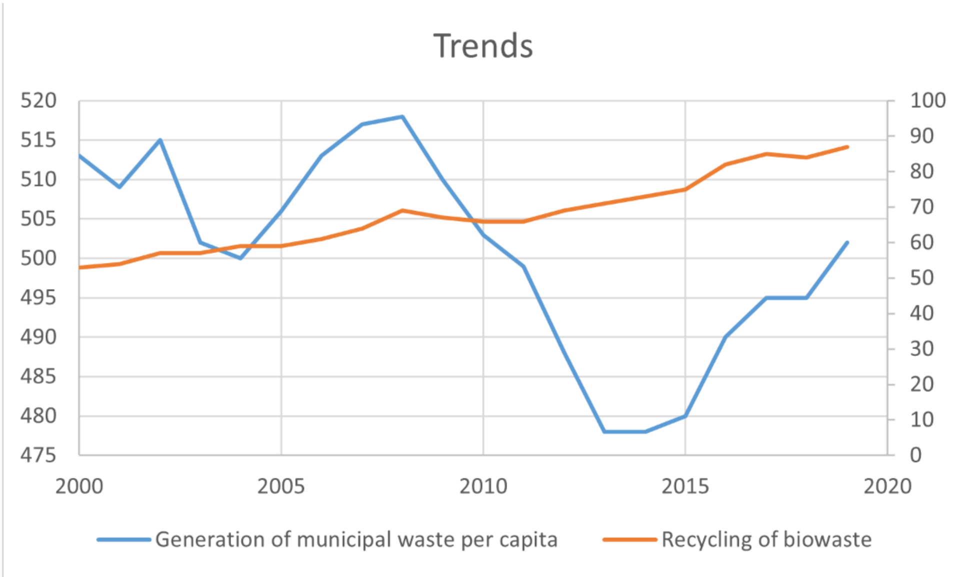

Figure 1. Revision of trends: the generated waste and the recycled biowaste.

Such analysis presents trends (Fig. 1) which show that for 19 years period the recycling rate of biowaste increased from 10 per cent to 17 per cent comparing to waste generation figures.

During further analysis, the authors figured out the links and their strength in data pairs. For the dependent variable, the authors took the recycling of biowaste and evaluated how the changes of other variables influence it. The regressors used for the regression model is provided below:

$$rec\_biow_t = \beta_0 + \beta_1\, rec\_ew_{(t-n)} + \beta_2\, rec\_mu_{(t-n)} + \beta_3\, rec\_pcw_{(t-n)} + u_t \quad (1)$$

where: rec_biow_t – logarithmic dependent variable of the recycling of biowaste (i.e., the ratio of composted municipal waste which is expressed in kg per capita) in year *t*.

β_0 – intercept;

$rec\_ew_{(t-n)}$– dlog of recycling rate of electrical equipment in year *t-n*;

$rec\_mu_{(t-n)}$– dlog of recycling rate of municipal waste in year *t-n*;

$rec\_pcw_{(t-n)}$ – dlog of recycling rate of packaging waste in year *t-n*;

u_t – random model error.

$\beta_1, \beta_2, \beta_3$ – coefficients of elasticity, reflecting the impact of regressors on the recycling of biowaste.

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The results of the analysis presented in the next sub-section.

4.2 Results of the analysis

The data for dependent and independent variables are normalised by applying a logarithmic procedure. The constructed regression model has its graphical representations, which is provided in Figure 2.

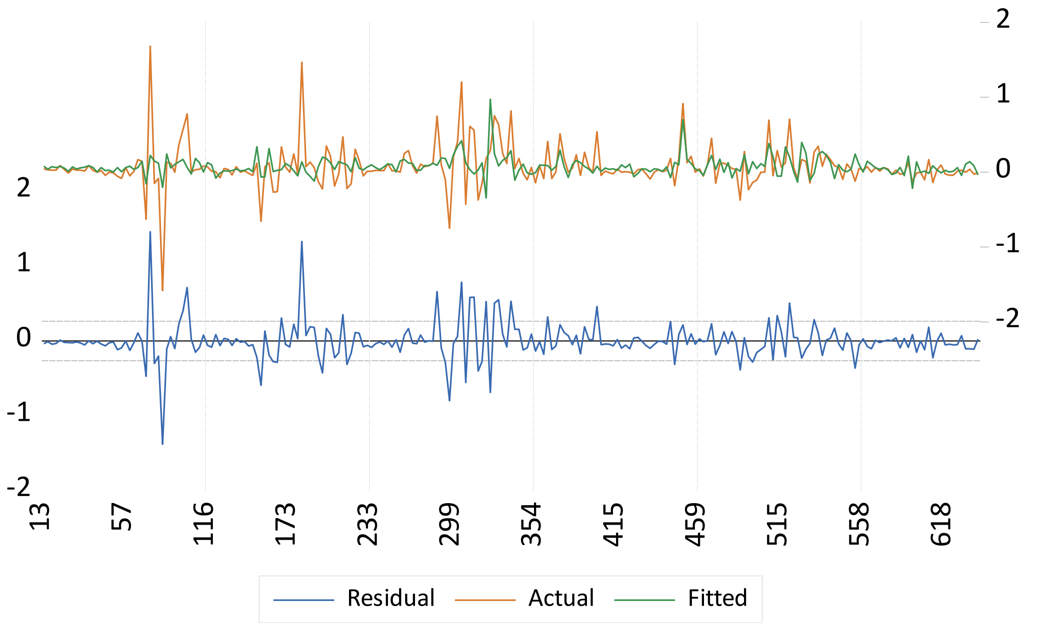

Figure 2. Forecasting the recycling of biowaste.

The regression model delivers such results:

$$rec\_\mathrm{biow}_t = 0.02 + 0.239\, rec\_ew_{(t-1)} + 0.58\, rec\_mu_{(t)} + 0.862\, rec\_pcw_{(t)} \qquad (2)$$

(0.019) (0.1) (0.11) (0.27)

The authors delivered the tests of statistical validity. The testing of probabilities t and chi-square does not show significant heteroskedasticity and autocorrelation. Detailed results of these statistics are provided below in Appendix A.

The authors indicated that the recycling rate of electronic waste has an impact on the recycling of biowaste in one year period. The authors foresaw that electronic equipment includes non-metallic components which recently are used for fuel production after being separated from other spare parts.

6. Discussion

The improvement of circularity is important under various levels: society, industry, and government. The implementation of high-level circularity is too optimistic as recycling takes only one-fifth of generated waste. First and foremost, focus on waste prevention could help dispose of waste at source, saving natural resources and energy, and delivery costs. The implementation of waste reduction activities is most appropriate for various circular approaches and waste streams, one of such is the application of smarter production. Further evaluation of recycling and composting options could be considered for managing unavoidable waste and could increase material circularity. The results of the study are important for policymakers as increase circularity leads to environmental sustainability.

Waste recycling saves energy, improve circularity, as supports the supplies of raw materials to produce new products. When waste cannot be avoided, recycling is the next

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best option. Recycling helps to prolong the life of landfills and is the best use of natural resources. Biowaste or composted waste is the recycling of organic matter. Organic matter, such as packing and non-metal waste, is transformed into a valuable soil replacement and guarantee the removal of organic waste from landfills.

The research indicated theoretical and practical gaps in which minimization could lead to the increase of circularity and faster transformation.

The research has some limitations and does not cover the revision of construction and decomposition waste and mineral waste streams and the avoidance of surplus. The high-level circularity could be reached in the long-term period as the current recycling of waste is less than 20 per cent and needs to be speeded up.

7. Conclusions

In recent years, many studies are focusing on circularity. However, the attention to all circular approaches is behind: only seven studies out of 65 covers all circular approaches. The attention to circular approaches related to smarter production is still small, as well as to single repurpose approaches from the end of life extend approaches. Therefore, the application of materials approaches is highly researched by authors and appear in studies as early as 2012.

The authors indicated key elements important for reaching high-level circularity. These elements are indicated during the revision of studies. These elements the authors have classified into the four categories - managing and reducing waste, resource recovery, material circularity, and general circular. The elements such as managing and reducing waste, resource-centred dimension, end-of-life concept, the recycling rate of final products, and value chains are the most interesting topics for studies.

For the revision of circularity as a complex process, the authors suggested a two-layer methodology, which covers theoretical and practical investigations. The practical investigations provided for the 19 years at EU 27 countries. The authors researched trends and identified waste streams having an impact on biowaste available for recycling increase and figure out that electronic waste, package waste, and municipal waste streams play an important role. Most of the waste streams have an impact during the same period, however, electronic waste needs some time for decomposition and preparation. The author constructed the dynamic regression equation and proved its statistical validity.

The future works could extend delivered study into some directions such as

- the revision of circularity measures and interlinks to show gaps;
- the involvement of other waste streams into empirical research;
- the review of waste management aspects by sectors;
- the prognosis of recycling rates.

The research extends the knowledge important for reaching higher circularity.

Author Contributions: Literature review and data analysis – Olga Lingaitienė; conceptualization and methodology – Aurelija Burinskienė

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

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Appendix A

Matrix of variables

Balanced sample (listwise missing value deletion)		The recycling rate of biowaste	The recycling rate of electronic waste (e-waste)	The recycling rate of municipal waste	The recycling rate of packaging waste by type of packaging
		DLOG(REC_BIOW)	DLOG(REC_EW)	DLOG(REC_MU)	DLOG(REC_PCW)
DLOG(REC_BIOW)	Correlation	1			
	Probability	-----			
DLOG(REC_EW(-1))	Correlation	0.102355	0.100917		
	Probability	0.5297	0.5355		
DLOG(REC_MU)	Correlation	0.862335	-0.179613	1	
	Probability	**0**	0.2674	-----	
DLOG(REC_MU(-1))	Correlation	0.265347	0.317882	0.386676	
	Probability	**0.098**	**0.0456**	0.0137	
DLOG(REC_MU(-2))	Correlation	0.376968	0.05477	0.15527	
	Probability	**0.0165**	0.7371	0.3387	
DLOG(REC_PCW)	Correlation	0.362384	-0.073196	0.544935	1
	Probability	**0.0216**	0.6535	**0.0003**	-----
DLOG(REC_PCW(-1))	Correlation	-0.150284	0.171152	-0.062798	-0.249102
	Probability	0.3546	0.291	0.7003	0.1211

Formation of equation (2):

Dependent Variable: REC_BIOW_DL Method: Least Sample: 1 640 IF Included				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.024597	0.019302	1.274323	0.2039
REC_EW_DL(-1)	0.239829	0.103325	2.321106	0.0212
REC_MU_DL	0.580162	0.117446	4.939827	0
REC_PCW_DL	0.862142	0.278934	3.090844	0.0022
R-squared	0.187391	Mean		0.077037
Adjusted R-squared	0.176556	S.D.		0.291053
S.E. of regression	0.264113	Akaike info		0.192434
Sum squared resid	15.69503	Schwarz		0.252411
Log likelihood	-18.03364	Hannan-		0.21663
F-statistic	17.29527	Durbin-		2.12933
Prob(F-statistic)	0			

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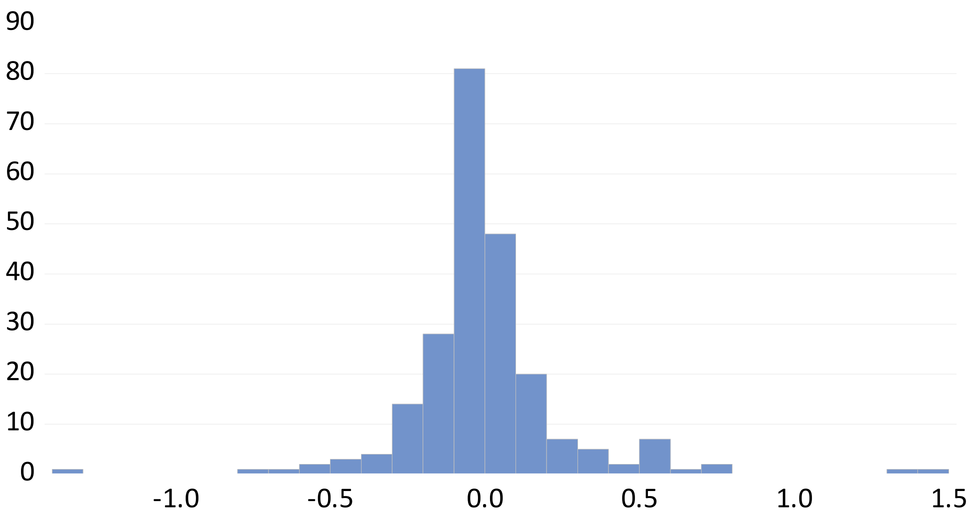
Analysis of residuals



Series: Residuals	
Sample 1 640 IF YEAR<>2000	
Observations 229	
Mean	-6.14e-18
Median	-0.023027
Maximum	1.458256
Minimum	-1.377543
Std. Dev.	0.262370
Skewness	0.885070
Kurtosis	12.94279
Jarque-Bera	973.1773
Probability	0.000000

Autocorrelation analysis: Breusch-Godfrey Serial Correlation L.M. test

Breusch-Godfrey Serial Correlation LM Test:				
Null hypothesis: No serial correlation at up to 2 lags				
F-statistic	0.966233	Prob. F(2,223)		0.3821
Obs*R-squared	1.967412	Prob. Chi-Square(2)		0.3739
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Sample: 1 640 IF YEAR<>2000				
Included observations: 229				
Presample and interior missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001069	0.01932	0.055342	0.9559
REC_EW_DL(-1)	-0.021258	0.105046	-0.202368	0.8398
REC_MU_DL	0.024584	0.118796	0.206939	0.8362
REC_PCW_DL	-0.013468	0.279375	-0.048208	0.9616
RESID(-1)	-0.103274	0.074298	-1.389998	0.1659
RESID(-2)	-0.013262	0.079371	-0.167089	0.8675
R-squared	0.008591	Mean dependent var		-6.14E-18
Adjusted R-squared	-0.013638	S.D. dependent var		0.26237
S.E. of regression	0.264153	Akaike info criterion		0.201272
Sum squared resid	15.56019	Schwarz criterion		0.291239
Log likelihood	-17.04569	Hannan-Quinn criter.		0.237567
F-statistic	0.386493	Durbin-Watson stat		1.923646
Prob(F-statistic)	0.857786			

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Heteroskedasticity analysis: ARCH test

Heteroskedasticity Test: ARCH				
F-statistic	2.066197	Prob. F(1,194)		0.1522
Obs*R-squared	2.0655	Prob. Chi-Square(1)		0.1507
Test Equation:				
Dependent Variable: RESID^2				
Method: Least Squares				
Sample: 1 640 IF YEAR<>2000				
Included observations: 196				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.057885	0.016729	3.460237	0.0007
RESID^2(-1)	0.105051	0.073083	1.437427	0.1522
R-squared	0.010538	Mean dependent var		0.065058
Adjusted R-squared	0.005438	S.D. dependent var		0.224151
S.E. of regression	0.22354	Akaike info criterion		-0.148299
Sum squared resid	9.694224	Schwarz criterion		-0.114849
Log likelihood	16.53332	Hannan-Quinn criter.		-0.134757
F-statistic	2.066197	Durbin-Watson stat		1.765764
Prob(F-statistic)	0.152208			

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