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Tracing Relationship between Cluster's Performance and Transition to the Circular Economy

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Abstract: Clusters are defined as geographically close groups of organizations that work together to gain a competitive advantage. Clusters' shared activities involve knowledge sharing, a common pool of resources, innovations, and cooperation. From a more advanced perspective, clusters can work in industrial symbiosis sharing resources, energy, water, and other products. Tendencies of recent research indicate the growing interest in shifting to an efficient use of resources and sustainable development through the circular economy (CE). Clusters can work as enablers of CE to achieve a competitive advantage. The purpose of this study is to trace the relationships between cluster performance and shifting to the CE indicators. Correlation analysis was used as a method to indicate the relationships between pairs of clusters' performance and shifting to the CE indicators. The limitations of the research refer to the selection of the indicators as both concepts gain insights, although still debatable. The results show that 16 out of 25 cluster performance indicators were identified that have strong or moderate relationships among pairs while shifting to the CE indicators. These indicators are recommended to be included in observation, benchmarking, or evaluation of the clusters' activities. They can be significant in monitoring the development of shifting to the CE or in combinations with other research areas.

Keywords: cluster; circular economy; sustainable development; correlation; indicators; competitiveness; relationships

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Citation: Razminienė, K.; Vinogradova-Zinkevič, I.; Tvaronavičienė, M. Tracing Relationship between Cluster's Performance and Transition to the Circular Economy. *Sustainability* **2021**, *13*, 13933. https://doi.org/10.3390/su132413933

Academic Editor: Antonella Petrillo

Received: 8 October 2021
Accepted: 14 December 2021
Published: 16 December 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

In the scientific literature, the problems of the CE are increasingly analyzed in various areas where the principles of the CE can be applied [1]. Researchers [2,3] already found a field of interest where clusters are seen as a means to invoke small and medium enterprises (SMEs) [4,5] to be more resource-efficient, environmentally focused, and waste-conscious [6]. The links between waste, food, energy, water, and health for environmental sustainability have been traced [7–10]. CE is seen as a part of a far-sighted business that can deal with environmental problems [11–16].

The concept of the cluster was developed by Porter [17], who introduced clusters as geographically close critical masses, that are unusually competitive in particular fields. The competitiveness of clusters lies within the most common things—knowledge, relationships, innovations, common pool of resources, digital transformations [18]. It is often suggested that companies that belong to a cluster often outperform companies that work on their own. Advantages such as higher salaries, better recognition of a product or service provided, easier access to funding, frequent participation in fairs, as well as better financial indicators and many more are mentioned in scientific literature [19]. Clusters can be initiated through different perspectives. The most effective model, giving prominent results, to create a cluster is the bottom-up model by private companies. The top-down model initiated by public administration usually provokes a sudden reaction with less probable long-term existence of the newly established cluster [20]. Naturally formed clusters containing geographically close companies, research institutions, higher education institutions, and other entities are seen as being capable of producing the most benefits from cooperation [21]. The geographical location of the companies is usually used up for urban and industrial symbiosis, aiming at co-operation between industry and urban functions [22,23]. Authors also suggest that clusters can work in industrial symbiosis [24,25], which can be defined as a way of interacting with other companies to share materials, energy, water, and other products in infrastructure to gain a competitive advantage [25,26].

According to Eurostat [27], the EU inhabitants have generated 5.2 tons of waste per person in 2018. In the same year, 38.5% of waste was landfilled and 37.9% was recycled. Around 34% of all waste is generated in the construction sector, 30% in the mining and extraction sector, 10% in manufacturing, 8% in households, and 17% in other economic activities. Production and extraction processes produce a wide range of materials that can be used for recycling. E-waste is unique and diverse as it contains various metals and non-metals which makes it complicated to recycle. It is also challenging as e-waste contains hazardous materials and rare metals. The nature of the e-waste makes the recycling and resource recovery important [28,29]. Industrial processes and production generate waste [30,31] which results in climate changes when the waste is ignored and the release of greenhouse gases into the environment increases.

As urbanization processes take place and public consumption increases, unused waste accumulates every year. Natural resources are already being depleted but still used for production. Governments are familiar with this problem [32] and contribute to reducing environmental pollution and stimulating the economy by investing in the use of secondary materials through the implementation of new technologies. The development of the CE would reduce greenhouse gas emissions by improving waste management and reducing the use of resources (such as energy water, land, and materials) in production [33–35]. The basic mechanisms of the CE include product design and production use of the final product [36]. Understanding these mechanisms can make changes from the linear system to the CE [37].

Global sustainable development requires a reduction in harmful emissions produced by intercontinental cargo transportations [18]. There are various solutions suggested in reducing the transportation distance when the delivery of raw materials is addressed. One of the features that are characteristic of clusters is geographic proximity that can be seen as a valuable advantage when the transportation distance is addressed. The sustainable development of a region can be achieved through clustering in industrial and production areas [38] to make transportation more concentrated and coordinated between several companies. Furthermore, supply chains and closed-loop networks can be formed by cluster members [39]. To be more environmentally concerned, cluster members should think of exporting and importing recyclable raw materials as well as trading in recyclable raw materials within a cluster.

It is believed that many concepts are delivered by researchers and are kept only on a theoretical basis. However, clusters can develop the next steps in applying research into practice. With abilities of knowledge transfer, a pool of resources, digitalization, and financial instruments provided by governments [40], clusters can move further with more sustainable use of resources and waste management approach [41]. Sustainability debates often include economic transformations, quality of life, production, and consumption patterns as environmental concerns [22,31,42]. To address these issues, researchers use socio-economic and resource indicators to trace the potential of sustainability concepts.

The CE includes planning, resource allocation, purchasing, production, and processing which are designed and managed as a process and output to maximize the sustainable functioning of ecosystems. The CE encompasses entire production networks, keeping producer and consumer involved [43]. The European Commission suggests several factors that can help in shifting to the CE [44]: introducing relevant technologies in companies, educating about the benefits of the CE, adopting the CE, harmonizing the EU legislation on nature protection, and the transition of the public sector, its subsidiaries and enterprises, into green public procurement so that the development of countries is encouraged [45,46]. SMEs can also work through clusters to use up benefits of belonging to a unit and get financial support and assistance from national governments or the EU [47].

The purpose of the study is to trace the relationships between cluster performance and shifting to CE indicators. The interest in clusters is gaining popularity as the potential advantages of cooperation are recognized. It is also seen by researchers and practitioners that the CE is adopted by companies that belong to clusters. Clusters should be convinced that they are able to adopt a new business model and get support to encourage shifting to the CE. Indicators that make up the system need to be introduced and their significance verified, as the recent study states.

Here, a cluster is viewed as an entity that comprise companies and associated institutions supplementing others by completing vertical (buying and selling chains) and horizontal links (complementary products and services, the use of similar specialized inputs, technologies or institutions, and other linkages) using geographical proximity to achieve competitive advantage through cooperation. Another concept used in the study is circular economy, which seeks to minimize waste and resource use through intelligent product design, product reuse and repair, recycling, sustainable use of resources, and innovative business models that offer, for example, services such as leasing, lending or sharing products as an alternative to purchasing them. A selection of cluster performance and shifting to the CE indicators previously suggested after a literature analysis is used in this research. A correlation analysis is seen as an appropriate method when the relationship needs to be detected. Clusters are seen as enablers of a more waste-conscious, resource-efficient, and sustainable business model within cluster members. Competitive advantage acquired through belonging to the cluster can help to cope with financial shortages and lack of knowledge when sustainable decisions have to be taken.

This study contributes to the field of economics as it provides an indicators' system that allows the evaluation of cluster performance and shifting to the CE and verifies the significance of these indicators. Selected indicators can be further processed and used for application with other methods. The implication of the study is to show the importance of cooperation through relations in cluster that can help companies to shift to the CE. The need to support clusters' development by funding opportunities is cleared by indicating the importance of relationships.

The article is structured accordingly. At the very beginning of the article, a short literature analysis reviewing clusters and CE is provided. The next section gives a specific method description with a clear evaluation system. Then a comprehensive review of the results follows. The discussion and conclusions finalize the article.

2. Materials and Methods

The data for the research was taken from six Lithuanian clusters that belong to different sectors. The data was collected from different open access and confidential data sources, such as the State Social Insurance Fund Board under the Ministry of Social Security and Labour, State Budgetary Institution (SODRA), the official website of clusters in Lithuania Klaster.lt, Environment Protection Agency (EPA), and coordinators of the clusters. The State Social Insurance Fund Board under the Ministry of Social Security and Labour State Budgetary Institution (SODRA), contains information about monthly salaries of Lithuanian companies. The salaries of two years were collected from an open access database and average values used in the study. Klaster.lt was used to collect information about clusters that is easy to access on an explanatory website presenting clusters operating in Lithuania. Most general information was collected from the website, such as number of cluster members, years since cluster establishment, official website, logo, and other. The Environment Protection Agency (EPA) provided confidential information about waste cumulated per cluster according to the waste quantities reported by companies that belong to a particular cluster. Then, information that was not available on official data sources was asked for coordinators of clusters. A questionnaire survey was prepared and submitted to cluster managers, who responded reasonably.

The collected data was processed by calculating a median of years 2017–2018. A two-year lifespan was chosen as the changes applied in proper management need time to show the improvement of the results. The indicators that define the cluster's performance and shift to the CE were selected concerning the European Secretariat for Cluster Analysis (ESCA) [48] benchmarking guidelines and the CE monitoring indicators suggested by the European Commission [44].

Researchers use correlation analysis when the relationship between indicators needs to be traced. Authors use correlation in studies analyzing clusters with regional economic development factors [49], entrepreneurship activity environment, development of the IT sector [50], and trust in relationships [51]. Correlation analysis was applied to see a relationship between every cluster's performance indicator and shifting to the CE indicator. The purpose of correlation analysis is to determine whether there is a relationship between the variables x and y, where x denotes an independent factor and y denotes a dependent. The existence of a relationship between the factors is determined from the available statistics by calculating the Pearson correlation coefficient r and estimating its significance. When the magnitude of the correlation is significant, it is concluded that there is a relationship between factors. The possible range of the correlation coefficient varies from -1 to 1. Calculations were performed using Excel which uses the correlation calculation formula:

$$r = \frac{\frac{1}{n-1}\sum(x_1 - \overline{x})(y_1 - \overline{y})}{S_x S_y} \quad (1)$$

Here:

r—correlation coefficient; x_1—independent variable;
$\overline{x}$—average of x samples;
y_1—dependent variable;
$\overline{y}$—average of y samples;
S_x—standard deviation of the x sample;
S_y—standard deviation of the y sample.

CORREL function in Excel calculates the Pearson correlation coefficient r between two data sets. Two cell ranges of values need to be selected, where Array 1 is cluster performance indicator and Array 2 is shifting to the CE indicator. These indicators are defined by different values, such as numbers, currency, tones, years. A matrix with 250 pairs of indicators should be completed.

Table 1 shows the scale of values used to determine the significance of the relationship.

Table 1. The scale of correlation coefficient values.

Very Strong	Strong	Moderate	Weak	Very Weak	No Relation
−1	−1 to −0.7	−0.7 to −0.5	−0.5 to −0.2	−0.2 to 0	0
1	1 to 0.7	0.7 to 0.5	0.5 to 0.2	0.2 to 0	0

The closer the value is to one, the stronger the relationship exists and at the zero value, no relation is found. It is also considered that with a positive correlation coefficient, the values of y increase in the same direction with the values of x, and a negative correlation shows that when values of independent factor increase, the values of the dependent factor decrease.

The selection of the indicators was determined by the previous research which covered the literature analysis [52]. Hence, 25 indicators are taken to determine the cluster's performance and 10—shifting to the CE. In total there are 35 indicators used in this research.

3. Results

The correlation was determined between pairs of clusters' performance and shifting to the CE indicators, where x is a cluster's performance and y—their shift to the CE. A table with 250 possible correlation pairs was formed. The results of the correlation analysis showed that among 25 cluster performance indicators and 10 shifts to the CE indicators, there were 24 strong relationships (10% out of all possible correlations), 51 moderate relationships (20% out of all possible correlations), 116 weak relationships (46% out of all possible correlations) and 59 very weak relationships (24% out of all possible correlations) (Figure 1).

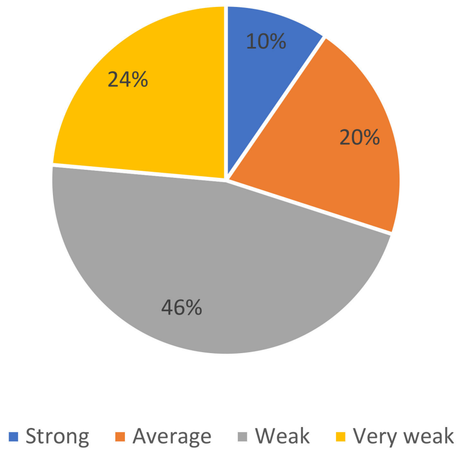

Figure 1. Percentage of correlations found from the total number of possible combination pairs.

As seen in Figure 1, strong and moderate relationships together make up on third of all possible relationships, while weak relationships make up almost half of all possible relationships.

Table 2 shows the number of strong correlations between pairs of indicators. There are 24 strong relationships between pairs of cluster performances and shifts to the CE indicators. Six strong relationships are detected with a co-operation indicator while creating new products or technologies, four—with the indicator for joint cluster members' tenders for external clients, three—with transference of technologies, two—with co-operation while creating innovations (organizational, marketing, etc.) and exchange of market information between cluster members, and one—participation in exhibitions and fairs, visual identification (logo, brand), number of cluster members—companies, R&D subjects, supporting organizations, number of cluster coordinating members, projects submitted together in two years, number of projects submitted together or funded by the EU SF projects in two years.

Looking at the correlations between the indicators, it can be seen that fifteen of the relationships are negatively defined, while the other nine are positively defined. According to the definition, the higher values in performance of the cluster are characterized by lower values in the shift to the CE criteria. In the case of positively defined relationships, this means that, according to the results of the study, it is observed that the higher values for performance of the cluster are characterized by higher values in the shift to the CE criteria.

There are several strong relationships between repetitive indicators. Cluster performance indicator—co-operation while creating new products or technologies—is negatively defined by six relationships with a shift to the CE indicators. This means that the better co-operation while creating new products or technologies, the lower the generation of municipal waste per cluster, packaging waste, plastic packaging waste, wooden packaging waste, biowaste, construction, and demolition waste detected.

Another cluster performance indicator—co-operation while creating new products or technologies—is negatively defined by two shifts in the CE indicators. This means that the better the co-operation while creating new products or technologies between cluster members, the lower the biowaste, construction, and demolition waste discovered.

Table 2. Strong correlations between cluster performance and shifting to the CE indicators pairs.

No	Axis *x*	Axis *y*	r
1	Co-operation while creating new products or technologies	Generation of municipal waste per cluster	−0.71
2		Packaging waste	−0.77
3		Plastic packaging waste	−0.71
4		Wooden packaging waste	−0.81
5		Biowaste	−0.70
6		Construction and demolition waste	−0.73
7	Co-operation while creating innovations (organizational, marketing, etc.)	Biowaste	−0.73
8		Construction and demolition waste	−0.88
9	Transference of technologies	Packaging waste	−0.75
10		Biowaste	−0.70
11		Construction and demolition waste	−0.70
12	Joint cluster members' tenders for external clients	Generation of municipal waste per cluster	0.70
13		Packaging waste	0.75
14		Wooden packaging waste	0.72
15		Construction and demolition waste	0.70
16	Exchange of market information between cluster members	Wooden packaging waste	0.70
17		Construction and demolition waste	0.78
18	Participation in exhibitions and fairs	Wooden packaging waste	0.70
19	Visual identification (logo, brand)	Wooden packaging waste	0.71
20	Number of cluster members—companies, R&D subjects, supporting organizations	Trade in recyclable raw materials within a cluster	−0.81
21	Number of cluster coordinating members	Trade in recyclable raw materials within a cluster	0.96
22	Projects submitted together in two years	Wooden packaging waste	−0.82
23	Number of submitted together/funded EU SF projects in two years	Wooden packaging waste	−0.78
24	Number of submitted together international R&D projects, funded not from EU SF, in two years	Construction and demolition waste	−0.86

The transference of technologies has three negatively defined relationships. This means that the better transference of technologies seen, the lesser packaging waste, biowaste, construction, and demolition waste is detected.

The situation is different with joint cluster members' tenders for external clients. There are four positively defined relationships, which means that when more joint cluster members' tenders for external clients are made, the quantity of generation of municipal waste per cluster, packaging waste, wooden packaging waste, construction and demolition waste grows. The exchange of market information between cluster members is also positively defined by two relationships. This means that the existing exchange of market information between cluster members may affect the increase in wooden packaging, waste, and construction and demolition waste.

Participation in exhibitions and fairs is positively related to wooden packaging waste. This means that participation in exhibitions and fairs may increase wooden packaging waste.

The same correlation is observed with visual identification (logo, brand), which is also viewed as being involved in a larger production of wooden packaging waste.

The number of cluster members—companies, R&D subjects, supporting organizations are negatively related to trade in recyclable raw materials between cluster members. This should indicate that the more companies belong to the cluster, the less trading in recyclable raw materials is detected.

Another cluster's performance indicator is also related to the same shift to the CE indicator. In this case, a number of cluster coordinating members are positively related to trade in recyclable raw materials between cluster members. This indicates that a greater number of cluster coordinators may increase the trade in recyclable raw materials between cluster members.

Projects submitted together in two years are negatively related to wooden packaging waste. This indicates that projects submitted together decrease the quantity of wooden packaging waste produced.

The same relationship is valid for the number of submitted projects together or funded EU SF projects in two years with wooden packaging waste. In this case, the cluster performance indicator is negatively related to shifting the CE indicator. This indicates that the shared submitted or funded EU SF projects have an impact on decreasing the amount of wooden packaging waste.

The number of submitted projects together international R&D projects, funded not from EU SF, in two years is negatively related to construction and demolition waste. This shows that the more shared international R&D projects, funded not from EU SF cluster members have, the less construction and demolition waste is produced.

Table 3 shows the number of moderate correlations between pairs of indicators. There are 51 relationships between pairs of cluster performances and shifts to the CE indicators. Seven moderate relationships are detected with indicator projects submitted together in two years and financed projects submitted together in two years with cluster initiative co-financing, six—with a number of submitted together or funded EU SF projects in two years, five—with participation in exhibitions and fairs, four—with co-operation while creating innovations (organizational, marketing, etc.), transference of technologies, exchange of market information between cluster members, three—with joint cluster members' tenders for external clients, an increase of cluster members' employees in two years, years of cluster establishment, two—with co-operation while creating innovations (organizational, marketing, etc.), visual identification (logo, brand), one—with a transference of technologies.

The correlation analysis results show that 33 relationships are negatively defined and the rest 18 are positively defined. The majority of relationships show that better value of cluster performance indicator is related to lower shifting to the CE values.

The relationship between co-operation while creating new products or technologies is negatively defined with a shift to the CE indicator—e-waste. This indicates that if clusters co-operate to create new products or technologies, less e-waste will be generated.

Another indicator, co-operation while creating innovations (organizational, marketing, etc.) is negatively related to four CE indicators. All four relationships are negatively defined, which indicates that quantities of generation of municipal waste per cluster, packaging waste, plastic packaging waste, and e-waste are lower when innovations are introduced by members working together.

E-waste may increase when informal sharing of knowledge and experience is present between cluster members. The relationship between these indicators is positively defined. The same cluster performance indicator is related to trade in recyclable raw materials between cluster members. The relationship is positively defined—sharing of knowledge and experience leads to trading between cluster members.

Transference of technologies is related to four CE indicators. The relationship is negatively defined. This shows, that when cluster members tend to share technologies, the generation of municipal waste, plastic packaging waste, wooden packaging waste, and e-waste is reduced.

On the contrary, joint cluster members' tenders for external clients cause increased quantities of plastic packaging waste, e-waste, and biowaste. The relationships between this cluster performance indicator and three shifting to the CE indicators are negatively defined.

The exchange of market information between cluster members has four positively defined relationships between shifting to the CE indicators. When cluster members exchange shared market information, the quantity of generation of municipal waste per cluster, packaging waste, plastic packaging waste, and biowaste increase.

Table 3. Moderate correlations between cluster performance and shifting to the CE indicators pairs.

No	Axis *x*	Axis *y*	r
1	Co-operation while creating new products or technologies	E-waste	−0.69
2	Co-operation while creating innovations (organizational, marketing, etc.)	Generation of municipal waste per cluster	−0.68
3		Packaging waste	−0.66
4		Plastic packaging waste	−0.66
5		E-waste	−0.67
6	Informal sharing of knowledge and experience	E-waste	0.60
7		Trade in recyclable raw materials within a cluster	−0.58
8	Transference of technologies	Generation of municipal waste per cluster	−0.69
9		Plastic packaging waste	−0.68
10		Wooden packaging waste	−0.62
11		E-waste	−0.68
12	Joint cluster members' tenders for external clients	Plastic packaging waste	0.69
13		E-waste	0.68
14		Biowaste	0.68
15	Exchange of market information between cluster members	Generation of municipal waste per cluster	0.51
16		Packaging waste	0.56
17		Plastic packaging waste	0.51
18		Biowaste	0.52
19	Participation in exhibitions and fairs	Generation of municipal waste per cluster	0.58
20		Packaging waste	0.67
21		Plastic packaging waste	0.58
22		E-waste	0.56
23		Biowaste	0.53
24	Visual identification (logo, brand)	Packaging waste	0.51
25		Construction and demolition waste	0.52
26	Increase of cluster members' employees in two years	Plastic packaging waste	0.60
27		Imports of recyclable raw materials	0.61
28		Trade in recyclable raw materials within a cluster	0.69
29	Years of cluster establishment	Wooden packaging waste	−0.58
30		Imports of recyclable raw materials	−0.69
31		Exports of recyclable raw materials	−0.65
32	Projects submitted together in two years	Generation of municipal waste per cluster	−0.59
33		Packaging waste	−0.60
34		Plastic packaging waste	−0.64
35		E-waste	−0.58
36		Biowaste	−0.56
37		Construction and demolition waste	−0.52
38		Trade in recyclable raw materials within a cluster	−0.56
39	Financed projects submitted together in two years with cluster initiatives co-financing	Generation of municipal waste per cluster	−0.56
40		Packaging waste	−0.55
41		Plastic packaging waste	−0.61
42		Wooden packaging waste	−0.69
43		E-waste	−0.56
44		Biowaste	−0.56
45		Construction and demolition waste	−0.63
46	Number of submitted together/funded EU SF projects in two years	Generation of municipal waste per cluster	−0.62
47		Packaging waste	−0.63
48		Plastic packaging waste	−0.68
49		E-waste	−0.62
50		Biowaste	−0.59
51		Trade in recyclable raw materials within a cluster	−0.55

The same is valid for participation in exhibitions and fairs. The relationships with a generation of municipal waste per cluster, packaging waste, plastic packaging waste, e-waste, and biowaste are positively defined. The positively defined relationship shows that participation in exhibitions and fairs by cluster members influences higher quantities of listed kinds of waste. Visual identification (logo, brand) also has positively defined relationships with packaging waste, and construction and demolition waste.

An increase of cluster members' employees in two years affects higher amounts of plastic packaging waste, trade in recyclable raw materials when they are imported by cluster members, and trade in recyclable raw materials within a cluster. The relationship among cluster performance indicator and trading of recyclable raw materials as well as an increase in plastic packaging waste is positively defined.

Years of cluster establishment has a negatively defined relationship when it is considered how old a cluster is with regards to wooden packaging waste, trade in recyclable raw materials when they are imported by cluster members, and trade in recyclable raw materials within a cluster. This indicates that the older the cluster is, the less likely it is that they are involved in the trading of recyclable raw materials.

The situation is different with projects submitted together. Negatively defined relationship indicates that if cluster members have shared projects, the quantities of generation of municipal waste per cluster, packaging waste, plastic packaging waste, e-waste, bio waste, construction and demolition waste are reduced. On the contrary, these positive effects are linked to negatively defined relationships with trade in recyclable raw materials within a cluster. This demonstrates that projects submitted together also make trading within clusters less likely.

Financed projects submitted together in two years with cluster initiatives co-financing has moderate relationships with all seven groups of waste. This means that financed cluster projects with cluster initiatives have a positive effect on reducing the generation of municipal waste per cluster, packaging waste, plastic packaging waste, wooden packaging waste, e-waste, bio waste, and construction and demolition waste.

A number of submitted together or funded EU SF projects in two years has negatively defined relationships with a generation of municipal waste per cluster, packaging waste, plastic packaging waste, e-waste, and biowaste. Cluster performance indicator also has a negative effect on trade in recyclable raw materials within a cluster. This shows that EU SF projects indicate better cluster performance and have an impact on reduced quantities of waste. However, it also reduces the chances that cluster members will increase the trading within a cluster.

The results of the correlation analysis indicate that 16 out of 25 cluster performance indicators have strong or moderate relationships with all ten shifting to the CE indicators (Figure 2). Most of the strong and moderate relationships are negatively defined (64% out of 75 relationships) while the rest of the strong and moderate relationships are positively defined (36% out of 75 relationships). As seen from the description of each relationship, most negatively defined relationships show that better cluster performance leads to lower waste generation. Positively defined relationships occur when external clients are being reached by shared activities of cluster members, which results in a higher generation of different types of waste.

Table 4 shows the number of strong and moderate relationships that occur in pairs of cluster performance and shifting to the CE indicators. These indicators can be marked out as being the most significant when the activities of a cluster are observed or evaluated. The indicators can be depicted according to their significance by the number of strong and moderate relationships that they have with shifting to the CE indicators. Most relationships are seen with an indicator that shows the number of projects submitted together in two years. There are eight relationships and the majority of them are moderate. Other important indicators have seven relationships. There are five such indicators: co-operation while creating new products or technologies, transference of technologies, joint cluster members' tenders for external clients, financed projects submitted together in two years with cluster initiatives co-financing, the number of submitted together/funded EU SF projects in two years. Four indicators have six strong and moderate relationships: co-operation while creating innovations (organizational, marketing, etc.), exchange of market information between cluster members, participation in exhibitions and fairs, an increase of cluster members' employees in two years. Then, the number of relationships as well as the number of indicators that possess these relationships decrease. Two indicators have three strong and moderate relationships: visual identification (logo, brand), years of cluster establishment. One indicator has two relationships—informal sharing of knowledge and experience. One strong relationship is possessed by three cluster performance indicators: number of cluster members—companies, R&D subjects, supporting organizations, number of cluster coordinating members, number of submitted together international R&D projects, funded not from EU SF, in two years.

Other results reveal less weighty relationships. Table 5 includes only those indicators that have no strong or moderate relationships, only weak or very weak. These indicators are not considered as being not significant in cluster performance and shifting to the CE monitoring. On the contrary, these indicators show less impact on shifting to the CE for researched clusters exceptionally in a recent study.

Weak relationships make up the majority of all relationships among pairs of cluster performance and shifting to the CE. This is also visible in distribution among indicators that do not have strong or moderate relationships. There are two indicators that have the weakest relationships: shared database and a total sum of cluster members' investments for cluster initiatives in two years. In this case, all ten relationships are weak. Seven weak relationships are found with three indicators: shared training, workshops, conferences, internships, the average salary of cluster members, external financing for cluster initiatives in two years. Another three indicators have five weak relationships: shared supply and order scheme, number of employees that upgraded qualification in two years, university graduates working at cluster companies. Only one cluster performance indicator has more very weak relationships (six) than weak relationships (four)—shared distribution channels.

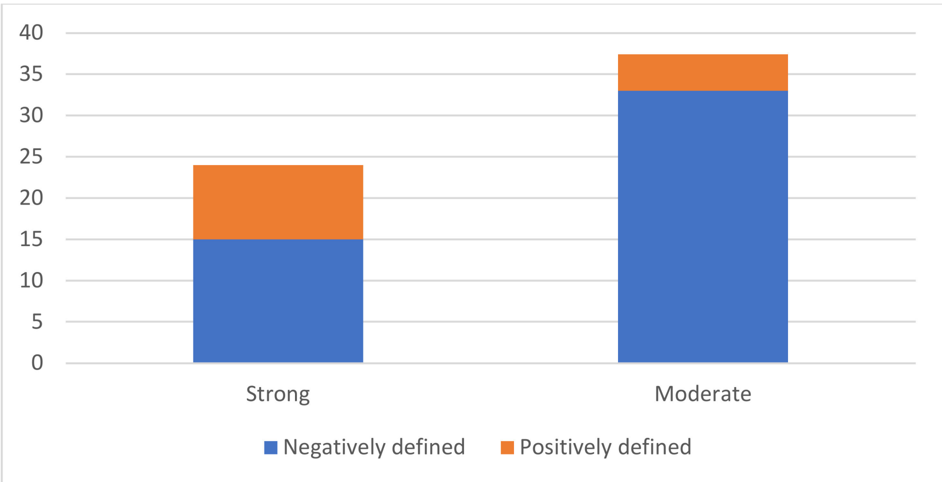

Figure 2. The distribution of positively and negatively defined correlations in strong and moderate relationships.

Table 4. The number of strong, moderate, and total correlations among pairs of cluster performance and shifting to the CE indicators.

No	Cluster Performance Indicator	Number of Relationships		
		Strong	Moderate	Total
1	Co-operation while creating new products or technologies	6	1	7
2	Co-operation while creating innovations (organizational, marketing, etc.)	2	4	6
3	Informal sharing of knowledge and experience	0	2	2
4	Transference of technologies	3	4	7
5	Joint cluster members' tenders for external clients	4	3	7
6	Exchange of market information between cluster members	2	4	6
7	Participation in exhibitions and fairs	1	5	6
8	Visual identification (logo, brand)	1	2	3
9	Increase of cluster members' employees in two years	3	3	6
10	Number of cluster members—companies, R&D subjects, supporting organizations	1	0	1
11	Number of cluster coordinating members	1	0	1
12	Years of cluster establishment	0	3	3
13	Projects submitted together in two years	1	7	8
14	Financed projects submitted together in two years with cluster initiatives co-financing	0	7	7
15	Number of submitted together/funded EU SF projects in two years	1	6	7
16	Number of submitted together international R&D projects, funded not from EU SF, in two years	1	0	1
	Total			75

Table 5. The number of weak and very weak correlations among pairs of cluster performance and shifting to the CE indicators.

No	Cluster Performance Indicator	Number of Relationships	
		Weak	Very Weak
1	Shared training, workshops, conferences, internships	7	3
2	Shared database	10	0
3	Shared supply and order scheme	5	5
4	Shared distribution channels	4	6
5	Number of employees that upgraded qualification in two years	5	5
6	The average salary of cluster members	7	3
7	University graduates working at cluster companies	5	5
8	External financing for cluster initiatives in two years	7	3
9	The total sum of cluster members' investments for cluster initiatives in two years	10	0

4. Discussion and Conclusions

Positively related indicators with strong relationships show debatable results. Cluster performance indicator—number of cluster members—and shifting to the CE indicator—trade in recyclable raw materials—are negatively related, meaning that the increase of cluster members makes trading less possible. Another indicator—the number of cluster coordinating members—is also related to the same shifting to the CE indicator, but it shows the opposite. This might refer to the present situation of observed clusters. The trade in recyclable raw materials is less common in clusters that have more members, but the potential is seen as cluster coordinators can affect trading in the opposite direction.

Most strong and moderate relationships are negatively defined. All of the clusters' performance indicators are of maximizing direction, which means that higher value indicates better performance. On the contrary, seven out of ten shifting to the CE indicators are of minimizing nature, which means that lower value indicates better performance. Negatively defined results of correlation analysis naturally verify the idea that clusters with better performance results are better at shifting to the CE. In general, shared members' activities within a cluster are related to the lower generation of different kinds of waste. On the contrary, developing external links together with clients may result in higher quantities of waste.

The activities within a cluster can be defined as reducing quantities of different kinds of waste. These activities enable cluster members to trade in recyclable raw materials between each other. At the same time, connections with external clients affects the increase in the quantities of waste. Cluster members should think of a possibility to reduce waste when external clients are involved. As generally observed from the results of correlation analysis, better cluster performance contributes to the reduction of waste. Which can apply to other areas to use up the cluster potential.

Sixteen cluster performance indicators were identified that have strong or moderate relationships among pairs with shifting to the CE indicators. These indicators are recommended to be included in observation, benchmarking, or evaluation of the clusters' activities. They can be significant in monitoring the development of shifting to the CE or in combinations with other research areas.

The study adds to the cluster and the CE analysis as it provides observations regarding the relationships between these entities. A number of indicators were collected and the relationships traced. Clusters can be used as a basis for cooperation that can help companies to shift to the CE. The suggested comparison between alternatives indicates that clusters' development needs to be supported and funding opportunities should be proposed. The research has limitations regarding the cluster performance and shifting to the CE indicators. As already mentioned, the concept of a cluster is relatively new and the interest of researchers is still growing. There are ambiguities in the use of a term, which is often related to the industrial districts, while a CE model may be referred to the industrial symbiosis. Hence, different indicators are depicted by researchers when cluster performance or shifting to the CE is assessed. In this research only officially operating clusters reaching for excellence are referred as clusters, because other organizations cannot provide the necessary data. The indicators for the research were selected according to the cluster excellence guidelines given by ESCA and the framework of monitoring the CE given by the European Commission.

Future research should include a greater number of clusters with updated information. The data for this research covers a period before the pandemics. Hence, additional indicators should be included regarding the changes in the situation worldwide. A comparison could be made in terms of how the pandemics affected the shifting to the CE if cluster members had to change their usual working models and adapt to changing markets. The pandemic has revealed the necessity to turn to circular business models as the reduced production uncovered the problems of resources exhaustion and massive pollution.

Author Contributions: K.R. and M.T. conceptualized the idea of the research; K.R. and I.V.-Z. prepared the methodology; K.R. performed a formal analysis, investigated the background of the research, prepared the original draft; M.T. and I.V.-Z. reviewed and edited. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Most of the data used in this research is confidential. Open access official information can be found in these databases: State Social Insurance Fund Board under the Ministry of Social Security and Labour, State Budgetary Institution (SODRA), https://atvira.sodra.lt/imones/paieska/index.html (Accessed on 15 September 2021); official website of clusters in Lithuania https://klaster.lt/; Environment Protection Agency (EPA) https://aaa.lrv.lt/.

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

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