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Reverse Logistics of Packaging Waste under the Conditions of a Sustainable Circular Economy at the Level of the European Union States

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Abstract: The efficient use of natural resources and the quality of the environment are the main priorities of sustainable development. The purpose of this paper is to demonstrate the role of reverse logistics in the context of sustainable development, starting from the premise that it combines environmental and economic objectives and aims to minimize the wastage of resources through the reuse of products and packaging. In the current context, the circular economy must be approached by considering the methods of waste collection and reuse, with reverse logistics playing an essential role in creating environmental, economic, and social benefits. The growing population obviously determines the increase in the consumption of resources, which inevitably leads to the increasing generation of packaging and packaging waste. This study aimed to highlight the evolution of recycling rates at the level of the EU member states, starting from the stability objectives of the European Commission for the years 2025–2030. Starting from the Eurostat database, for the 27 member states of the European Union, regarding the recovery rate, recycle rate, and waste generation kg_per_capita related to the period of 2009–2020, we extrapolated the trends of the recycling rate of packaging for the period of 2021–2030 with the help of the Prophet model. Using the Prophet forecasting program, we identified states from the European Union that will meet the stability targets set by the European Commission for the years 2025 to 2030, considering the need to develop a circular economy.

Keywords: packaging and packaging waste; recycling; reverse logistics; circular economy; sustainable development; Prophet model; hierarchical clusters; SDG17

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1. Introduction

Transitioning to the circular economy means to transform the current economy into a more sustainable one, contributing to the achievement of SDG17. The circular economy model implies maintaining products and materials for the longest possible period of time, as well as creating jobs in the circular economy sector, attracting investments in the circular economy area, and mitigating climate change. Decoupling economic growth from negative effects on the environment requires a new model of sustainable consumption and production. Sustainable development proposes the solution of more efficient production, sustainable waste management, and performing activities in accordance with the principles of environmental protection. In terms of consumption, recycling is imperative, and this requires a transition to a circular economy and the population's awareness of the planet's limits.

A circular economy refers to maintaining the value of products, materials, and resources for as long as possible, minimizing the generation of waste [1]. This process starts at the very beginning of a product's life cycle: intelligent design and production processes can help save resources, avoid inefficient waste management, and create new business opportunities [2]. Sustainable development requires the need to move from a logic of "taking and throwing away" [3], typical of a linear economy, to a logic of reuse, recycling, and recovery, typical of a circular economy [4,5]. In other words, the circular economy reduces resource input and waste, emissions, and energy losses through design, maintenance, repair, reuse, regeneration, reconditioning, and recycling. Europe generates too much waste—and does not recycle enough. The EU is working to create a more circular economy by, among other things, preventing waste and improving waste management [6].

In order to support the transition to a circular economy, the European Commission formulated a directive that deals with the problem of waste [7]. Within this directive, a series of targets regarding the management of waste are to be fulfilled by 2030. However, the current reality does not demonstrate that the laws developed by the EU states generate the expected effects, being insufficient in the face of excessive consumption. Packaging is a growing problem as the average European generates almost 180 kg of packaging waste per year [2]. The aim is to tackle excessive packaging and improve its design to promote reuse and recycling. Thus, switching to more reliable products that can be reused, upgraded, and repaired would reduce the amount of packaging waste. Packaging waste reached 64% in 2020 [6]. The new rules aim to ensure that all packaging on the EU market is reusable or economically recyclable by 2030. Most works in the field of logistics have noted the importance of a resilient and sustainable supply chain. In this context, some authors are discussing the essential role of advanced technologies in ensuring the continuity of operations [8]. As such, we consider that this kind of approach should also be considered in the case of reverse logistics, which must be characterized by resilience and sustainability. With certainty, technology will provide an extra chance in the process of ensuring the continuity of reverse logistics operations; as such, governments must think of a strategy starting from investments in specific technology.

In a study conducted by Dilkes-Hoffman et al. in 2019 [9], it became clear that consumers consider the government and industry to be the characters responsible for reducing waste. From the perspective of the circular economy, reverse logistics can be considered necessary for the transition to the circular system, which would close the loop of end-of-life products.

Reverse logistics implies the existence of a circular supply chain, with concepts such as sustainability, green logistics, and recycling being attached to the notion of product management [10,11]. This closed life cycle has positive effects at the social level, but especially on the environment [12]. Thus, modern reverse logistics is considered to be a relevant component of ecological supply chain management [13].

The novelty of the research results from the correlation of a palette of concepts including circular economy, reverse logistics, recycling, packaging waste, and sustainable development, all of which generate effects on the environment. The study focuses on the packaging and packaging waste component, tracking the recycling rate of packaging waste and its evolution over time. Thus, the study presents the evolution of the recycling rate of packaging and packaging waste at the level of EU member states for the period of 2021–2030. To carry out this research, we used three representative indicators, namely, the recovery rate, recycle rate, and waste generation kg_per_capita, from the Eurostat data source [2], and we forecasted the recycling rates for the period of 2021–2030 with the help of an advanced Prophet processing model. This research approach aims to provide relevant information regarding the medium and long-term evolution of the recycling rate of packaging and packaging waste, respectively reaching the limits set by the European Union directives. The results of our research bring more information on this topic and can be a basis for reflection for those interested in this issue at the national or European levels. In Section 2 of this paper, a review of the specific literature in the field is presented, in which the theoretical concepts of circular economy, sustainable development, packaging waste, and reverse logistics are illustrated, as well as the correlation between them. The Section 3 follows with data processing using the Prophet model. The Section 6 is dedicated to the research results and conclusions regarding the researched topic.

2. Literature Review

In recent years, the concept of the circular economy has gained more and more importance in academic research and on the agenda of the decision-makers of the European Union. The circular economy is considered to be the solution through which future generations will benefit from sustainable development. The circular economy presents a consumption model based on the reuse of existing products and their reintegration into the economy after reconditioning processes. The essence of this intervention is to reduce waste as much as possible, thus creating an environment conducive to sustainable development [14]. In 2015, the United Nations launched the 2030 Agenda for Sustainable Development, an action plan for people, planet, and prosperity [15]. Responsible consumption and production aim to ensure sustainable patterns of consumption and production [15]. The circular economy is essential in achieving the EU commitments regarding sustainability—in particular, to achieve objective no. 12.

The objectives of sustainable development were widely debated in the European Parliament (2015) when the European Commission adopted the First Action Plan for the Circular Economy. The objectives of this initiative were the transition to a more sustainable model of industrial development, the stimulation of global competitiveness, and the creation of new jobs. Concrete actions included responsible production and consumption, waste management, a market for secondary raw materials, and a revised legislative proposal on waste [7].

The concept of the circular economy is based on the transition from the linear production system to the closed loop system, reducing the use of resources and the creation of waste, pollution, and carbon emissions. In practice, a circular economy has the effect of minimizing waste by reusing, refurbishing, and recycling existing products. This new economic model aims to eventually decouple global economic development from limited resource consumption, thus generating economic growth and reducing negative effects on the environment [16,17].

In 2019, the European Commission published a comprehensive report [7] on the implementation of the action plan to achieve climate neutrality and minimize the pressure on natural resources. So, the circular economy has strong links with the EU's climate and energy goals. Reusing and recycling products would slow down the use of natural resources, reduce disruption to the landscape and habitats, and help limit the loss of biodiversity [14].

The plan adopted in March 2020, considering circular economy objectives, aims to promote a more sustainable product design, reduce waste, and empower consumers by creating a right of repair to encourage product recycling [7]. In February 2021, the European Parliament adopted a resolution on the new circular economy action plan, calling for further action to achieve a carbon-neutral, environmentally sustainable, toxic-free, and fully circular economy by 2050. The plan also provides strict recycling rules and binding targets for material use by 2030 [14].

In March 2022, the European Commission adopted the first package of measures to accelerate the transition to a circular economy. The proposals include boosting sustainable products, encouraging consumers to go green, revising building materials regulations, and creating a strategy for sustainable textiles. In November 2022, the European Commission developed new rules on packaging. These aimed at reducing packaging waste, improving packaging design to promote reuse and recycling, and switching to biodegradable and compostable materials [7]. These rules are included in Directive (EU) 2018/852 and help to achieve the objectives of the European Green Deal and the new circular economy action plan to ensure that "all packaging on the EU market is reusable or recyclable in an economically viable way by 2030" [14].

The amount of packaging waste at the EU level is increasing, and the materials and products used are not reintroduced into the economy in the expected proportion [18]. The packaging uses virgin materials, with the GDP being thus overtaken by the amount of packaging waste [19]. Until 2030, packaging waste is expected to increase by 19%, if appropriate measures are not taken to eradicate this phenomenon [7].

Consumers buy packaged products with the aim of keeping them in optimal conditions [20,21], so waste collection represents an important problem [22]. Consumers must be informed about the possibility of contributing themselves to the reduction of waste in order to facilitate the transition to a circular economy [23].

An alternative to educating consumers regarding recycling activities includes other efforts to increase recycling by attaching labels with clear instructions, explicit guides to follow, or even the use of other materials [24]. The habit of recycling is a subject of major interest, being considered an environmentally responsible behavior, which must be perceived as easy to apply and implement [25,26]. Prevention and innovation are the key factors for reducing packaging waste at source and minimizing the environmental impact of packaging throughout its life cycle.

According to Ripanti et al. [27], there is a strong relationship between reverse logistics and the circular economy. Both concepts aim to support a more sustainable socio-economic development; focus on environmental, economic, and ecological aspects; and prioritize the proper management of used product waste; the concepts also have some similar characteristics, such as cycles of repair, refurbishment, recycling, and disposal [28]. Natural resources are exhaustible, which calls for the need to think about new possibilities for repeatable use and the disposal of industrial waste [29]. In the specialized literature, reverse logistics has various connotations [30]. Reverse logistics is the process by which companies can become "environmentally efficient by recycling, reusing, and reducing the amount of materials used" [31].

Additionally, reverse logistics is the term used to denote the role of logistics in recycling, waste disposal, and hazardous materials management [32]. Reverse logistics can be seen as a business strategy where "recovery activities are imposed in order to increase sustainability" [33]. Reverse logistics is part of green logistics combining environmental and economic objectives. Businesses promoting reverse logistics can streamline their logistics processes by returning and recycling packaging and by designing activities that reuse materials and products [34].

The circular economy is connected to supply chain management. A number of authors have clarified the links between packaging and logistics [35], while others have presented the link between ecological packaging and ecological transport, referring to a new concept—"Sustainable Packaging Logistics" [36,37]. The management of a supply chain must be analyzed through the prism of its components, as the decisions targeting the components of the logistics chain should include supply and reverse logistics [38]. Studies in the field have demonstrated the relationship established between sustainable development and the sustainability of packaging logistics [39]. This type of logistics incorporates the sustainability component into the supply chain [40].

Over time, this concept has been presented under various phrases, such as inverted supply chain, sustainable supply chain, circular economy, or closed-loop supply chain [41]; they all designate the same reality. In the specialized literature, this can also be found under terms such as ecological procurement and ecological production, material management and green distribution, and marketing and reverse logistics [11]. In this register, the management of the green supply chain involves reducing waste, improving the effects of pollution, saving energy, protecting nature, etc. [42].

Bearing in mind the objectives stated by the European Commission regarding the packaging recycling rate as well as the limited time until the first milestone set by it, the current study is based on three research questions intended to support the stated objectives:

1. Which EU member states will manage to reach the objectives set for the year 2025 and the year 2030?

2. Are there homogeneous clusters of EU member states that are formed considering the packaging recycling rate forecast for the year 2030?

3. Can we speak of an upward trend in terms of packaging recycling rates at the level of the EU states, considering the forecast made for the interval 2021–2030?

3. Materials and Methods

This study starts its academic approach by considering directive 2018/852/EU, which presents a series of measures assimilated to waste management in order to prevent waste generation and increase the recycling rate. This directive proposes deadlines for achieving this objective as well as objectives in the form of percentages that the EU states must be achieved in 2025 and 2030, respectively. Thus, the recycling rates proposed as objectives for 2025 and 2030 are 65% and 75%, respectively. Considering that the reduction and recycling of packaging waste are the priority factors for the transition to a sustainable and circular economy, the indicators with which we forecast the packaging recycling rate for the period of 2021–2030 are recovery rate, recycle rate, and waste generation kg_per_capita.

The data source for this research was the Eurostat database on packaging waste for the period of 2009–2020 regarding the 27 member states of the European Union (EXCEL file). To process these data, we used the Prophet model and an analysis based on hierarchical clusters for a more rigorous comparison of the recycling rates of packaging waste within the targets of the European Union directive.

3.1. General Introduction

Time series forecasting refers to the process of predicting future values of a dataset based on the analysis of past trends and patterns that are dependent on time. Time series data are characterized by their temporal dependency, where the observed data points are influenced by the passage of time.

Various techniques have been developed for time series analysis and forecasting, including traditional methods like Auto-Regressive Integrated Moving Average—ARIMA—and Seasonal Auto-Regressive Integrated Moving Average—SARIMA—as well as deep learning-based approaches such as Long Short-Term Memory—LSTM—and Recurrent Neural Network—RNN—which are specifically designed to handle sequential data analysis and forecasting.

One notable tool for time series forecasting is Prophet, an open-source library developed by Facebook. Prophet aids in forecasting time series data, enabling businesses to gain insights and potentially make predictions about market trends. It utilizes a decomposable additive model that incorporates non-linear trends and seasonality, taking into consideration the impact of holidays as well. Understanding certain key terms is important before delving into the coding process. Although Facebook states that Prophet "works best with time series that have strong seasonal effects and several seasons of historical data and is robust to outliers and shifts in the trend", the studied model proves its applicability in other situations as well, where the influence of seasonality is minimal. The trend component of a time series represents the long-term tendency of the data, indicating whether it exhibits an increasing or decreasing pattern over an extended period. The trend component helps filter out short-term seasonal variations.

Seasonality refers to the recurring patterns or variations that occur over shorter periods of time. These patterns are not significant enough to be classified as trends but exhibit regularity within specific time intervals.

3.2. Explaining Prophet Model

The model developed by Facebook is based on a generalized additive model (GAM) [43–45].

The proposed approach for time series forecasting utilizes a decomposable model based on the work of Harvey and Peters [46]. The model consists of three main components: trend, seasonality, and holidays. These components are combined in the following equation [43]:

$$y(t) = g(t) + s(t) + h(t) + e(t)$$

In this equation, $y(t)$ represents the value of the time series at time t, $g(t)$ captures the trend component accounting for non-periodic changes, $s(t)$ represents the seasonal component capturing periodic changes, $h(t)$ represents the effects of holidays, and $e(t)$ is the error term accounting for idiosyncratic changes.

Advantages of this approach include:

1. Flexibility: The model can easily accommodate seasonality with multiple periods and allow the analyst to make different assumptions about trends. It provides the ability to capture various patterns in the data.

2. Irregular Spacing: Unlike ARIMA models, the measurements do not need to be regularly spaced, and there is no requirement to interpolate missing values caused by outliers or irregularities. This enhances the model's applicability to real-world scenarios where data collection may be irregular.

3. Fast Fitting: The model can be fitted quickly using either backfitting or L-BFGS optimization. This enables analysts to interactively explore and experiment with different model specifications. The speed of fitting is particularly beneficial when working with large-scale datasets.

4. Interpretable Parameters: The forecasting model has easily interpretable parameters that can be adjusted by the analyst to impose assumptions on the forecast. This allows for an intuitive customization and adaptation of the model to specific requirements or domain knowledge.

5. Extension and Adaptation: Analysts experienced in regression methods can easily extend the model to include new components or factors that may influence the time series. This flexibility enables the model to adapt and incorporate new sources of seasonality or other relevant factors as they are identified.

By framing the forecasting problem as a curve-fitting exercise, this approach provides practical advantages for analysts. While it may sacrifice some inferential advantages offered by generative models like ARIMA, it offers greater flexibility, ease of interpretation, and efficient exploration of different model specifications. These advantages make it particularly suited for forecasting at scale and for time series with complex patterns such as piecewise trends, multiple seasonality, and floating holidays.

3.3. Data Selection

The utilization of Eurostat data for recovery_rate, recycle_rate, and waste_generation_kg_per_capita (Table 1) to forecast the recycle_rate from 2020 until 2030 is motivated by the correlation and interdependence among these features [2].

Table 1. The recycle rate, recovery rate, and waste generation.

Variable	**Data Sets**	**Measures**	**Reference**
Recycle rate	EU states recycle rate 2009–2020	Percentage	Eurostat [47]
Recovery rate	EU states recovery rate 2009–2020	Percentage	Eurostat [48]
Waste generation	EU states waste_generation_kg_per_capita 2009–2020	kg_per_capita	Eurostat [49]

Source: own design based on Eurostat.

1. Correlation between Recovery Rate and Recycle Rate: Recovery_rate and recycle_rate are closely related as they both pertain to the recycling and recovery of waste materials. A higher recovery_rate indicates a larger proportion of waste being diverted from disposal and recycled, which consequently contributes to an increase in the recycle_rate. By analyzing the historical correlation between these two variables, we can leverage this relationship to forecast the recycle_rate for future periods.

2. Correlation between Waste Generation and Recycle Rate: Waste_generation_kg_per_capita reflects the amount of waste generated per person in a specific time period. There is an inverse relationship between waste_generation_kg_per_capita and the recycle_rate. As the recycle_rate increases, a larger portion of waste is recycled, resulting in a potential reduction in waste_generation_kg_per_capita. By examining the historical correlation between waste_generation_kg_per_capita and recycle_rate, we can identify any underlying patterns and incorporate this relationship into the forecasting process.

3. Comprehensive Data Coverage: The Eurostat data offer a comprehensive coverage of recovery_rate, recycle_rate, and waste_generation_kg_per_capita across EU member states. This extensive coverage enhances the reliability and accuracy of the data, allowing for a more robust analysis of the correlations between these features. By utilizing this rich dataset, we can leverage the correlations observed in a diverse range of regions and countries to improve the accuracy of the recycle_rate forecast.

4. Policy Implications: The correlations between these features have significant policy implications for waste management and recycling strategies. Governments and policymakers can use the insights gained from analyzing these correlations to develop and implement effective waste management policies aimed at increasing the recycle_rate and reducing waste_generation_kg_per_capita. Forecasting the recycle_rate based on the historical correlations enables policymakers to evaluate the potential impact of different policy interventions and make informed decisions.

3.4. Working Mechanism

Prophet uses an additive model where non-linear trends are fitted with yearly, weekly, and daily seasonality, plus holiday effects [43].

Trend Model: Prophet automatically detects changes in trends by selecting changepoints from the data.

Seasonality: Prophet relies on time-series decomposition to accommodate seasonality. For a yearly dataset, it captures patterns that reoccur on an annual basis.

Holiday Effects: Although we did not mention any holidays in our dataset because the data we have area at a yearly level, Prophet can also account for holidays or certain specific dates that could affect the recycle_rate.

Additional regressors: By using the add_regressor method, the added columns (recovery_rate and waste_generation_kg) are used as additional regressors in the model. Prophet fits these regressors, enabling them to model their effects on the recycle_rate.

In this way, the model can make future predictions of recycle rate considering the trend, seasonality, and influences of recovery_rate and waste_generation_kg.

Although it assumes a time-series forecasting methodology, which is relatively new, Prophet is often mainly used in the environmental field in order to make reliable predictions [50,51].

Considering the results obtained for the year 2030 with the use of the Prophet model, we proceeded to create some clusters with the use of the SPSS program in order to group the EU states according to the recycling rate analyzed, with the objective of identifying the common points that characterize the environmental policy of the states in each cluster. Thus, the comparison of clusters represents a useful method to identify models of good practices, as well as possible inefficient approaches, which at the level of 2030 will demonstrate their inefficiency.

In order to develop the proposed clusters, we used the Center Distance Method (average group linkage)—(Hierarchical Cluster) for the hierarchical classification, and the distance selected for their delimitation was the Euclidean distance for continuous data.

4. Results

According to the methodology presented in the previous section, for each member state of the European Union, the packaging recycling rate for the period of 2021–2030 was estimated. An analysis of the data obtained shows the degree of inclusion of the EU states in the targets of directive 2018/852/EU, as well as the evolution of the recycling rate of packaging waste in the period of 2021–2030. The obtained results related to the estimation of the recycling rate of packaging and packaging waste are presented in the following table (Table 2).

Table 2. Packaging and packaging waste recycling rate estimates for European Union states for the period of 2021–2030 (percentages).

NO	Row Labels	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1.	**Austria**	63.7	62.65	62.1	61.6	60.6	60.1	59.5	59.02	58.01	57.5	56.95
2.	**Belgium**	79.64	77.36	75	71.8	82.2	80.6	78.2	75.03	85.38	83.8	81.44
3.	**Bulgaria**	61.2	60.93	60.7	60.28	61.4	61.2	61	60.59	61.72	61.6	61.27
4.	**Croatia**	54.2	53.88	53.8	53.7	53.1	53	52.9	52.79	52.2	52.1	51.94
5.	**Cyprus**	59.81	55.16	52	48.24	57.4	54.7	51.6	47.82	56.92	54.3	51.13
6.	**Czechia**	68.63	64.29	62.1	59.85	56.5	54.3	52.1	49.86	46.48	44.3	42.1
7.	**Denmark**	70.09	75.97	79.8	84.17	82.5	85.7	89.6	93.94	92.27	95.5	99.31
8.	**Estonia**	66.92	68.6	69.5	70.52	64.1	65	65.9	66.92	60.54	61.4	62.34
9.	**Finland**	73.03	81.52	86.4	91.57	87.5	91.9	96.7	100	97.85	100	100
10.	**France**	61.17	57.18	54.8	52.12	55.7	53.6	51.2	48.5	52.07	49.9	47.54
11.	**Germany**	67.9	69.76	71.1	72.62	71	72.1	73.4	74.94	73.35	74.4	75.71
12.	**Greece**	60.22	58.14	56.1	53.4	60.8	59.4	57.3	54.64	61.98	60.6	58.57
13.	**Hungary**	47.42	42.29	38.5	34	41	38	34.3	29.75	36.74	33.8	30.03
14.	**Ireland**	63.09	66.85	70.3	74.67	60.6	63	66.4	70.8	56.72	59.1	62.51
15.	**Italy**	72.8	74.99	76.3	77.64	77.1	78.3	79.6	80.92	80.38	81.5	82.83
16.	**Latvia**	61.94	60.84	57.5	52.34	75.8	74.3	71	65.81	89.26	87.8	84.46
17.	**Lithuania**	61.75	60.19	59.9	59.86	50.8	50.1	49.8	49.79	40.68	40.1	39.74
18.	**Luxembourg**	71.81	70.32	67.8	64.01	77.7	76.3	73.8	70.02	83.7	82.4	79.79
19.	**Malta**	40	40.37	40.7	41.07	39.9	40.2	40.5	40.87	39.74	40	40.26
20.	**Netherlands**	77.15	82.36	85.6	89.35	85.8	88.7	91.9	95.66	92.14	95	98.25
21.	**Poland**	54.98	54.92	55	55.13	58.2	58.2	58.3	58.39	61.42	61.4	61.5
22.	**Portugal**	59.99	60.95	61.5	61.99	60.2	60.7	61.2	61.76	59.99	60.5	61
23.	**Romania**	40.03	40.55	41	41.69	38.5	38.8	39.3	39.99	36.81	37.1	37.64
24.	**Slovakia**	70.95	68.39	66.4	63.85	69.5	68	65.9	63.42	69.07	67.5	65.51
25.	**Slovenia**	70.24	71,64	71.4	70.63	79.9	80.3	80.1	79.26	88.52	88.9	88.71
26.	**Spain**	68.3	71,76	74.2	77.01	71.2	73.2	75.6	78.44	72.66	74.6	77.02
27.	**Sweden**	61.23	57,57	56.2	55.15	54.6	52.9	51.5	50.47	49.89	48.2	46.85
	AVERAGE	63.27	63,31	63.16	62.90	64.20	64.17	64.02	63.68	65.06	64.94	64.61

Source: own design based on Eurostat using Prophet.

From the data obtained, it is noted that only 12 EU member states reach the target set for the year 2025 (65%), and only 10 states reach the target set for the year 2030 (70%). The states that manage to achieve the proposed objectives for the years 2025 and 2030 are highlighted in Table 2 in yellow.

From the analysis carried out, it can be observed that there are EU member states that exceed the recycling rate target, the upward evolution of this indicator during the estimation period can also be observed. Thus, for the year 2025, we can identify a series of states that register a much higher recycling rate than the average European rate (64.38%), such as Finland (91.91%), Netherlands (88.67%), Denmark (85.73%), Belgium (80.59%), and Slovenia (80.28). We can also observe recycling rates below the target of 65% in countries such as Hungary (38.03%), Romania (38.84%), Malta (40.17%), Lithuania (50.12%), and Croatia (52.97%). For the year 2030, the objective of 70% recycled packaging waste is met by the member states Finland (100%), Denmark (99.31%), Netherlands (98.25%), Slovenia (88.71%), and Belgium (81.44%) at levels that far exceed the average European recycling rate (65.19%). Exceptions to achieving this objective are countries such as Hungary (30.08%), Romania (37.64%), Lithuania (39.74%), and Malta (40.26%).

Although only a small number of states will reach the target set for the year 2030, by applying the Prophet model, we can still observe an upward trend at the level of annual averages at the EU level (Figure 1). Hence, combining the actual evaluation of the following years and the comparison with these estimates, new strategies can be imposed, or the current strategies can be rethought, so that the pace is intensified, and, therefore, the goal can be reached to a greater extent.

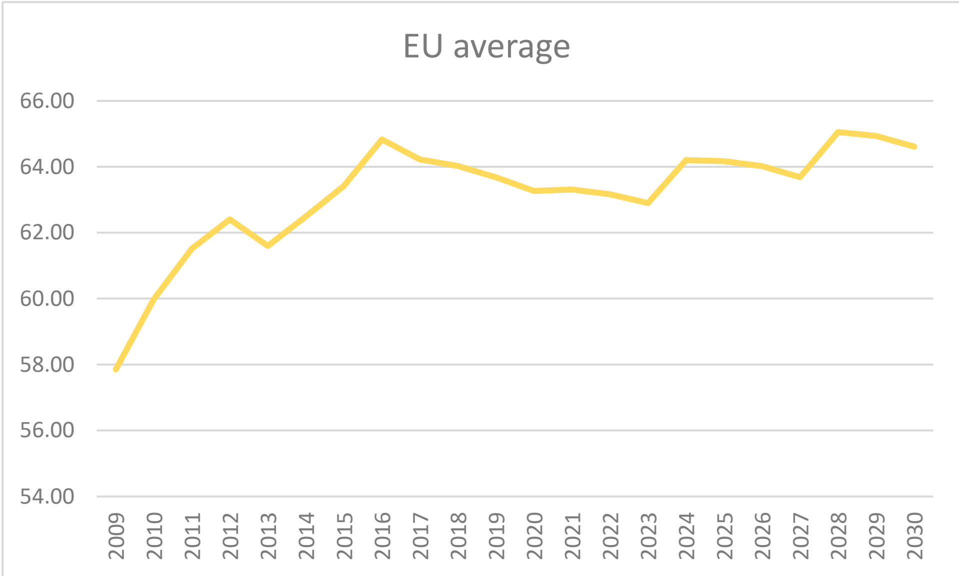

Figure 1. The average recycling rate of packaging waste at EU level in the period of 2009–2030. (percentage). Source: own design.

In Table 2, we can see the data recorded at the level of the EU member states both for the year 2020 and those estimated for the year 2030.

Belonging to a group of states also facilitates the analysis of other elements that can influence positive or negative developments, thus facilitating the construction of a strategy in order to apply them at group or subgroup levels. For example, in addition to elements of a financial nature, which can be quantified and analyzed with the use of statistical analysis tools, other variables that can influence the strategy and approach of a company can be analyzed. Such variables can be the type of culture prevailing at the state level and at the cluster level, which can influence the behavior of citizens or governments as regards the transmission of messages. At the same time, depending on the type of culture prevalent in a state, an efficient model can be transferred to another state that shares the same type of culture, starting from the premise that the transposed strategy will be easier to transfer, accept, and implement if it is communicated in a manner tolerated by the other society. Environmental responsibility is another variable that helps predict recycling behavior, especially as individual behavior is influenced by group behavior [52]. Some studies have considered that advertising impacts environmental behaviors differently depending on the cultural and social background of consumers [53]. As such, it is very important to identify the cultural background before imposing any environmental strategy.

Thus, at the level of 2030, the existence of two main clusters can be observed, within which other subclusters are created. As such, there are groups of states that register exceptional values (Denmark, Finland, Germany, Holland, Slovenia) and groups of states that register very good values that reach the proposed objectives for the year 2030 (Belgium, Denmark, Finland, Germany, Italy, Latvia, Luxembourg, Netherlands, Slovenia and Spain), which are visually highlighted. There are also groups of states with growth potential that can leave a cluster to migrate to a performing group (Ireland, Poland, Slovakia, Portugal), as well as groups of states that do not register significant values and form sub-mediocre clusters at the level of which significant intervention is required (Sweden, Romania, Malta, Czech Republic, Lithuania). Another representative example is Hungary, which records values below the average of the previously mentioned subcluster. In this context, the analysis will have a global approach: the group of clusters that achieve their objectives will turn into a mentor role for other clusters, considering the fact that the polluted environment in one region will inevitably affect the less polluted environment in another region. Thus, the states that make important efforts and that invest considerable sums of money in order to achieve these objectives will be affected by other states, which, although grouped in another cluster, may be states in their immediate vicinity. For example, Austria, which does not register significant progress regarding the analyzed indicator, can negatively influence Germany, a state which, according to the Prophet model, manages to achieve the proposed objectives. Another such example is Hungary, which can negatively influence Slovakia and others. As such, it is necessary to have a unitary environmental policy for all EU member states, as well as unitary constraints and penalties to mobilize other state structures. We note that the states that belong to a cluster are not necessarily neighboring states, so that the decisions and policies adopted by states in the immediate vicinity influence the quality of life in other countries as well. Whitmarsh [54] shows in his study that the pressure exerted by a family or neighbors is particularly important in shaping a responsible behavior toward the environment, being an important element in predicting behavioral intention.

Figure 2 shows the dendrogram obtained after grouping the European Union countries into homogeneous clusters at the level of 2030 [55], taking into account the forecast made with the help of the Prophet program.

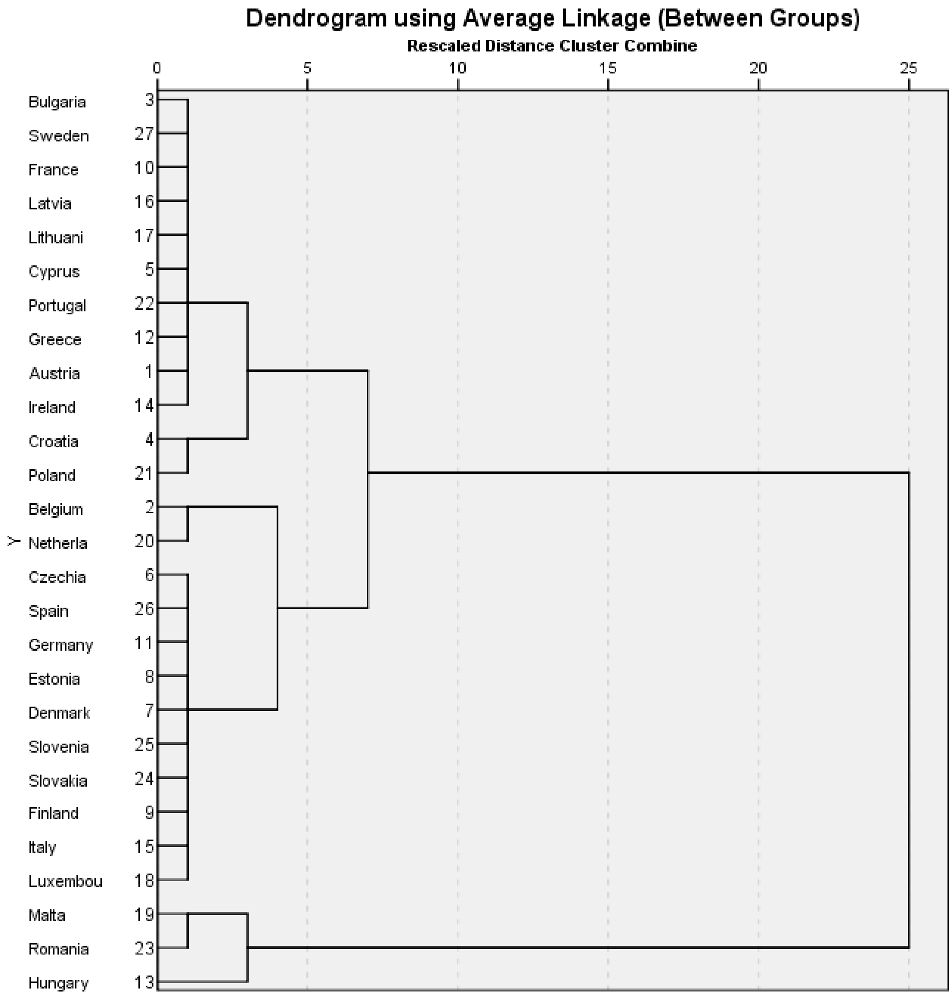

Figure 2. Dendrogram using average linkage at the level of 2030. Source: own design based on gathered data using SPSS v22.

At the same time, we created a dendrogram (Figure 3) at the level of the year 2020 as well in order to compare the packaging recycling rate actually achieved by the EU member states, with the packaging recycling rate estimated for the year 2030. As can be noted, two main clusters and several sub-clusters are formed at the level of 2020, being nevertheless significant differences between the two time periods analyzed. Thus, for 2020, we identify a totally mediocre cluster consisting of three states (Romania, Malta, and Hungary) and a cluster in which states with a higher or lower potential to grow are integrated. There is a phenomenon of migration between clusters, such as Lithuania, which detaches from the slightly mediocre sub-cluster in which it is included at the level of the 2020s but which manages to integrate into a performing cluster at the level of 2030 together with states such as Luxembourg, Italy, Belgium, Spain, and Germany. Another example of the phenomenon of migration between subgroups is represented by Romania and Malta, which until 2030 detach from Hungary and join a group formed by the Czech Republic and Lithuania, thus registering significant increases. It should be noted that the Czech Republic and Lithuania register consistent decreases in the 2030s, following a downward trend. If in the 2020s the average recycling rate is around 60%, in 2030 these values will drop dramatically, reaching the level of 40% of the recycling rate. As such, the formation of a new cluster does not represent an evolution of the two states, Romania and Malta, but rather a significant evolution for the Czech Republic and Lithuania. Hungary forms a separate group without joining any group of countries, thus signaling real problems regarding the implementation of environmental policies. A new interesting cluster is formed at the level of 2030, a cluster of which France, Sweden, Croatia, and Cyprus are part. The four states share a downward trend at the level of recorded values, thus creating a group of countries with an inverse trend compared to global dynamics, a fact that should attract the attention of the European Commission.

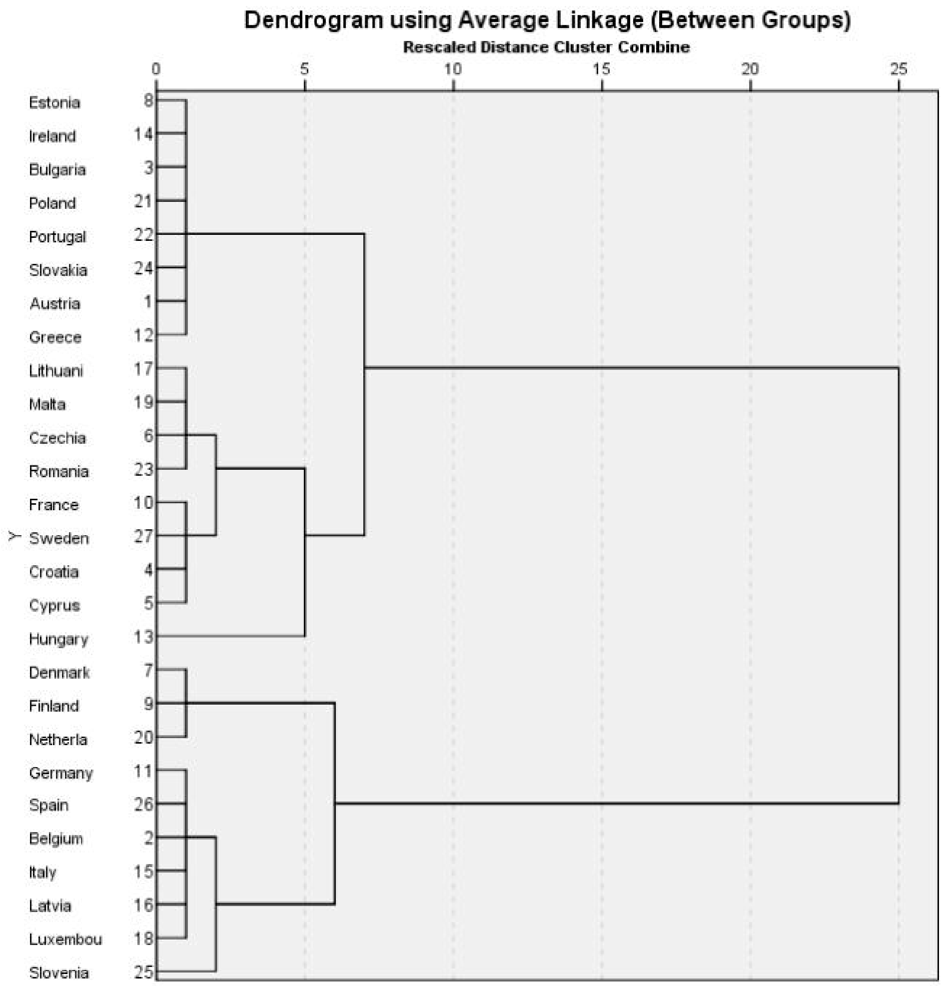

Figure 3. Dendrogram using average linkage at the level of 2020. Source: own design based on gathered data using SPSS v22.

The evolution of the packaging recycling rate at the level of the EU member states is highlighted graphically by drawing the two clusters obtained using the SPSS program. They provide an image illustrating the efforts made by different EU member states regarding the implementation of the principles of the European Commission. Additionally, the two clusters highlight mosaic-type phenomena that characterize the evolution of the recycling rate at the level of the EU member states. While some countries maintain their growth trajectory (Belgium, Denmark, Finland, Germany, Holland, Spain, Luxembourg, Slovenia, etc.), others register an exponential regression, generating the emergence of new clusters (e.g., the Czech Republic, Lithuania, Hungary), while other countries stagnate (Romania and Malta). As a result, the states under analysis register different evolutions of the recycling rate. There is a need to implement some national strategies to reach the recycling targets established by the European Commission.

5. Discussion

5.1. Practical Implications

The circular economy is central to the European Green Deal strategy, and the positive effects of the transition to a new model of production and consumption are being increasingly evident. Packaging waste represents a major problem for the European Union states. The European Commission has in mind the objective of quantitative recycling in order to improve the effect produced by packaging on the environment. As such, the reduction of packaging waste as well as its recycling is considered in order to build a sustainable economy. Waste management in the Union should be improved in order to protect, preserve, and improve the quality of the environment, protect human health, ensure an efficient and rational use of natural resources, and promote the principles of the circular economy. Considering the results obtained, the governments of the EU member states, environmental organizations, managers, and even citizens can identify the vulnerabilities that prevent the EU member states from reaching the objectives, but they can also identify the countries that belong to a performing group of clusters that can constitute a model of good practices.

5.2. Theoretical Implications

The theoretical contribution of research on the circular economy, reverse logistics, and packaging waste is very topical and particularly complex due to the correlations presented. There are currently no studies addressing this complex correlation at the European Union level. The results of this research give an impetus to those interested at the national and European levels in the establishment of more effective legislative instruments for the environmental policy. It is also very important that national authorities encourage the use of reverse logistics by providing incentives such as subsidies that improve the performance of the logistics chain and enable the transition to a circular economy. In addition to this contribution is the use of the Prophet forecast model which adds value to the research by outlining a scenario regarding the evolution of the packaging recycling rate at the level of the EU member states until the year 2030. The novelty of the research consists in the fact that the forecast was not only made by running the recycling rates recorded in previous years, but also by combining a number of three interconnected variables (Recovery Rate, Recycle Rate, Waste Generation), which significantly influence the results of the analyzed period. The results obtained in this research by using the recycling rate contribute to the theoretical and practical development of packaging waste management at the level of the EU states in the current context of sustainable development.

5.3. Limitations and Further Research

A limitation in carrying out this research is the fact that the data used from the Eurostat database are not recent (they stop at the level of 2020), but the consistent time series analyzed (2009–2020) allowed for the creation of a coherent forecast model for the period of 2021–2030. Regarding the use of the Prophet forecasting model, the accuracy of the estimates can increase if we introduce a consistent set of variables, compared to using only three (Recovery Rate, Recycle Rate, Waste Generation). But this represents another limitation of the research because economic, social, political, and cultural factors specific to each state influence how to approach the problem of packaging waste. However, the paper does not present an analysis of the common cultural points of the analyzed states, which could significantly contribute to drawing common objectives for the states that are part of the same cultural group. This work aims to be the starting point for a new analysis, which takes into account the type of culture prevailing at the cluster level and how it can influence the environmental policy communicated and adopted by the states subject to the debate.

As such, the current work constitutes a motivation for other more rigorous and detailed studies to be carried out at the national level, taking into account the peculiarities of each member state.

6. Conclusions

In this work, starting from three representative packaging indicators, recovery rate, recycle rate, and waste generation kg_per_capita, related to the period of 2009–2020, we determined the trends of the packaging recycling rate for the period of 2021–2030 using Prophet, an advanced forecasting model. The estimates of the packaging recycling rate for the 27 member states of the European Union in the period of 2011–2030 enabled us to analyze the evolution of this indicator and the performance recorded by each state in the context of reaching the targets set for the years 2025 and 2030. For a more in-depth analysis of the results obtained, we also resorted to cluster analysis to compare the performances recorded at the level of groups of states that recorded better and constant results in the period lysed regarding the recycling of packaging waste. The analysis shows that there are countries that record high levels of packaging recycling rates, such as Finland, Denmark, the Netherlands, and Belgium, as well as countries such as Romania, Malta, and Hungary, which do not achieve this performance. These different results are determined by the national systems of collection, recycling, and recovery, and by the factors that influence the increase in the amount of packaging waste in each member state (income of the population, dynamics of urbanization, changing lifestyles and consumption patterns, education of the population regarding environmental protection).

It is worth noting that between countries with a high recycling rate and countries with a high GDP, there is a direct relationship of conditioning in the sense that economic development prints an alert rhythm of recycling. The relationship between waste generation and GDP must also be analyzed, as strongly industrialized countries tend to produce more, often in a chaotic rhythm, without realizing the effects of the activities. Given that the packaging waste management systems in European countries are heterogeneous, the laws in force are not harmonized, and the autonomous recycling objectives represent barriers to the transition to a circular economy. The authorities of each state should identify solutions starting with the creation of an appropriate infrastructure and logistics for the collection and recycling of packaging waste (the allocation of major budgets for investments in technologies for the recycling activity, as well as correct and fair methodologies for accessing such funds). Also, the adoption of good practices from states that have a high recycling rate can represent a starting point in the development of strategies regarding the management of packaging waste. The harmonization of measures to manage packaging waste flows and the creation of an integrated framework at the European level can solve this packaging problem. It is also important to highlight the role of the population, which through proper education contributes to the transition to a more circular economy in terms of minimizing packaging waste and recycling.

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