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COMPARATIVE ANALYSIS OF ECO-INNOVATIONS USING THE CIRCULAR ECONOMY PERSPECTIVE IN EUROPEAN UNION COUNTRIES

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Abstract: This paper aims to examine the crucial role of eco-innovations in driving the transition towards a circular economy model, with a focus on the development of patents related to recycling and secondary raw materials. The purpose is to fill the research gap on this topic, internationally and domestically, with a specific focus on the European Union and its member states. The research utilized secondary data obtained from the Eurostat website, specifically in the field of Competitiveness and Innovation within the circular economy model. Patents related to recycling and secondary raw materials used as the indicators for eco-innovation. The statistical analysis included descriptive statistics, trend analysis, and forecasting. The research results show that Germany is the leader, followed by France and Poland, while all other countries have the significantly lower rankings. The trend analysis for European Union countries and Germany shows that the maximum result was achieved in a year 2019, with a significant decline in a year 2020. Predictions indicate a trend of increasing the number of patents for recycling and secondary raw materials in the year 2021, for both the European Union countries and Germany, followed by downward to the year 2024. All things considered, this research presented new and significant results, considering it analyzes the situation in EU countries. The recommendation would be to intensify efforts in creating new patents for recycling and secondary raw materials in order to increase eco-innovation

Keywords: eco-innovation, circular economy, comparative analysis, patents related to recycling and secondary raw materials

Field: Social science and Humanities

1. INTRODUCTION

In recent years, the consequences of people's lifestyles that negatively impacts all aspects of life, as well as the environment, have become increasingly apparent. Globalization, industrialization, consumer society, mass production, and excessive consumption have all led to serious consequences for the planet. The increasing wastes of energy, resources, and the accumulation of large amounts of waste are the results of a global and ecological crisis, which is precisely the outcome of the pursuit of social progress and growing profit (Milanović et al., 2022). The consequences manifest in several directions: the reduction of natural capital constantly extracted from the environment, pollution of natural capital by waste, and, finally, overall environmental degradation (Milanović et al., 2019). More precisely, the transformation of natural resources into waste represents a model of the economy known as a linear economy.

The model of circular economy (CE) is one of the main solutions for achieving a sustainable future (Zwart, 2021) and represents a promising approach to a sustainable transition from a linear to a sustainable economic model. The model of CE aims to enable production and consumption with minimal losses in renewable energy, materials, and everything used, to achieve to reuse of products. Reuse is facilitated through product and service recovery, product recycling, consumption with minimal material and energy losses, recycling, and successful recovery (Milanović et al., 2022; MacArthur, 2013). Inside the model of CE, everything has economic value, and everything represents value. The primary purpose of a product after use can represent value for another purpose and reuse. According to Hislop (2011) the model of CE represents a development strategy that seeks to maximize resource efficiency, minimize waste generation, and maintain the value of products, materials, and resources in the economy for as long as possible (Milanović et al., 2022; EC, 2015a). Specifically, one of the goals of the circular economy model is to sustain and share value over time (Vence & Pereira, 2019).

An economy aimed at sustainable development must develop advanced technology and a production culture that achieves its growth through inventive activities (Khaertdinova et al., 2021), thus contributing to the creation of new jobs, improvement of product design for ease of use and promotion

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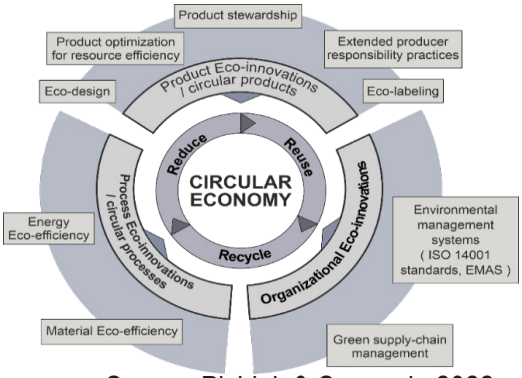
innovative industrial processes. (EC, 2018). During the implementation of the circular economy model and its principles, eco-innovations are of particular importance, as they can affect both products and services, as well as producers. The close connection between eco-innovation, but also the development of patents and CE activities, is recognized, so these innovations in the field of patents and eco-innovation appear as one of the most important mechanisms that enable the transition from a linear to a circular economy in production processes (Maldonado-Guzman et al., 2021).

The business models are considered to be key drivers during the opening towards the circular economy through eco-innovation, but also the development of patents within the field of innovations (Vence, & Pereira, 2019). Precisely through the introduction of changes within business models, the development of patents and changes in the design of new products and services, the development of patents in supply chains, patents related to recycling and secondary raw materials and others, eco-innovations enable an increase in the ecological and social value of products, as well as change practices of producers and consumers influencing the transition to a circular economy model (Vence, & Pereira, 2019). However, it is not easy to provide all the conditions for the CE model to be applied, especially in times of huge competition and constant changes. Many models are unusable without modifications and the introduction of additional practices, like radical changes such as transformation and reengineering within organizations (Erić & Dabetić, 2019), as well as specific managerial practices which would promote the transition to model of CE and its principles. In the contex of these practices, eco-innovation as the basic determinants within the application of the model of CE, three types of eco-innovation are recognized: process eco-innovation, product eco-innovation and organizational eco-innovation (Pichlak & Szromek, 2022), as shown in Picture 1.

Picture 1. Managerial practices that promote the creation and implementation of eco-innovations for the transition to CE



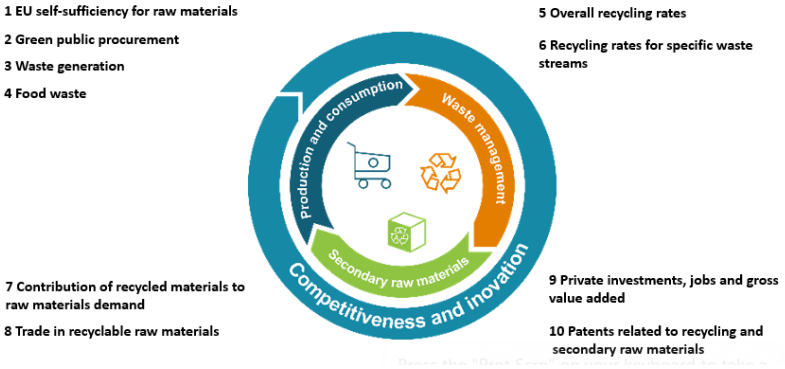
Source: Pichlak & Szromek, 2022

The aim of the paper is to present the significance of eco-innovations, with a special focus on the development of patents related to recycling and secondary raw materials, and their contribution to the advancement of the circular economy model. Emphasis is placed on the development of patents related to recycling and secondary raw materials in the European Union countries. Many developed countries have long since achieved a certain level of progress in this field and in the circular economy, while others, less developed, should invest significantly more in step forward. The development of patents contributes to better implementation and transition towards a circular economy since patents represent innovations and knowledge exchange (Barragán-Ocaña et al., 2021). They also serve as tools in the application of new technologies, development, and the fight for the preservation of a healthy environment (Khaertdinova et al., 2021). Carrying out a mutual comparison and ranking of the EU countries, the differences can be clearly seen, but also apply some future guidelines of leading countries in developing patents related to recycling and secondary raw materials.

2. MATERIALS I METHODS

The economy of a country can be made significantly more competitively, advanced and innovative through the transition to a circular economy model (EC, 2018).

Picture 2. Indicators of CE in EU



Source: EC, 2018

Since in this case the focus of the work is on the EU countries the European Commission adopted the "Monitoring and Following Framework for CE" in order to monitor and measure the progress of the CE practices in EU member states. The framework consists of four areas related to production and consumption, secondary raw materials, waste management, and competitiveness and innovation (EC, 2018). Furthermore, to establish measurement and monitoring of CE, ten indicators and their sub-indicators have been developed (EC, 2015b) as presented in Figure 2.

During the preparation of the paper, the methods of analysis and synthesis, as well as induction and deduction used in reviewing the relevant theoretical literature. Specifically, the analysis focused on three types of eco-innovations and then their synthesis with managerial practices that would enable the transition to a circular economy model. Induction and deduction were applied in presenting the literature related to CE indicators in the EU. Data from the field of Competitiveness and Innovation were used for this paper where two indicators were developed, one of which is Patents related to recycling and secondary raw materials. The mentioned indicator is important for the aim and subject of this paper because it represents as an indicator of innovative solutions and technologies applied in CE to enhance the global competitiveness of the EU (EC, 2018). Statistical analysis utilized real data from the Eurostat website for the period from 2015 to 2020, covering a total of 27 EU member countries (https://ec.europa.eu/eurostat/databrowser/view/cei_cie020). Descriptive analysis methods, trend analysis, and forecasts for the EU were applied, along with trend analysis and forecasts for Germany as the leading economy in terms of patents related to recycling and secondary raw materials. During the quantitative analysis were used the Statistical Package for Social Science (SPSS) and Power Bi.

3. REZULTS

Table 1 show the original data on the number of patents related to recycling and secondary raw materials, as well as the results of descriptive statistics obtained using the Statistical Package for Social Science (SPSS).

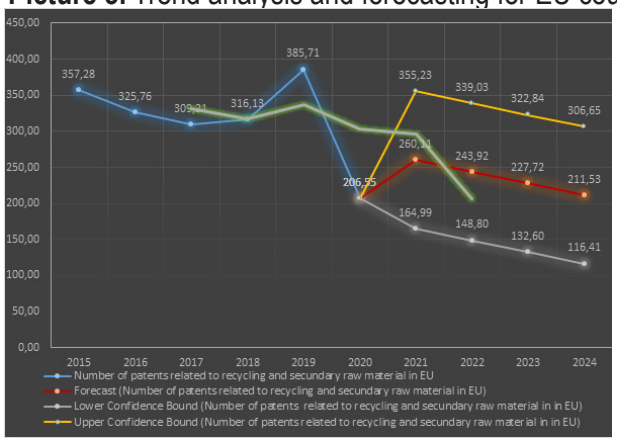
Table 1. Descriptive statistic and original data

States\ Years	2015	2016	2017	2018	2019	2020	Mean	SD	Min	Max	Skew
Austria	10,6	7,71	5,33	13,01	17,53	6,49	10,11	4,59	5,33	17,53	0,81
Belgium	19,26	16,26	19,35	16,08	15,58	5,49	15,34	5,10	5,49	19,35	-1,88
Bulgaria	0,5	0,33	0,22	0,5	0	0	0,26	0,23	0	0,5	-0,15
Czech	2,66	1,84	6,4	4,67	9,49	7,16	5,37	2,88	1,84	9,49	0,16
Denmark	5,75	7,18	6,34	5,63	8,4	2,83	6,02	1,87	2,83	8,4	-0,80
Estonia	0	1	0	0	0	0	0,17	0,41	0	1	2,45
Finland	18,47	18,96	18,78	18,63	16,38	15	17,70	1,63	15	18,96	-1,22
France	39,34	36,88	38,46	37,16	52,41	27,09	38,56	8,11	27,09	52,41	0,64
Greece	3,5	1	2,25	0	0,3	0,5	1,26	1,35	0	3,5	1,08
Netherlands	23,93	24,25	24,47	33,46	33,52	13,25	25,48	7,52	13,25	33,52	-0,57
Croatia	0	2,16	0	0	0	0	0,36	0,88	0	2,16	2,45
Ireland	1,45	4,93	3,75	1,87	5,42	3,83	3,54	1,60	1,45	5,42	-0,33
Italy	20,82	29,34	28,61	23,39	48,51	21,51	28,70	10,34	20,82	48,51	1,84
Cyprus	1	0	0	0	0	0	0,17	0,41	0	1	2,45
Latvia	2,3	1	1	0	0	0,5	0,80	0,86	0	2,3	1,10
Lithuania	0	0	0	0	1,5	0	0,25	0,61	0	1,5	2,45
Luxembourg	3,54	2,7	5,74	2,33	2	2,5	3,14	1,38	2	5,74	1,77
Hungary	2,33	3,16	1	2	3	0	1,92	1,22	0	3,16	-0,75
Malta	1	0	0	0	0	0	0,17	0,41	0	1	2,45
Germany	89,46	82,62	71,18	84,57	103,78	45,67	79,55	19,69	45,67	103,8	-0,95
Poland	69,61	44,35	34,27	22,21	20,23	17,25	34,65	19,91	17,25	69,61	1,27
Portugal	5	1	1	2	3	5,42	2,90	1,94	1	5,42	0,44
Romania	4,5	5,71	8,49	9,5	7,9	5	6,85	2,05	4,5	9,5	0,12
Slovakia	4,25	0	2,27	1,5	3,67	0	1,95	1,80	0	4,25	0,13
Slovenia	0	0	0,99	0	1	1	0,50	0,55	0	1	0,00
Spain	18,21	27,31	15,34	18,45	17,68	21,34	19,72	4,18	15,34	27,31	1,41
Sweden	9,8	6,07	13,98	19,17	14,41	4,72	11,36	5,51	4,72	19,17	0,14
Grand total	357,28	325,76	309,22	316,13	385,71	206,55					

Source: Calculation of authors based on https://ec.europa.eu/eurostat/databrowser/view/cei_cie020

Based on the analysis, the obtained results showed that during the five-year period, on average, Germany was the leading country with 79.55, followed by France (38.56) and Poland (34.65) with approximately 50% fewer number of patents related to recycling. and secondary raw materials. Norway (25.48) and Italy (28.70) recorded an average three times less patents. Twelve EU countries had an average of fewer than six patents, of which seven countries had even less than 1 patent related to recycling and secondary raw materials over the five-year period. The remaining countries are catching up with the leading ones, so they are characterized as follower countries. By using Power BI, a trend analysis and forecast were performed the period up to the year 2024. Picture 3 illustrates the trend analysis and forecast for all EU countries.

Picture 3. Trend analysis and forecasting for EU countries



Source: Calculation of authors based on https://ec.europa.eu/eurostat/databrowser/view/cei_cie020

Trend analysis showed that from the year 2015 to 2019., there was an upward trend in the number of patents related to recycling and secondary raw materials. The peak year was 2019 with a number of 385.71, surpassing the values of all previous individual years. However, starting from the year 2020, their number fell to 206.5 represented the lowest number of patents related to recycling and secondary raw materials compared to all previous years. The forecast predicts growth during a year the 2021, followed by a downward trend. The lower and upper confidence levels are shown in the picture.

Picture 4. Trend analysis and forecasting for Germany

Source: Calculation of authors based on https://ec.europa.eu/eurostat/databrowser/view/cei_cie020

The trend analysis for Germany indicates a slight decline in the number of patents related to recycling and secondary raw materials from the years 2015 to 2017., followed by a continuous increase from the years 2017 to 2019. After reaching the highest value of 103.78 in a year 2019, there was a sharp decline in their number in a year 2020 to 46.6, which is approximately 50% lower compared to all previous years. The forecast suggested a slight increase during a year 2021, after which a downward trend is expected.

4. DISCUSSIONS

It is evident which EU member states are leaders in the development of patents related to recycling and secondary raw materials based on the results of research for the period from the years 2015 to 2020. An upward trend is indicated until a year 2019, followed by a downward trend from a year 2020 onwards. According to the author's opinion, the abrupt decline in 2019 by 60.9% compared to the previous period's average can be attributed to the Covid-19 crisis, which slowed down economic and non-economic activities in all countries. In addition to the trends presented in the work, a forecast was also made, taking into account that there are no official data after 2020.Table 1 displays the results according to which the leading country is Germany, followed by France and Italy with approximately 50% of the number of developed patents which refer to recycling and secondary raw materials. After the United States, Japan and South Korea, Germany definitely represents a leader in all types of innovation especially patents related to recycling and secondary raw materials (Pata et al., 2024). According to the European Patent Office (2021), Europe and the US have undertaken 30% of worldwide patenting activity in these sectors between the years 2010 and 2019 or 60% together. In Europe, Germany recorded the largest share of patent activity in plastic recycling and bioplastics technologies (8% of the total world) while France, Great Britain, Italy, the Netherlands and Belgium stand out for greater specialization in these areas (European Patent Office, 2021).

The paper emphasizes the year 2019 as the most successful in terms of the number of developed patents related to recycling and secondary raw materials. In that year, out of the total 385.71 patents, Germany had 103.78, effectively making up 30% of the total for the EU. Following Germany, France had 52.41 and Italy ranked third with 48.51 patents related to recycling and secondary raw materials. The Netherlands secured the fourth position with 33.52, and Poland held the fifth position with a total of 20.23 patents in the mentioned field. The data presented indicate that only three out of the total 27 EU countries collectively had 204.7 patents related to recycling and secondary raw materials in a year 2019. This means that the remaining 24 countries had a total of only 181 patents in a year 2019. More precisely, the first five countries (including Poland and the Netherlands) achieved a sum of 258.45 patents related to recycling and secondary raw materials out of the total 385.71.The other 22 EU countries together accounted for

only 30% in the year 2019. The dominance of Germany is evident, but so is the underdevelopment of other EU countries in this field, where many countries in this five-year period did not have a single patent or had an only one, such as Malta, Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Croatia, and Slovenia.

Germany is the leading country with the highest share of patented activities related to recycling and secondary raw materials (25.1%) followed by France (12.18%), and Italy (9.1%). The authors of the paper have observed that the level of living standard is not decisive for the development of patents related to recycling and secondary raw materials, considering that Germany ranks 8th, France 11th, and Italy 12th in terms of GDP per capita in PPP (https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD) among EU countries. However, Italy reached the 3rd position due to significant investments in developing plastic recycling technologies (European Patent Office, 2021). On the other hand, Germany is specific in terms of the amount allocated for research, development, and innovation. For instance, in a year 2016, the federal government and German industry spent a record sum of 92.2 billion euros on research and development, which represents 2.94% of Germany's GDP. In comparison, the last time the 28 EU countries spent an average of 2.03% of GDP (Göbel, 2018).

Innovations and new technologies are changing resource demand requirements worldwide (GTAI – German Trade & Invest, 2021), while patent information provides strong statistical evidence of a country's technical progress (European Patent Office a, 2021). Therefore, it is not surprising that globally, Germany, along with China and Japan, is considered to be a pioneer in the implementation of the Circular Economy (CE). This stems from Germany's extensive experience in developing efficient strategies by establishing strict goals and fundamental rules in waste management while simultaneously staying closely tied to the CE concept (Milanović et al., 2022; Ogunmakinde, 2019). In many aspects, Germany is an innovation leader and innovation is crucial for its leading role in the global market for environmental technologies (GTAI, 2021). Strong government support a highly skilled workforce, collaborative relationships, energy transition, digitization and growing sustainability awareness among consumers, among other factors, have led to the development of various markets offering growing potential for innovative companies in the circular economy (GTAI – German Trade & Invest, 2021). Germany's investments in education are far more concentrated and specialized compared to other countries such as France, Italy, the United Kingdom, and the United States (Naudé & Nagler, 2021), representing another significant difference compared to other EU countries.

5. CONCLUSIONS

Each of the four areas of the circular economy is significant in itself and within the overall framework of the circular economy model. The area of Competitiveness and Innovation, represented in this paper through a specific focus on the development of patents for recycling, highlights the strength of the CE model. The development of innovations, eco-innovations, patents related to recycling and secondary raw materials, as well as the regulation and development of international cooperation in this area, can only accelerate the implementation of CE principles. The theoretical contribution of the paper lies in approaching eco-innovations from a different perspective through the lens of the developed circular economy model (patents related to recycling and secondary raw materials), unlike dominant analyses in the literature based on a composite eco-innovation index. Furthermore, for the first time, EU countries were analyzed according to this indicator, and disparities were identified, with their causes clearly stated. Practical implications suggest that countries significantly lagging behind dominant EU countries, as well as countries aspiring to become EU members, necessarily need to invest resources in developing scientific research bases, target education, adopt efficient strategies by establishing strict goals and fundamental rules, and collaborate with leading countries. Ultimately, progress would be greater if successful management practices promoting the transition from a linear to a circular economy were applied.

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