

## **Analyzing the root of regional innovation performance in the European territory**

### **Abstract**

Regional innovation performance is an important indicator for decision-making regarding the implementation of policies intended for regional development. However, regional development policies have led economies to very different competitive positions in matters of innovation. To address these issues, this paper aims to identify the variables that most contribute to the positioning of economies in terms of performance innovation in Europe. The data for this study were collected at the Regional Innovation Scoreboard (RIS). We use a quantitative methodology, through a multivariate statistical technique (Discriminant Analysis). The results suggest that specific innovation strategies explain the competitive positioning of economies within each group of countries. It was possible to demonstrate that economies with Leader classification show greater comparative robustness in the variables “SMEs with Product or Process Innovations”, “SMEs with Product or Process Innovations”, “R&D Expenditure Public Sector” and “Population with Tertiary Education”, constituting an effective instrument of innovation policy. Furthermore, it was possible to show that the economies belonging to the Modest group do not have a competitive advantage in any of the variables under study, thus providing a reflection opportunity for policymakers at this level. The present research identifies which variables are most relevant to the classification considering the regional innovation performance in Leader, Strong, Moderate, and Modest. Several suggestions were given to companies, policy makers, and higher education institutions in the sense that the regions where they operate can improve their innovative performance, which may help to a change in their current classification.

**Keywords:** Innovation, Regional Innovation Policy, European Innovation Scoreboard, Regional Innovation Scoreboard, Regional Innovation Systems, RIS3, Regional Innovation Performance.

## 1.Introduction

Innovations are seen as a source to create competitive advantages and even used to compare companies and regions. In the past decades, we have seen changes in regional development policies around the world. These changes are related to the constant need to build more robust innovation ecosystems, and assure they remain globally competitive to respond to the constant new challenges resulted from globalization (Saftescu, Simion, Paul and Mitroi, 2016).

In this context, the regional policy of the European Union (EU) has been changing, supporting the development of innovation in its member states. EU regional policy is applied throughout various initiatives and programs, which are co-financed by structural funds (Szopik-Depczyńska, Cheba, Bąk, Kędzierska-Szczepaniak, Szczepaniak and Ioppolo, 2020). Regional government policies focused the investment in certain areas, which were previously defined as smart specialization domains, and adapted to the local context. These policies are called Research and Innovation Strategies for Smart Specialization (RIS3) and were implemented in 2014 in the EU (Lopes, Ferreira and Farinha, 2019b, Tiits, Kalvet and Muerk, 2015, Landabaso, 2014), and will be adjusted for the period 2021-2027 (Bilas, 2020). These policies aim to create the conditions for a sustainable, inclusive and intelligent growth (Spisakova, Gontkovicova and Hajduova, 2016).

Such policies have provided relevant progress in science and industry, improving quality and living conditions, implementing greener technologies, and increasing employment (Dziallas and Blind, 2019). However, the models in regional innovation structures are complex, non-linear and diverse, despite the investment and efforts that have been made in the reformulations of policies (Hajek and Henriques, 2017, Becheikh, Landry and Amara, 2006). In this way, EU regional development policies have been under constant review, both by researchers and society in general, particularly in the field of innovation implementation and development. The classification of the level of innovation in the regions has been studied, taking into account different sources of information such as the Regional Innovation Scoreboard (RIS), Global Innovation Index, or European Innovation Scoreboard (Szopik-Depczyńska *et al.*, 2020). For the present paper, we will use the data available in RIS 2016. RIS 2016, classifies the regions regarding innovation and performance by: Leader, Strong, Moderate and Modest (RIS, 2016, Lopes, Farinha, Ferreira and Silveira, 2018b).

Research on the regions and their innovation have been increasing, with strong divergences, regarding the abilities of public bodies to spend structural cohesion funds (Surubaru, 2017, Farole, Rodríguez-Pose and Storper, 2011, Arbolino, Boffardi and De Simone, 2019), the need to increase the efficiency of policies was identified, increasing the capacity to use European cohesion structural funds by less developed countries and with less innovative capacity (Wamser, Nam and Schoenberg, 2013). On the other hand, it appears that in the EU, the amounts available in the structural cohesion funds, have a positive impact on innovation activities, but not significant (Mohl and Hagen, 2010, Arbolino *et al.*, 2019). Thus, it is necessary to investigate which variables have the greatest impact on the classification of regions, with regard to the performance of innovation, and not only build rankings of innovation level (Szopik-Depczyńska *et al.*, 2020). Being so, the results of the present paper are complementary to other researches, such as the ones by Arbolino *et al.* (2019), Delgado-Márquez and García-Velasco (2018), Garcia-Bernabeu, Cabello and Ruiz (2020), Lewandowska and Švihlíková (2020), Lopes *et al.* (2018b), Lopes, Farinha and Ferreira (2019a), Saftescu *et al.* (2016) and Szopik-Depczyńska *et al.* (2020).

In this context, the objective of the present paper is to identify which of the variables under study, shown in table 1, allow to significantly discriminate the four groups of Regional Innovation Performance (Leader, Strong, Moderate, Modest), intended to identify the variables that most contribute to the

classification obtained by each group. Once the values of these variables are known, this research will allow, a priori, classification, of a group belonging to a region not yet classified.

We anticipate that the results of this research will be a valuable source of information for regional stakeholders. The regions will be able to see which variables referring to innovation, have to improve, in order to increase their innovative performance. Knowing which variables contribute most to the classification of regions, regional stakeholders can establish specific measures to increase the performance of these variables. In this way, regions can more easily change/raise their ranking with regard to its performance. We expect to prove that the technique used to classify the four groups (Leader, Strong, Moderate, Modest) regarding the Regional Innovation Performance is valid.

This paper commences with the introduction, where the theme under study is outlined. In the second part, an extensive literature review about RIS3 and RIS is carried out. In part three the followed methodology is described. In the fourth part, the results are presented. In part five results, are discussed and compared with the literature. Finally, we highlight the contributions of the present research, as well as the practical implications, concluding with the limitations of the research and future lines of investigation.

## **2. Literature Review**

The development of states, regions and cities is uneven, as such, it causes macroeconomic problems, which are not focused exclusively at the regional, national or international level (Rentková, 2018). According to Stejskal (2009), regional development is characterized by a complex set of processes that take place in the respective regions, in order to influence and manage these processes, a systemic and holistic approach is necessary. Stimson, Stough and Salazar (2005) also addressed the issue of a regional definition for development. According to these authors, regional development is the application of processes and resources available in the region, the result of which translates into sustainable development and the desired economic performance for the region, which meets the expectations of people and organizations.

Thus, the analysis of regional disparities is a fundamental issue, when it is intended to guarantee regional development. The term regional disparities means regional differences in the economic, social and ecological levels of the regions under analysis, which cause uneven development across the EU (Rentková, 2018). In this context, it is necessary to clarify the need to differentiate the notion of disparity and diversity. While diversity is a positive phenomenon. Generally, it has its origins in a historical evolution, where the regions present themselves with unique characteristics, which can be translated into strengths and arguments to be used in their own benefit for the region. These characteristics and strengths make them more competitive and sustainable. The disparity is an undesirable difference between regions, which, due to its simple existence, causes an asymmetric development, becoming the weak side of the region that needs to be faced and mitigated (Zdražil and Applová, 2016, Xiao, Du and Wu, 2017). The regional disparities that give rise to social inequalities are economic, cultural, infrastructural, of living conditions, and which, ultimately, can provoke regional polarization.

Aware of this reality, the EU supports the development of its regions through a regional development policy, with a view to mitigating these disparities, using a set of measures called regional development policies, which have evolved over the last few decades. Since the mid-1990s, the European Commission has supported regional development, stimulating innovation processes in the regions. These innovative processes include regional development strategies and

an exhaustively developed methodology. Cohesion policy operates through structural, regional and social policies designed to balance the resulting economic and social disparities in EU regions.

Several authors have tackled the subject of regional innovation systems (Lopes and Franco, 2019, Cooke, Uranga and Etxebarria, 1997, Asheim and Coenen, 2005, Cooke, 1992, Leydesdorff and Fritsch, 2006). The Regional Innovation Systems reflects an interactive learning process capable of very quickly producing evidence about institutional reactions (Cooke, 1992). A system is defined as a series of discrete elements, as well as the relationships between them (Georghiou, 1993, Lundvall, 2007). Regional innovation systems consist of interactive learning from formal institutions, public or private, which have common interests (Doloreux, 2011, Fagerberg, 2003). A regional innovation system can be defined as a system of innovative networks and institutions, whose purpose is to develop the innovative capacity of companies in a region (Lopes and Franco, 2019).

Recently, smart specialization and RIS3 has emerged. The smart specialization consists of the promotion of efficient use and the enhancement of the real effects of public investment, in the view of economic growth and prosperity of countries and regions (McCann and Ortega-Argilés, 2013, McCann and Ortega-Argilés, 2015). RIS3 derives from the EC proposal, aiming to regulate the structural financing program for the period 2014–2020 and 2021–2027. These regulations include innovation strategies for smart specialization (Tiits *et al.*, 2015). RIS3 is the local-based integrated economic transformation political agenda, that starts with the identification of the specific characteristics and assets of each region, enabling a process participated by all interested parties, to establish a vision of a sustainable future for the territory (Panciroli, Santangelo and Tondelli, 2020). Consequently, they are a response to the complex development challenges on policy adaptation to the regional context (Lopes *et al.*, 2019b). RIS3 channels economic development efforts and investments to the relative gains in each region, exploring their respective economic opportunities and emerging trends, and taking measures to enhance their economic growth. RIS3 ensures that the combination of policies and the available instruments in a given regional environment is effective, whether through grants, loans and other type of support, proving to be effective in achieving the desired goals (Costa, 2020, Iammarino, 2018). In this sense, it is valid to affirm that RIS3 represents the evolution of the RIS concept, which encompasses the concept of intelligent specialization.

According to the objectives of the research announced earlier, this paper starts from the idea that the competitiveness of European regions is necessarily linked to regional innovation systems, and that a good knowledge of the relationship between innovation and competitiveness is essential to assess its effects and economic policies capable of increasing the level of competitiveness and growth of European regions (Sabatino and Talamo, 2017, Hajek and Henriques, 2017). Therefore, as industries and companies can base their competitiveness on indicators such as innovation, at the territorial level, the regions are also positioned amongst themselves, which characterizes them as more or less innovative. Ideally, the performance of regional innovation should be measured using the complete measurement table of the Regional Innovation Scoreboard (RIS), that is, using regional data for the same indicators applied to measure innovation performance at the country level. RIS (2016), classifies the regions in terms of their Regional Innovation Performance as: Leader, Strong, Moderate, Modest (Lopes, Farinha, Ferreira and Ferreira, 2018a).

RIS (2016), encompasses the following 12 variables (table 1): i) Population with Tertiary Education (%); ii) R&D expenditure in the public sector (%); iii) R&D expenditure in the business sector (%); iv) Non-R&D SME innovation expenditures (%); v) SME innovating in-house (%); vi) Innovative SMEs collaborating with others (%); vii) EPO patent applications (per billion GDP); viii) SME with product or process innovations (%); ix) SME with marketing or organizational innovations (%); x) Employment in medium-high/high tech manufacturing and knowledge-intensive services (%); xi) Exports of medium-

high/high technology-intensive manufacturing (%); and xii) Sales of new-to-market and new-to-firm innovation by SMEs (%) (Lopes et al., 2018b, Lopes et al., 2019a). Table 1. presents the definitions of each variable under study.

*Table 1 - Regional innovation scoreboard 2016 – variables*

<b>Regional Innovation Scoreboard - Indicators</b>	<b>Definition</b>
Population with Tertiary Education	Corresponds to the number of people in the age group with some type of post-secondary education. The indicator focuses on the population aged between 30 and 34.
R&D expenditure in the public sector	It represents expenditure on research and development (R&D) which is one of the main drivers of economic growth in a knowledge-based economy.
R&D expenditure in the business sector	It captures the formal creation of new knowledge within companies.
Non-R&D innovation expenditures in SMEs	Quantifies non-R&D related innovation expenditures as a percentage of total turnover.
SMEs innovating in-house	It is based on the introduction of new products or production processes in SMEs, whether they are products or production processes that have been significantly improved and that companies have innovated internally.
Innovative SMEs collaborating with others	Measures the degree of participation of SMEs in cooperation for innovation.
EPO patent applications	Measures the number of patent applications at the European Patent Office.
SMEs with product or process innovations	Indicates technological innovation, which is measured by the introduction of new products (goods or services) and processes, which are a key ingredient for innovation in manufacturing activities.
SMEs with marketing or organizational innovations	It captures the extent to which SMEs innovate through non-technological innovation.
Employment in medium-high/high tech manufacturing and knowledge-intensive services	Indicates the share of employment in the high-tech manufacturing sectors.
Exports of medium-high/high technology-intensive manufacturing	Measures technological competitiveness in a region, that is, its ability to commercialize R&D and innovation results in international markets.
Sales of new-to-market and new-to-firm innovation in SMEs	Measures the turnover of new or significantly improved products for the company as a percentage of the total turnover.

Source: RIS (2016)

### 3. Methodology

In the present research, the followed methodology is quantitative. The quantitative methodology explains phenomena, based on numerical data which is analyzed using mathematical methods, and mainly statistics (Creswell, 1994, Mills and Gay, 2019). The present research aims to identify which of the variables allow to significantly discriminate the four groups regarding the Regional Innovation Performance (Leader, Strong, Moderate, Modest), catalogued in RIS (2016). Thus, this methodology is the most appropriate because, as a rule, it requires large representative samples, selected in order to generalize the results achieved, prediction of cause and effect relationships through deductive reasoning (Yilmaz, 2013).

The data for the present research was collected at the Regional Innovation Scoreboard (RIS) 2016 (<https://op.europa.eu/s/oofu>) on June 26<sup>th</sup>, 2018. The collected data was inputted and analyzed using the SPSS (version 26). RIS (2016) contemplates a comparative assessment, regarding the performance of innovation systems in the 22 EU Member States, which is divided into 214 regions, including Serbia, Switzerland and Norway. RIS (2016), also includes the countries of Malta, Cyprus, Latvia, Estonia, Luxembourg and Lithuania. RIS (2016) ranks 53 regions in Leader, 60 regions in Strong, 85 regions in Moderate, and 22 regions in Modest.

According to Marôco (2018), Discriminant Analysis is a multivariate statistical technique whose objectives are: (i) identification of the variables that best differentiate or “discriminate” between two or more structurally different and mutually exclusive groups; (ii) the use of these variables to create a discriminant function that sparingly represents differences between groups; and (iii) the use of this function to classify new individuals in groups a priori. Being so, for this research, Stepwise Discriminant Analysis was used with Wilks  $\Lambda$  method to identify which of the variables under study allow to significantly discriminate the four groups of Regional Innovation Performance (Leader, Strong, Moderate, Modest).

The normality assumptions of each group were tested, respectively with the Kolmogorov-Smirnov test in the group's Leader (N=53), Strong (N=60) and Moderate (N=85) and Shapiro-Wilk test in Modest group (N=22). According to these tests, all variables have a normal distribution in each of the Regional Innovation Performance groups ( $p < 0,05$ ) except for the variable *Non-R&D Innovation Expenditures* in Leader group (KS=0.148;  $p=0,005$ ) and in Strong group (KS=0.13;  $p=0,01$ ), of variable *SMEs Innovating In-House* in Leader group (KS=0.139;  $p=0,01$ ), in Strong group (KS=0.124;  $p=0,02$ ), in Moderate group (KS=0.128;  $p=0,001$ ) and in Modest group (SW=0.842;  $p=0,003$ ), of variable *Innovative SMEs Collaborating with Others* in Leader group (KS=0.128;  $p=0,03$ ) and in Modest group (SW=0.820;  $p=0,001$ ) and variable *Sales of New-To-market and New-To-Firm Innovations* in Leader group (KS=0.260;  $p=0,00$ ), in Strong group (KS=0.188;  $p=0,00$ ) and in Moderate group (KS=0.121;  $p=0,004$ ). This is, because Discriminant Analysis is robust to variations from normality (Marôco, 2018) these variables were used in the analysis.

The assumption of homogeneity of the variance-covariance matrices was tested with the Box M test, which proved to be valid ( $p = 0.365$ ), accepting the hypothesis of homogeneity of the variance-covariance matrices.

Finally, a classificatory analysis with cross-validation was used to obtain classification functions to allow to predict in which Regional Innovation Performance group new case studies could be classified.

#### 4. Results

The focus on regional innovation policies is seen as a source of competitive advantage for economies (Hajek and Henriques, 2017). Thus, there is an urgent need to make innovation ecosystems more robust, capable of asserting themselves at a competitive global level (Saftescu *et al.*, 2016). In this alignment, Research and Innovation Strategies for Smart Specialization (RIS3) have been achieving political popularity, especially in Europe (Lopes *et al.*, 2019b, Tiits *et al.*, 2015). In the EU, it appears that the structural cohesion funds have a positive impact on innovation activities, with the need to increase the capacity to use these funds, by less developed countries and with less innovative capacity (Arbolino *et al.*, 2019, Mohl and Hagen, 2010, Wamser *et al.*, 2013).

For such, the behavior of the variables of RIS 2016 was analyzed, to study the agglomeration of countries by innovative performance groups: i) Population with Tertiary Education (%); ii) R&D expenditure in the public sector (%); iii) R&D expenditure in the business sector (%); iv) Non-R & D SME innovation expenditures (%); v) SME innovating in-house (%); vi) Innovative SMEs collaborating with others (%); vii) EPO patent applications (per billion GDP); viii) SME with product or process innovations (%); ix) SME with marketing or organizational innovations (%); x) Employment in medium-high / high tech manufacturing and knowledge-intensive services (%); xi) Exports of medium-high / high technology-intensive manufacturing (%); and xii) Sales of new-to-market and new-to-firm innovation by SMEs (%) (Lopes *et al.*, 2018b, Lopes *et al.*, 2019a). Thus, Analysis of Variance or ANOVA was used to compare the distribution of three or more groups in independent samples. In this perspective, the individual ANOVA for each of the independent variables considered shows that only the variable Non-R & D Innovation Expenditures cannot be considered as discriminant ( $p = 0.98$ ) for the usual levels ( $\alpha = 0.05$ ) (see table 2).

Table 2 - Tests of Equality of Group Means

Tests of Equality of Group Means					
	Wilks' Lambda	F	df1	df2	Sig.
Population with Tertiary Education	,719	28,091	3	216	,000

R&D Expenditure Public Sector	,707	29,845	3	216	,000
R&D Expenditure Business Sector	,455	86,080	3	216	,000
Non-R&D Innovation Expenditures	,971	2,128	3	216	,098
SMEs Innovating In-House	,540	61,424	3	216	,000
Innovative SMEs Collaborating with Others	,566	55,239	3	216	,000
EPO Patent Applications	,377	118,984	3	216	,000
SMEs With Product or Process Innovations	,466	82,577	3	216	,000
SMEs with Marketing or Organizational Innovations	,489	75,150	3	216	,000
Employment Medium-High/ High Tech Manufacturing & Knowledge Intensive Services	,754	23,489	3	216	,000
Exports in Medium-High/ High Tech Manufacturing	,921	6,212	3	216	,000
Sales of New-To-market and New-To-Firm Innovations	,697	31,295	3	216	,000

In each step of the Stepwise method, the selected variable is the one that minimizes the value of  $\Lambda$  of Wilks, that is, the one for which the greatest differences between groups occur. The process is repeated until there are no significant differences in  $\Lambda$ .

The Stepwise Discriminant Analysis extracted 3 discriminating functions, retaining Population with Tertiary Education, R&D Expenditure Public Sector, R&D Expenditure Business Sector, SMEs Innovating In-House, Innovative SMEs Collaborating with Others, EPO Patent Applications, SMEs with Product or as statistically significant. Process Innovations, SMEs with Marketing or Organizational Innovations, Exports in Medium-High / High Tech Manufacturing and Sales of New-To-market and New-To-Firm Innovations.

Table 3 below shows the standardized coefficients of these variables in the discriminant functions.

Table 3 - Standardized Canonical Discriminant Function Coefficients

Standardized Canonical Discriminant Function Coefficients			
	Coefficients in discriminant functions		
	1	2	3
Population with Tertiary Education	,277	-,200	-,586
R&D Expenditure Public Sector	,234	,452	-,081
R&D Expenditure Business Sector	,096	,624	-,041
SMES Innovating In-House	-,149	-,432	1,730
Innovative SMEs Collaborating with Others	,587	-,707	,502
EPO Patent Applications	,636	-,555	-,346
SMEs with Product or Process Innovations	,306	,823	-1,165
SMEs with Marketing or Organizational Innovations	,269	-,406	-,088
Exports in Medium-High/ High Tech Manufacturing	,263	-,215	,235
Sales of New-To-market and New-To-Firm Innovations	,076	,824	,245

Function 1 is essentially defined by the EPO Patent Applications and Innovative SMEs Collaborating with other variables, positively discriminates the four groups ( $\Lambda = 0.091$ ;  $\chi^2 = 507.53$ ;  $p = 0.000$ ) and explains 89.1% of the variability between the groups ( $\lambda = 5,272$ ).

Function 2 is essentially defined by the variables Sales of New-To-market and New-To-Firm Innovations, SMEs with Product or Process Innovations and R&D Expenditure Business Sector, positively discriminates against the 4 groups ( $\Lambda = 0.572$ ;  $\chi^2 = 118.28$ ;  $p = 0.000$ ) and explains 6.1% of the variability between groups ( $\lambda = 0.364$ ).

Function 3 is essentially defined by the variables SMEs Innovating In-House and Innovative SMEs Collaborating with Others, positively discriminates the 4 groups ( $\Lambda = 0.781$ ;  $\chi^2 = 52.49$ ;  $p = 0.000$ ) and explains 4.7% of the variability between groups ( $\lambda = 0.281$ ).

Figure 1 illustrates the positioning of each country in the territorial map of the scores of the first two discriminating functions and the centroids of each of the four Regional Innovation Performance groups (Leader, Strong, Moderate, Modest).

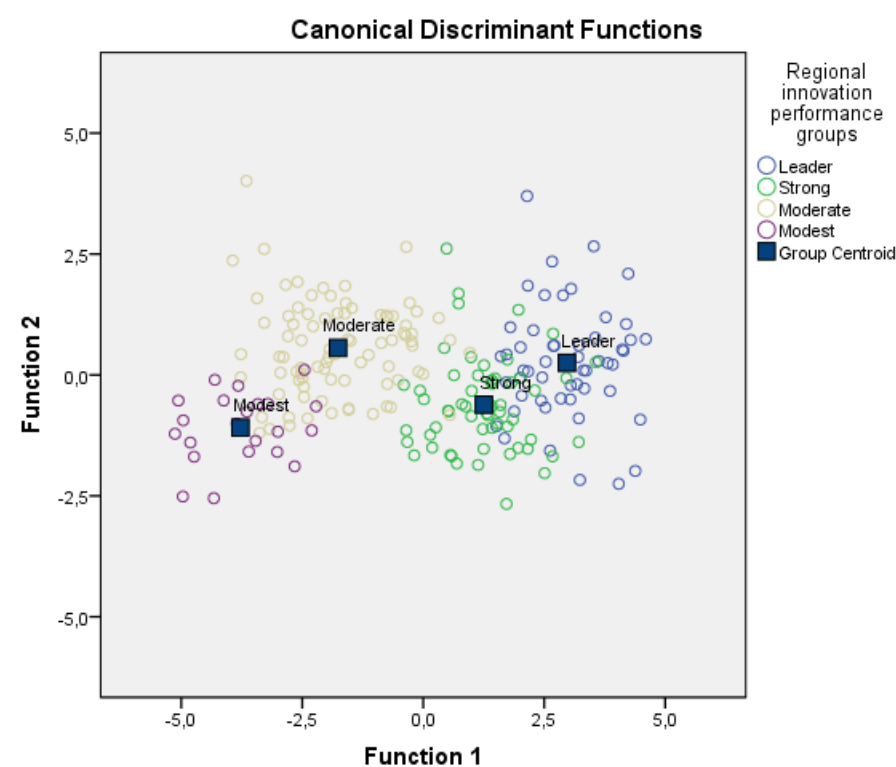


Figure 1 - Canonical discriminant functions

Table 4 exhibits the coefficients of the classification functions defined for each of the Regional Innovation Performance groups. The competitiveness of European regions is necessarily linked to regional innovation systems and a good knowledge of the relationship between innovation and competitiveness is essential to assess the effects of public policies on increasing the competitiveness and growth of the European regions (Hajek and Henriques, 2017, Sabatino and Talamo, 2017). According to RIS (2016), economies are grouped into four groups, depending on their level of performance in terms of regional innovation (Leader, Strong, Moderate, Modest) (Lopes *et al.*, 2018b).



These functions serve only as an *a priori* classification for new individuals in the groups, without any discriminative interpretation. Depending on the values of the variables of a new subject and its substitution in the respective equation, these coefficients allow the determination of the group to which the individual belongs as being the one whose classification function allows to obtain a higher score.

Table 4 - Classification Function Coefficients

Classification Function Coefficients				
	Regional innovation performance groups			
	Leader	Strong	Moderate	Modest
Population with Tertiary Education	31,299	25,059	19,936	22,450
R&D Expenditure Public Sector	27,956	21,929	20,973	13,312
R&D Expenditure Business Sector	-5,340	-11,111	-7,577	-16,607
SMEs Innovating In-House	4,865	24,284	18,607	12,468
Innovative SMEs Collaborating with Others	25,270	26,556	8,757	5,213
EPO Patent Applications	38,520	29,834	9,285	9,310
SMEs with Product or Process Innovations	33,106	11,907	16,236	10,437
SMEs with Marketing or Organizational Innovations	4,776	3,100	-6,635	-4,924
Exports in Medium-High/ High Tech Manufacturing	28,070	28,138	22,855	20,867
Sales of New-To-market and New-To-Firm Innovations	30,933	26,279	31,638	16,651
(Constant)	-63,613	-46,606	-28,149	-16,241
Fisher's linear discriminant functions				

Through the analysis of function 1 (which is the most discriminating), table 5 shows, that the average of this function assumes the highest value in the Leader group and that this average value decreases when the Leader classification is passed for each of the others ( Strong, Moderate and Modest). When analyzing table 4, it is possible to see which variables have greater weight and, therefore, discriminate more in the classification of each group.

For the Leader classification, and in descending order, are the variables EPO Patent Applications, SMEs With Product or Process Innovations, Population with Tertiary Education, Sales of New-To-market and New-To-Firm Innovations, Exports in Medium-High / High Tech Manufacturing, R&D Expenditure Public Sector and Innovative SMEs Collaborating with Others have the greatest weight in the classification obtained. In this group and the SMEs Innovating In-House variable, the lowest values of all groups (Strong, Moderate, Modest) are obtained.

For the Strong classification and, in descending order, are the variables EPO Patent Applications, Exports in Medium-High / High Tech Manufacturing, SMEs Collaborating with Others, Sales of New-To-market and New-To-Firm Innovations, Population with Tertiary Education, SMEs Innovating In-House, R&D Expenditure Public Sector and SMEs with Product or Process Innovations have the greatest weight in the classification obtained. In this group and compared to the other variables of the Leader Group, there is a greater relative weight of the variables SMEs Innovating In-House and Innovative SMEs Collaborating with Others, a very similar weight in the variable Exports in Medium-High / High Tech Manufacturing and a lower relative weight in all other variables, although not far from the Leader classification values.

In the Moderate classification, overall, the weights of each of the variables are lower than those of the Strong and Leader groups. The variables with the greatest weight are Sales of New-To-market and New-To-Firm Innovations (which obtain even the highest value of all groups), Exports in Medium-High / High Tech Manufacturing, R&D Expenditure Public Sector and Population with Tertiary Education (which obtains the lowest value of all groups).

In the Modest classification, in general, the weights of each of the variables are the lowest of all groups, obtaining, nevertheless, better scores than the Moderate classification in the variable Population with Tertiary Education and very approximate values in the variable’s EPO Patent Applications and Exports in Medium-High / High Tech Manufacturing.

The pace of development in the regions is uneven and causes macroeconomic problems, according to a complex set of processes related to each territory or country (Rentková, 2018, Stejskal, 2009). Generally, we can affirm that Leader-rated economies show greater comparative robustness in the variables “SMEs With Product or Process Innovations”, “SMEs with Product or Process Innovations”, “R&D Expenditure Public Sector” and “Population with Tertiary Education”; presenting a worse performance in the variable “SMEs Innovating In-House”. The economies classified in the Strong group, stand out as positive in the variables “Exports in Medium-High / High Tech Manufacturing”, “Innovative SMEs Collaborating with Others” and “SMEs Innovating In-House”, presenting a worse performance at the level of the variable “SMEs with Marketing or Organizational Innovations”. The group of economies classified as Moderate, have a competitive advantage in the variable “Sales of New-To-market and New-To-Firm Innovations”, losing in comparison with the other groups, in the variables “EPO Patent Applications” and “Population with Tertiary Education”. Finally, the economies belonging to the Modest group do not have a competitive advantage in any of the variables, presenting even worse comparative performance in the variables “R&D Expenditure Public Sector”, “Innovative SMEs Collaborating with Others”, “SMEs with Product or Process Innovations”, “Exports in Medium-High / High Tech Manufacturing” and “Sales of New-To-market and New-To-Firm Innovations”.

Table 5 - Functions at Group Centroids

Functions at Group Centroids			
Regional innovation performance groups	Function		
	1	2	3
Leader	4.369	.202	-.580
Strong	1.820	-.505	.645
Moderate	-2.691	.531	.115
Modest	-5.091	-1.161	-.805
Unstandardized canonical discriminant functions evaluated at group means			

Comparing the Regional Innovation Performance groups originally assigned with those determined by the use of the classification function coefficients, the percentage of countries correctly classified in each group was 83.6%. This means that with the discriminant functions obtained and without knowing the classifications of the various groups, we would be able to classify 83.6% of them, which represents a high value. The correct classifications by group are, respectively, Leader - 84.5%, Strong - 85%; Moderate -78.8% and Modest - 95.5%, as shown in table 6.

Table 6 - Classification Results

Classification Results <sup>a</sup>							
		Regional innovation performance groups	Predicted Group Membership				Total
			Leader	Strong	Moderate	Modest	
Original	Count	Leader	45	8	0	0	53
		Strong	7	51	2	0	60
		Moderate	0	6	67	12	85
		Modest	0	0	1	21	22
	%	Leader	84,9	15,1	,0	,0	100,0
		Strong	11,7	85,0	3,3	,0	100,0
		Moderate	,0	7,1	78,8	14,1	100,0
		Modest	,0	,0	4,5	95,5	100,0
a. 83,6% of original grouped cases correctly classified.							

As we can see in table 7, the variables that have a greater weight in the classification of regions in Leader are: 1) SMEs with Product or Process Innovations; 2) SMEs with Product or Process Innovations; 3) Population with Tertiary Education; 4) Sales of New-To-market and New-To-Firm Innovations; 5) Exports in Medium-High / High Tech Manufacturing; 6) R&D Expenditure Public Sector; and 7) Innovative SMEs Collaborating with Others. Regarding the variables that have a greater weight in the classification of regions in Strong are: 1) EPO Patent Applications; 2) Exports in Medium-High / High Tech Manufacturing; 3) SMEs Collaborating with Others; 4) Sales of New-To-market and New-To-Firm Innovations; 5) Population with Tertiary Education; 6) SMEs Innovating In-House; 7) R&D Expenditure Public Sector; and 8) SMEs with Product or Process Innovations. Considering the variables that have a greater weight in the classification of regions in Moderate are: 1) Sales of New-To-market and New-To-Firm Innovations; 2) Exports in Medium-High / High Tech Manufacturing; 3) R&D Expenditure Public Sector; 4) Population with Tertiary Education; 5) SMEs Innovating In-House; and 6) SMEs with Product or Process Innovations. Finally, the variables that have a greater weight in the classification of regions in Modest are: 1) Population with Tertiary Education; 2) Exports in Medium-High / High Tech Manufacturing; 3) Sales of New-To-market and New-To-Firm Innovations; 4) R&D Expenditure Public Sector; 5) SMEs Innovating In-House; and 6) SMEs with Product or Process Innovations.

Table 7 - Regional innovation performance groups - Variables that most contributed to the obtained classification

	Leader	Strong	Moderate	Modest
1°	EPO Patent Applications	EPO Patent Applications	Sales of New-To-market and New-To-Firm Innovations	Population with Tertiary Education
2°	SMEs with Product or Process Innovations	Exports in Medium-High/ High Tech Manufacturing	Exports in Medium-High/ High Tech Manufacturing	Exports in Medium-High/ High Tech Manufacturing
3°	Population with Tertiary Education	Innovative SMEs Collaborating with Others	R&D Expenditure Public Sector	Sales of New-To-market and New-To-Firm Innovations
4°	Sales of New-To-market and New-To-Firm Innovations	Sales of New-To-market and New-To-Firm Innovations	Population with Tertiary Education	R&D Expenditure Public Sector

5°	Exports in Medium-High/ High Tech Manufacturing	Population with Tertiary Education	SMEs Innovating In-House	SMEs Innovating In-House
6°	R&D Expenditure Public Sector	SMEs Innovating In-House	SMEs with Product or Process Innovations	SMEs with Product or Process Innovations
7°	Innovative SMEs Collaborating with Others	R&D Expenditure Public Sector	EPO Patent Applications	EPO Patent Applications
8°	SMEs Innovating In-House	SMEs with Product or Process Innovations	Innovative SMEs Collaborating with Others	Innovative SMEs Collaborating with Others
9°	SMEs with Marketing or Organizational Innovations	SMEs with Marketing or Organizational Innovations	SMEs with Marketing or Organizational Innovations	SMEs with Marketing or Organizational Innovations
10°	R&D Expenditure Business Sector	R&D Expenditure Business Sector	R&D Expenditure Business Sector	R&D Expenditure Business Sector

## 6. Final Remarks

### 6.1. Contributions and Practical Implications

The Regional Innovation Scoreboard (RIS) includes a broad comparative analysis, with regard to the performance of innovation in different regions/countries of the EU, as well as other regions/countries neighboring the EU. Specifically, it shows the impacts on the economy resulting from innovation activities (Kijek and Matras-Bolibok, 2019). RIS classifies countries/regions into four distinctive groups of innovation performance: Leader, Strong, Moderate, Modest (RIS, 2016). Thus, the present paper aims to identify which of the variables that allow to significantly discriminate the four groups regarding the Regional Innovation Performance (Leader, Strong, Moderate, Modest).

With the present research, we concluded that by comparing the Regional Innovation Performance groups originally assigned with those determined by the use of the classification function coefficients, the percentage of countries correctly classified in each group was 83.6%. This points out that with the discriminant functions achieved and without knowing the classifications of the various groups, we would be able to classify 83.6% of them, which represents a high value. We also concluded that the correct classifications by group, regarding Regional Innovation Performance, are 84.5% in Leader regions, 85% in Strong regions, 78.8% in Moderate regions, and 95.5% in Modest regions. The statistical results of the present research also suggest that the technique used to classify the four groups (Leader, Strong, Moderate, Modest) regarding the Regional Innovation Performance is valid and robust. In Table 7, we summarize the results obtained in the present research, clearly identifying which variables contributed the most to the classification obtained by each group. They are ordered from the most significant to the least significant.

Having identified the variables that have the greater weight in the classification of regions, Leader, Strong, Moderate and Modest, it is important to postulate some suggestions for policy makers, companies, and universities to take into consideration, in order to improve the innovation performance of regions where they operate. Recently, EU regional policy makers have had to adjust their actions regarding regional innovation. Regional development strategies, or RIS3, were implemented in 2014 and will be adjusted for the period 2021-2027 (Bilas, 2020). Within this framework, regional policy makers in the EU were urged to adopt regional currencies policies, in order to guarantee concentration and prioritization in certain areas of smart specialization, thus leading to the growth of entrepreneurship and innovation, with the aim of promoting regional economic development (Saftescu *et al.*, 2016, Simion, Paul and Mitroi, 2016)

That said, for Strong regions to increase their innovative performance, eventually becoming Leader regions, the results suggest that they implement measures in the variables EPO Patent Applications, SMEs with Product or Process Innovations, and Population with Tertiary Education. Regarding the EPO Patent Applications variable, it is essential that local governments support/encourage more financially higher education institutions/research centers when applying for patents (Verspagen, 2006). Universities should be able to mobilize their professors, researchers, and students to develop new products which may

be patented. Another important measure is to grant publications in journals indexed to Scopus (Maraut and Martinez, 2014) and Web of Science. On the other hand, in Europe, it is regularly verified that university investigations are listed by the inventors, with universities being excluded from patent ownership. Thus, universities are left without bargaining power with regard to patent ownership, which in turn can lead to a lack of commitment by higher education institutions in joint projects with companies and may even lead to little valuable innovations (Verspagen, 2006). In such a manner, the SMEs with Product or Process Innovations variable are also affected. It is in this variable that the greatest difference lies between the regions classified as Leader and Strong. Higher education companies and institutions must have the capacity to cooperate and establish win-win agreements. Companies need higher education institutions because they have the knowledge. On the other hand, higher education institutions also need companies, as they can receive extra income for the research contracted by companies, as well as receiving the information from companies, necessary to develop their research (Lopes *et al.*, 2018a). Finally, it is essential to raise the values of Population with Tertiary Education, as human resources with higher degrees they have a positive impact, regarding labor and productivity, thus, increasing growth regions. That said, the educational policy in each country should be adapted to the real needs of the labor market (Spisakova *et al.*, 2016). The weak interactions between companies, government, and universities are pointed out in the literature as one of the main reasons why regions are unable to pay dividends from higher education and R&D activities (Sterlacchini, 2008).

For Moderate regions to increase their innovative performance, and possibly becoming Strong regions, the results suggest that they should implement measures in the EPO Patent Applications and Innovative SMEs Collaborating with other variables, as there is a great disparity in these variables comparing the two regions in particular. Despite the efforts of regional policy makers to strengthen public funds for innovation, they are still not enough, it is recommended that they should be strengthened (Lewandowska and Švihlíková, 2020, Stanculescu, 2015). Being so, for Moderate regions it is important to reinforce tailored consultancy, which can be done by higher education institutions, or by specialized companies, to increase financial support from regional, specialized, and public organizations. Financing conditions for companies that want to invest in innovation can be made more flexible and easier, thus meeting demand (Lewandowska and Stopa, 2019). The regulatory framework, education, and training of a greater number of specialists and researchers in information and communication technology can also be improved, reinforcing the efforts of the EU institutions to stimulate the international acceptance of innovation results, fostering external associations with institutions active in innovation, supporting investors in the patent application process, significantly increasing the existing R&D infrastructure, including the creation of innovative clusters and platforms, supporting SMEs and higher education institutions in their efforts to invest in innovation and R&D, creation of clusters and innovative platforms to strengthen the connection between companies and higher education institutions (Stanculescu, 2015).

In summary, according to Ponsiglione, Quinto and Zollo (2018) the relevant factors that affect the regional innovation capacity, and differentiate the leading innovation regions from the less developed regions (Modest and Moderate innovators) are: 1) the propensity cooperation; 2) exploration capacity; and competence. These three factors can contribute to reduce the disparities between European regions with regard to the performance of innovation.

The present research is original, pertinent and clearly identifies which variables are most relevant to the classification considering the regional innovation performance in Leader, Strong, Moderate, and Modest. Several suggestions were given to companies, policy makers, and higher education institutions in the sense that the regions where they operate can improve their innovative performance, which may help to a change in their current classification. This research also contributes to a better understanding of the Regional Innovation Scoreboard, as well as clarifying the current literature on the subject under study.

## 6.2. Research limitations and future lines of investigation

With regards to limitations, primarily, the paper only covers the data from countries/regions present in RIS 2016 and new data are available every year. These data are from EU countries/regions and some countries in the vicinity. Having only data from countries in Europe, it is not possible to carry out an analysis on a global level.

Secondly, the paper covers data from a pre-pandemic context, and probably the results will be different as the pandemic deaccelerates, we cannot stop seeing the emergence of regional and local economies where small geographical and political areas will try to be independent economically withing several sectors (Samarathunga and Weerathunga, 2020). Furthermore, as countries and regions start looking into reopening the economy, guide decisions not only give the pace of lifting mitigation policies but also leverage other measures that may be needed to restore confidence and trust for people to return to pre-COVID-19 behaviors (Chen, Igan, Pierri and Presbitero, 2020). Afar from the immediate crisis response, policymakers will also have to think about sustained measures after the epidemic subsides. What kind of measures will be needed to reboot the economy and ranks in the regions? This is not only a local question for the EU but also for the global economy, as different parts of the world might be in different phases of fighting the virus (Demertzis, Sapir, Tagliapietra and Wolff, 2020).

As for future lines of research after the pandemic, we suggest that qualitative data on policy actions and performance of EU Member States should be collected, with the aim of identifying best practices on innovation, consequently contributing to the development of increasingly intelligent, more intelligent, sustainable policies and greens. Comparative studies can be made between the different years of the RIS. It should be noted that as of RIS 2017, new variables were inserted in the RIS, as previously indicated in the present study, and it is pertinent to investigate these new variables and verify their impact on the measurement of the innovative performance of the regions and what are their practical effects.

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