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FROM THE REBOUND EFFECT TO THE PERSPECTIVE OF CIRCULAR ECONOMY:A STRUCTURE CHANGES ANALYSIS AMONG EU COUNTRIES

Abstract. European Union represents a multicultural organization which aims to promote the common well-being and diversity in all forms. The national diversity leads to economic gaps among EU countries. Hence, two of the most important targets of European Union are reducing the discrepancies among countries and increasing social inclusion. Starting from the idea of inequalities among EU-27 countries, the paper aims to find out solutions to the structural relationship between economic gaps and resources efficiency among EU countries, the linkage between rebound effect and economic development and to analyse the perspective of Romanian economy across European Union over the period 2000-2019.In order to achieve all objectives, the period 2000-2019 will be split in two distinct periods, before Romania's accession to European Union (2000-2006) and after Romania's accession (2007-2019). Likewise, in consonance with paper's targets there were used data mining methods, like K-Means Clustering Algorithm and Random Forest Classification Model. By using these two methods of unsupervised and supervised learning, the paper shows the demeanour of European countries over the period 2000-2019 and, also, provides a radiography of the transition to European desiderates, a sustainable society and green economic. Following the objectives, it generates an analysis the EU-27 economic structure and the changes over the years, especially from rebound effect perspective.

Keywords: rebound effect, sustainable society, economic gaps, environment, public policies, EU-27.

JEL classification:F64, I38, L72, L78

1. Literature Review

The "Two-speed Europe" slogan is still actual when it is talking about economic inequality across European Union. According to Immarino et al. (2019), Dobre et al. (2019), the gap between EU countries are coming from mobilising

human resources and other resources. The main goal to all countries is to combat under-utilisation of regions` people and resources. They concluded that institutional sector plays an important role in inequality between countries. Howbeit, beyond economic productivity and economic growth, when it is developed an economic growth strategy, it's necessary to take into account the rebound effect. The economic growth in the context of rebound effect was analysed by Vivanco et al. (2016), affirming that the main cause of rebound effect is energy consumption. As Stern (2020) concluded, the improved energy efficiency hasn't a major impact of reducing rebound effect, because consumption become more oriented to energy-intensive goods and services. Circular economy is not enough to reduce rebound effect, Zink & Geyer (2017) affirmed that circular economy rebound occurs when circular economy activities, which have lower per-unit production impacts, cause increased levels of production, reducing their benefits. Therefore, in order to come closer to a sustainable society the main objective should be the trade-off between ecosystems services (Figge & Torpe, 2019).

In order to have a sustainable economic growth, each country should focus on the best way of resources use. Andabaka et al. (2019), sustained that eco-innovation is a powerful instrument that underpins the EU's commitment to sustainable economic growth. From their point of view, there are two important ways to curb countries gap. Firstly, institutional support through EU policies, regulatory framework, and mechanisms for stimulating innovation and application of new technologies are particularly important driver of eco-innovation in catching-up countries. Secondly, the rate of recycling of municipal waste is the key to re-use materials. Also, the former idea is sustained by Akadiri et. al (2019) through their article within they carried out a comprehensive analysis over the period 1995-2015 of 28 European Union Countries (EU-28), presenting as main result the existence of a significant, long run, nexus among environmental sustainability, renewable energy consumption and economic growth. So, it can say that the transition to circular economy is the key to fill the gap between countries across EU.

Despite being actual, the problem seems to be older, the discrepancies of economic growth increased rapidly since 2005(Wiedenhofer et al., 2020). The main reason of the discrepancies among EU countries is the specificity of regions, many panel data presented fixed effects (Mihai et al., 2018). A special case is represented by ex-communist countries, which has another structure of economic development. For example, according to Goschin et al. (2015), Romania should, roughly, spend between 5 and 25 years in order to fill the gaps. One of the direction to be followed up by Romania is municipal waste management which integrates a circular economy model. Applying and integrating a circular economy concepts, the gaps beetwen Romania and EU-contries has narrowed over the time (Popa &

Albu,2019). Moreover, the EU funds attracted by Romania had a positive impacton its economy and, also, in the process of reducing offsets(Diaconu & Maxim, 2019).Nonetheless, the transition of Romanian economy to a circular economy using coercive measures is not the right option, because of the negative correlation between environmental taxes and GDP growth, said Radulescu et al. (2017). However, Romania has a good potential to make the transtion from a conventional economic behaviour to circular economy (Dragoi et al., 2018), being obvious that Romania changed its social and economic behaviour after accession to European Union.

2. Data& methodology

Starting from literature review it`s seems to be imperative to analyse the differences among EU's countries from the angle of economic development model. In this section are presented data and methodology used to have relevant results. The data were collected from EUROSTAT database for all 27 countries of European Union (EU-27). The completeness and comparability of data were the most important criteria in the process of selecting relevant variables. In order to achieve paper's objectives, the variables selected were: Domestic Extraction, Material Import Dependency, Resource Productivity, Total Environmental Taxes, Gross Domestic Product. Domestic extraction, Material Import Dependency and Resource Productivity are three relevant variables for resource efficiency sector, more or less, these variables could be linked with the concept of circular economy.Total Environmental Taxes is an important variable in the process of slashing the rebound effect. Also, GDP per capita is the suitable indicator when it comes to economic development and standard of living. To have a wider view, in the next table the variables were presented in more details.

Table 1. Variables details

Acronym	Name of variable	Unit measure
DE	Domestic Extraction	Tonnes per capita
MID	Material Import Dependency	Percentage
RP	Resource Productivity	Index
TET	Total Environmental Taxes	Percentage of Gross Domestic Product
GDP	Gross Domestic Product	Gross Domestic Product per capita

In order to assure the completeness and comparability across EU-27, the time horizon of variables is between 2000 and 2019. In addition, to achieve one of the paper objectives, the period was split in two different periods, before 2007 (before

Romania's accession to EU) and after 2007 (after Romania's accession to EU). These two periods help to a better understanding of Romania's place among EU-27 countries, because it's certain that the economic demeanour of Romania was different before EU's accession. Starting from that, for each period, the variables values represent a mean of each country. In other words, each country has two attributes for each variable, one for the first period and one for the second period. Further, in order to have a comprehensive analysis and to achieve all paper's targets, it will be used methods like K-means clustering and Random Forest Classification Methods. The main scope of these methods is to find out a statistical association between resource efficiency, rebound effect and economic growth. Using K-means method, the article aims to show the similarities and gaps among EU-27 countries from economic growth point of view. Moreover, to identify a possible association between economic growth, resource efficiency and rebound effect, it was used a Random Forest model. The results of Random Forest model show the structural relationship between economic growth and rebound effect.

K- means clustering is an unsupervised method of clustering which divides a data set into K distinct, non-overlapping clusters. To perform K-means clustering, we must first specify the desired number of clusters K (Celebi et al., 2013). Then, the K-means algorithm will assign each observation to exactly one of the K clusters. The K-Means clustering is an iterative process in two phases. In the first phase, are assigned random numbers, from 1 to k, to each observations. These serve as initial cluster assignments for the observations. In the second phase, the process iterates until the cluster assignments stop changing. The second phase is split in two different sub-phases. In the first instance, for each k clusters, it is computed the cluster centroid, the kth cluster centroid is the vector of the p feature means for the observations in the kth cluster. In the second instance, it is assigned each observation to the cluster of which centroid is closest (where closest is defined using Euclidian Distance) (Gareth et al., 2013).

Briefly, the main target is to partition the observations into K clusters such that the total within-cluster variation, summed over all K clusters, is as small as possible(Timmerman et al., 2013).

According to Gareth et al. (2013), random forests provide an improvement over bagged trees by way of a random small tweak that de-correlates the trees. As in bagging, it builds a number forest of decision trees on bootstrapped training samples. But when building these decision trees, each time a split in a tree is considered, a random sample of m predictors is chosen as split candidates from the full set of p predictors. The split is allowed to use only one of those m predictors. A fresh sample of m predictors is taken at each split, and typically we choose m ≈

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$\sqrt{p}$ that is, the number of predictors considered at each split is approximately equal
to the square root of the total number of predictors (Scornet et al., 2015). The main
difference between bagging and random forests is the choice of predictor subset
size m. For instance, if a random forest is built using m = p, then this amounts
simply to bagging. Random forests using m = $\sqrt{p}$ leads to a reduction in both test
error and OOB error over bagging. Using a small value of m in building a random
forest will typically be helpful when we have a large number of correlated
predictors (Scornet et al., 2015).

All methods are carried out using R, helped by packages as: readxl, ggplot2, rpart,
randomForest, factoextra.

3. Resultsand discussions

The economic gaps among EU countries

In order to know which is the number of optimal k clusters, it applied 3 methods:
Elbow method, Silhouette method and Gap statistic method.

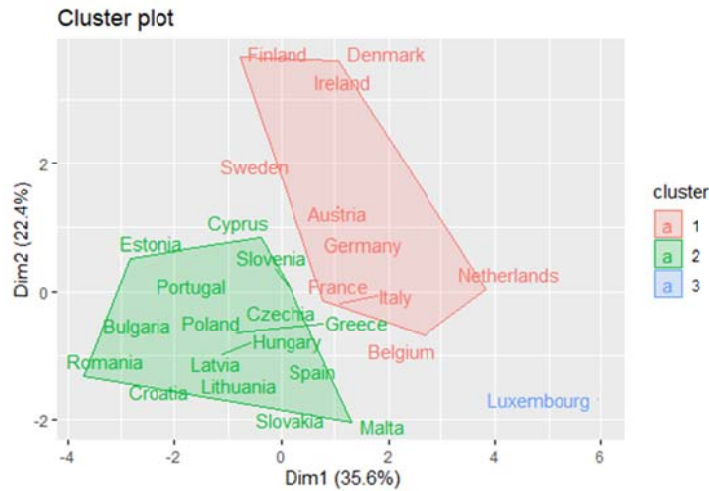**Figure 1. Optimal number of clusters (2000-2006)**
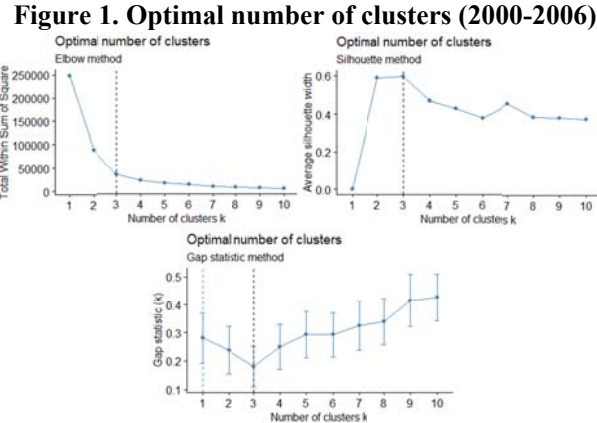
Source: own processing using RStudio

Performing all 3 methods to view the optimal number of k clusters, it is clear that
the k number of clusters is 3 (Figure 1).

Because it`s known the number of clusters, EU-27 countries were clusterized for
k=3.

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Figure 2. Cluster plot distribution (2000-2006)

Source: own processing using RStudio

The first cluster is made up of countries from west or north of the Europe. The second is mainly consisted of ex-communist countries, like: Romania, Bulgaria, Czech republic, Latvia, Estonia, Lithuania, Hungary, Slovakia, Slovenia or Croatia and south countries, as: Greece, Malta or Cyprus. Although, there are two west countries (Spain and Portugal) with analogous economic growth model like East and South countries. On the other hand, Luxembourg is the only country from cluster 3 which lead us to conclusion that it is the outlier of European Union (Figure 2).

In order to have a more comprehensive analysis of these 3 clusters, the results were analysed in more details. The first cluster is composed of 10, the second of and the third cluster is represented only by one country which is the outlier of European Union, Luxembourg.

Table 2. Cluster's features (2000-2006)

Number of cluster	Mean	Within cluster variance
1	146.98	3651.02
2	45.55	10304.04
3	289.14	0

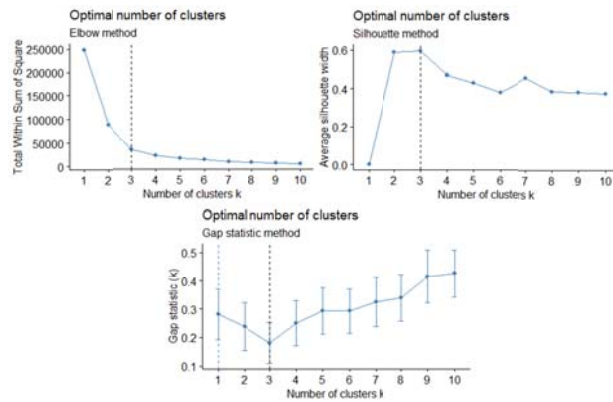*Source: own processing using RStudio*

The cluster number 1 is characterized by a huge value of GDP per capita, the second by a low level of GDP per capita with the biggest variation within cluster

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and the third is represented by Luxembourg with the highest level of GDP per capita (Table2).
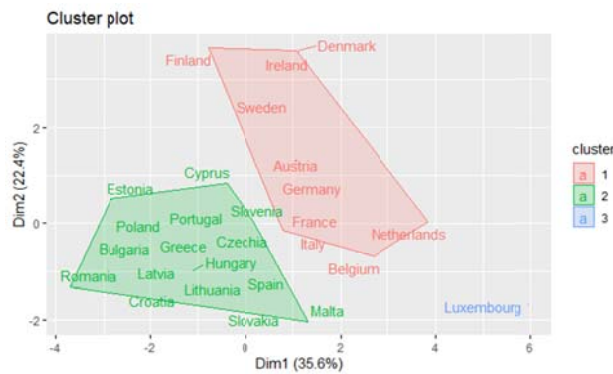During the period 2007-2019, the optimal number of clusters is 3.

Figure 3. Optimal number of clusters (2007-2019)

Source: own processing using RStudio

In other words, it will be performed the method of k-means using k=3 (Figure 3).

Figure 4. Cluster plot distribution (2007-2019)

Source: own processing using RStudio

All of three clusters have the same composition as the period before 2007. Although, it is important to notice the main features of each cluster (Figure 4).

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Table 3. Cluster's features (2007-2019)

Number cluster	Mean	Within cluster variance
1	144.26	4959.98
2	54.99	5532.34
3	323.38	0

Source: own processing using RStudio

Comparing with the prior period, the mean of GDP per capita for each cluster seems to be on the rise. It is important to mention that the variation within clusters is on the rise in first cluster which means that the discrepancies between EU-27 countries are on the rise. On the other side, when it talks about the second cluster it is a good sign that the gap between countries seems to be on decrease (Table 3).

The relationship between rebound effect and economic growth across EU-27

In order to observe structural change from 2000-2019 period, it was performed Random Forest model for both periods analysed. The predicted variable was „The number of cluster of each country" (variable computed in the prior section), having as predictors variables like: Domestic Extraction, Material Import Dependency, Resource Productivity, Total Taxes Environmental.

More than the classification result, it is important to analysis and understand the influence of each predictor to each cluster. Starting from the predictor's influence, it is identified the right directions to be followed in order to develop a sustainable economic growth and, perhaps, the most important thing, to reduce the gap among EU-27 countries.

Table 4. Classification matrix (2000-2006)

| Number of clusters	1	2	3	Classification error
1	4	6	0	60%
2	3	13	0	18.75%
3	0	1	0	100%

Source: own processing using RStudio

Until 2007, at each split, the number of discriminant variables used was two. Random Forest model provided only two clusters, having the error rate of classification was around 37%. The result brings in discussion the existence of countries which not present correlated GDP per capita with the predictors. Excluding Luxembourg (cluster 3), which is a particular case, the biggest error rate of classification (60%) had cluster 1 (west and north countries). According to the confusion matrix majority of countries from cluster 1 should be in the second cluster from the predictors point of view. On the other hand, cluster number 2

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presented the lowest error rate of classification which means the predictors are strongly correlated with economic growth (Table 4). With other words, a relevant solution to reduce the gaps between countries from cluster 2 and countries from cluster 1 and cluster 3 is to manage predictors from this model. This is why it have to analyse the importance of predictors.

Figure 5. The importance of predictors (2000-2006)
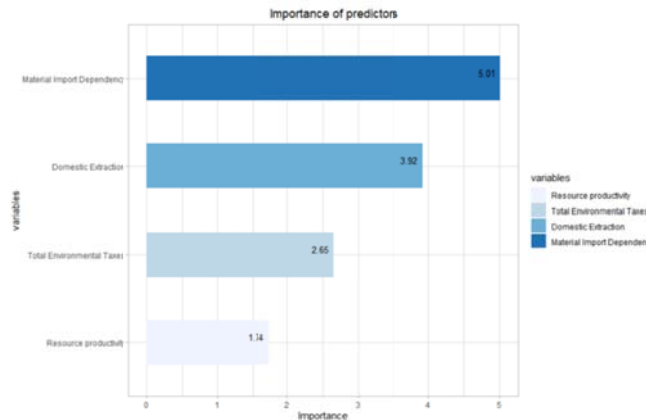
Source: own processing using RStudio

The most important predictor until 2007 is Material Import Dependency, on the opposite the lowest influence comes from Resource Productivity. Mostly, economic growth is influenced by relationship between Material Import Dependency and Domestic Extraction, being complementary variables (Figure 5). Now, it is interesting to see which country change their cluster and which remain in the same cluster. But, first of all, it should be presented the new members of each clusters:

Table 5. Composition of new clusters (2000-2006)

Number of cluster	Countries
1	Belgium, Denmark, Finland, Germany, Lithuania, Slovakia, Slovenia
2	Bulgaria, Croatia, Cyprus, Czech republic, Estonia, Greece, Hungary, Latvia, Malta, Poland, Portugal, Romania, Spain, Austria, France, Ireland, Italy, Luxembourg, Netherlands, Sweden

Source: own processing using RStudio

The are a lot of changes among clusters. Countries from est and south of Europe are now in the same cluster with East and North countries. Moreover, ex-soviets countries, like: Lithuania, Slovakia or Slovenia are in the same cluster with developed countries, as: Belgium, Denmark, Finland or Germany (Table 5). However, to have a holistic view about changes, it is mandatory to analyse the mean value of each variable of both clusters.

Table 6. Mean of variables of each cluster (2000-2006)

Number of cluster/Name of variables	Domestic Extraction	Material Import Dependency	Resource Productivity	Total Environmental Taxes
1	14.83	33.03	100.84	2.7
2	14.36	31.07	100.07	2.61

Source: own processing using RStudio

The differences between clusters are not huge. First cluster is characterised by higher levels of value for each variable. Meanwhile, the second cluster has lower values of each variable. It's interesting how countries like Slovakia, Lithuania or Slovenia are now in the first cluster and in the first instance was in the second. That could lead it to an unconventional explanation (Table 6). In spite of the fact that they have a good Resource Productivity or a Domestic Extraction Rate, through the fact of having a high level of Material Import Dependency and Tax Environmental make them to have another rate of development than the other countries from cluster 1(Belgium, Denmark, Finland or Germany). That could be logical, because the ex-soviet countries are using as preponderant economic activity the production of goods and services which involve a growth in Material Import Dependency with a high level of costs. Also, a high level of Environmental Taxes could be a break in investment sector, many business move to a cheaper tax scheme.

On the other hand, cluster 2 is comprises by countries from East and South of the Europe, and, in the same time, by developed countries from west and north of the Europe. It is clear that for majority of countries from cluster 2 the predictors could be directions to take into account. The paradox comes from countries like France, Italy, Netherlands, Luxembourg, Sweden, Austria or Ireland, countries with a high standard of living and a high level of economic productivity. The main factor of the belonging of these countries to the first cluster or third (Luxembourg), clusters with higher level of GDP per capita, is due to an effective economic leadership. Probably, these countries has, as economic trigger, the capital market which make them more independent than the countries with main economic revenue from production of goods or services. Although, for the countries which are in the second cluster in both classification phases, the predictors are significant in order to develop their rate of economic productivity and to improve the use of resources.

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Next, to have a full vision about evolution of the EU-27 countries over 2000-2019
period, it was carried out the same analysis to 2007-2019 period.

Table 7. Classification matrix (2007-2019)

Number of cluster	1	2	3	Classification error
1	3	7	0	70%
2	5	11	0	31.25%
3	1	0	0	100%

Source: own processing using RStudio

At each split, the number of variables used was two and as in the case of prior
period, there are only two clusters. The classification error is higher than the
previous period analysed (before 2007) which means for most of the countries, the
predictors are not strong correlated with GDP per capita. Somehow, the demeanour
of countries is similar with the previous analysis (Table 7). From predictors point
of view, Luxembourg is going from third cluster to the first. Most of the countries
from second cluster are still there, but it is important to notice classification error
rate is increasing.

Figure 6. The importance of predictors (2007-2019)
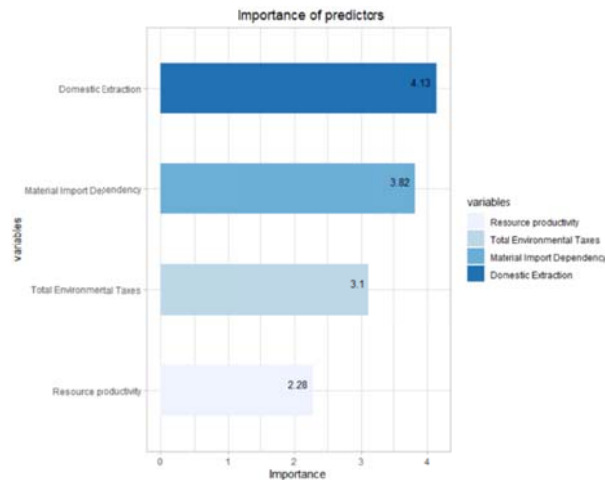
Source: own processing using RStudio

The main influence on classification comes from Domestic Extraction and the
lowest from Resource Productivity. The differences of influence among predictors
seems to be decreasing. It is important to notice a structural change based on
importance of predictor, Total Environmental Taxes has overtaken Resource

Productivity as influence. In addition, Domestic Extraction is a more significant predictor than Material Import Dependency which means another structural change in discriminant analysis (Figure 6).

Now, it is useful to see the new members of each cluster in order to notice the changes among clusters.

Table 8. Composition of new clusters (2007-2019)

Number of cluster	Countries
1	Belgium, Estonia, France, Lithuania, Luxembourg, Malta, Netherlands, Slovakia, Spain
2	Austria, Bulgaria, Croatia, Cyprus, Czech republic, Denmark, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Poland, Portugal, Romania, Slovenia, Sweden

Source: own processing using RStudio

There are a lot of changes in clusters composition. For instance, in the first cluster are several new names, like: Estonia, France, Malta, Netherlands, Luxembourg or Spain. In addition, there are several countries (Denmark, Finland, Germany) which are part of the second cluster over the period 2007-2019 (Table 8). To have a good understanding of these mobilities, it has to observe the features of each cluster.

Table 9. Mean of variables of each clusters (2007-2019)

Number of cluster/ Variables	Domestic Extraction	Material Import Dependency	Resource productivity	Total Environmental Taxes
1	11.05	53.37	129.52	2.39
2	16.52	29.4	125.8	2.74

Source: own processing using RStudio

The first cluster has higher values for Material Import Dependency, Resource of Productivity and lower value for Domestic Extraction, Total Environmental Taxes than the second cluster. With other words, the first cluster is comprised by countries with a high level of Material Import Dependency and Resource Productivity. In spite of this, in the first cluster are countries with a high level of GDP per capita and, in the same time, countries with a lower level. That could be explained through the development of the economic strategy of each country. As it was explained earlier, there are countries with a high level of Material Import Dependency which raise the cost of productivity, like Malta, Lithuania, Estonia, Slovakia or even Spain. On the other hand, there are countries where Material Import Dependency represents a sustainable cost, these countries have another type

of economic strategy and structure (Table 9). Mostly, these countries are focused
on capital market and investment in infrastructure or other big strategic objectives.
Cluster 2 presents a higher level of heterogeneity than first cluster. For most of
these countries the predictors are correlated with GDP per capita. In these cases, is
somehow easy to identify the directions of GDP per capita growth. Although, there
are several countries like Germany, Sweden, Austria, Ireland or Italy which have
another relevant variables correlated with GDP per capita, which means that all of
these countries has another trigger to increase the growth economic rate.

Romania's structural changes of economic demeanour after accession to EU

Over the period 2000-2019, Romania is in the second cluster, both for K-means
clustering and for Random Forest. Romania is a country with a high level of
Domestic Extraction and a low level for Material Import Dependency, Resource
Productivity, and Total Environmental Taxes. Although, there are several changes
in Romanian economic behaviour. Firstly, Material Import Dependency, Domestic
extraction and Total Environmental Taxes are decreasing, the only variable which
are increasing is Resource Productivity, meaning that Romania is in the phase of
improving productive efficiency. Secondly, Romania seems to have an economic
model of development which is correlated with variables analysed in this paper. In
other words, the Romanian economic policies should be deployed relying on the
improvement of the indicators analysed in this article. Like a general conclusion
about Romania's economic behaviour inside EU-27, the improvement of Resource
Productivity could be the key in the process of reducing offsets.

Conclusions and recommendations

Both periods confirms the literature in this field, more or less. There are several
structural changes form the perspective of economic strategies of EU-27 countries,
the best angle to view these changes is from the changes of predictors importance.
Now, the most important predictor is Domestic Extraction which means national
independence of resources and a high level of productivity effectiveness. The
theory set out earlier is confirmed by Immarino et al. (2019) and Dobre et al.
(2019).
The problem of disparities is the complex one, that's why it's needed a holistic
strategy which take into account all resources (human, natural, institutional, even
geographically). Using a holistic strategy, it comes closer to circular economy
transition which means a better resource use, idea confirmed by Adabaka et al.
(2019). Surely, it noticed there are several countries with low rate of Productivity
Resource or Domestic extraction and, despite all of these, are developed countries

from economic angle. It is somehow clear that all of these countries are using renewable resources and has a great strategy of circular economy. In addition, probably, at the level of economic strategies of these countries is a holistic strategy which comprises renewable resources and circular economy, confirming Akadiri et al. (2019). For this reason, it is important for each country to take into account the opportunities of circular economy and, also, to invest in entrepreneurial ecosystem sector. Furthermore, another argument in favour of circular economy is the menace of rebound effect. Rebound effect could be reduced if the economy is relying on alternative and renewable source of energy and through a good strategy of waste management, idea confirms the theories of Vivanco et al. (2016) and Stern (2020).

Also, there are several countries which are alike from economic strategy and predictors influence on GDP per capita. The majority of these countries are coming from ex-soviet countries. Thus, there are several ex-soviet countries which presented another pattern of economic development (Estonia, Lithuania, Slovakia or even Slovenia). From Romania's perspective, even if the social-economic behaviour has changed after accession to EU, it is not recorded a huge progress in the process of reducing the gaps, Romania needed a long period of economic recovery, like Goshin et al. (2015) sustained. In order to draw a sustainable framework of economic growth, the Romanian decision makers should focus on developing potential GDP. There are many ways to increase the potential GDP. One of them is to attract more European funds, clue upheld by Diaconu and Maxim (2019), because EU funds represent the trigger of development. Moreover, Romania is a country with a huge potential in Domestic Extraction which could make our country a resource trader and an independent country from resource perspective. If Romania will become an active player on resource market, using the potential of Domestic Extraction, it will never have again the problem of costs with Material Import Dependency. The specificity of Romanian economy not afford a rise in the Environmental Taxes, because of negative relationship between environmental taxes and GDP per capita, idea sustained also by Radulescu (2017). Thus, the negotiating strategy on the resource market plays a more important role in Romania's economic development.

As a generic conclusion, each country should take into account their opportunities and threats from economic and environmental point of view in order to develop a sturdy strategy of economic development.

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