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Analysis of factors associated with Grant for PCT national phase entries patent: a mathematical model

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SUMMARY

We developed a multivariate linear regression model to analyze factors associated with Grant for PCT national phase entries patent, in order to identify patentability success indicators.

Information was gathered from the Eurostat and World Intellectual Property Indicators databases (period 2004-2014). Thre regression model were constructed using as response variable: Grant for PCT national phase entries patent in the national phase and considering 11 variables related to R&D funding and research personnel as predictor variables. Multivariate linear regression models were estimated using the Bayesian Information Criterion (BIC). The most influential predictive variables were: Total R&D personnel and researchers by performance sectors, sex and fields of science. The regression coefficient was 0.001 with ($P < 0.05$). In conclusion, the mathematical model shows that the most effective predictors of patentability are qualified R&D personnel.

Key words: Patents multidisciplinary analysis – Quality Signal, Research and Development – Patent indicator – Patent statistics – Multivariate linear regression model

INTRODUCTION

Studies in the area of patents have increased exponentially, providing quantitative and also qualitative information (Alvarez et al., 2012; Érdi et al., 2013). The value of intellectual property and its protection through the registration of patents is an aspect that constitutes an intrinsic value for universities or for OPIS and industries with departments of I+D.

Patents are considered as measurement elements that demonstrate the efficiency of the ID expense, being these factors the ones that condition the sustained economic reactivation (Capaldo and Messeni-Petruzzelli, 2011; Buesa and Baumert, 2010). Therefore, they are promoted in the universities and the industry and, through their research groups, the promotion of intellectual property, aware of the central role that this variable determines in the knowledge economy (Tetko et al., 2016).

The knowledge economy focused on the transfer of technology from its scientific discoveries and achievements constitutes a growing trend (Daim et al., 2006; Freeman and Soete, 2009; Alvarez et al., 2015). The research laboratories of universities and industry, through their research groups, are

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Author contributions : Pablo Álvarez designed the study, gathered data, contributed to the statistical analysis and interpretation, and wrote the first draft of the article; Marta Reyes collaborated in the data review and final statistical analysis; Arturo Argüello collaborated in the data review; and Julia Sánchez-Cantalejo designed and contributed to the statistical analysis. All authors contributed to the analysis and interpretation of results and have read and approved the final manuscript.

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promoting the development of intellectual property.

Patents are considered measurement elements that demonstrate the efficiency of research and development spending and their social profitability (Bessen, 2008; Cubico et al., 2014; Hoenen et al., 2014; Hottenrott et al., 2015); the total number of patents produced by a country or per capita is often used as an indicator of innovation.

It is known that different approaches to patents need a multidisciplinary analysis to detect which of the factors related to patents is the most determining (Bird and Frey, 2013; Chang, 2012; Conti et al., 2013).

The Patent Cooperation Treaty (PCT) is a system for "filing" patent applications.

The possible routes that a European patent application could follow include the Euro-PCT route. Each applicant has to go through a European patent application process, which includes corresponding costs or fees for each stage of the application process.

In this article, we have conducted an analysis to measure the degree of interest of financing agents to increase the number of patent registrations. We have done an analysis of the variable Grant for the patent of entries in the National Phases of the PCT, constructing a mathematical model of the variable: the Grant for the patent of entries in the National Phases of the PCT and with eleven predictor variables.

MATERIAL AND METHODS: METHODOLOGY

Search strategy

The search that was carried out to find the patent information is based on official data from Eurostat and WIPO Statistics Database and ScienKnowledge indicator, previously used in patent research articles in the field of knowledge protection.

The analyzed temporal space is understood between 2004 and 2014, both included.

Source of data

Eurostat WIPO statistics database. European Patent Office EPO and ScienKnowledge: Google Scholar.

Last updated: November 2018. We have used the relevant patent indicators for this specific research.

For the realization of the mathematical model of the analyzed response variable: Grant for PCT national phase entries patent, we made a careful bibliographic analysis to select the Explanatory Variables.

The inclusion criteria were those referred to the Response Variable: Grant for PCT national phase entries patent on which we have constructed the mathematical model and the 11 Explanatory Variables used in this study.

We have used tools of descriptive statistics and we have obtained, by means of measures of magnitude and heterogeneity, their mean, median and percentiles and standard deviation.

The graphic representation has been carried out by boxes (box plot).

Statistical analysis

Predictive Model of Variable Response Grant for PCT national phase entries patent.

The relationship between the variable Response Variable Grant for PCT national phase entries patent and Explanatory Variables or predictor variables was carried out using the multivariate linear regression model. With this we have established that the average of the variable Grant for PCT national phase entries patent is a linear combination of Explanatory Variables variables.

With the data obtained and using the least squares method, we have detected the effect of each of the Explanatory Variables or predictors on the variable Grant for PCT national phase entries.

To obtain the most parsimonious model, we have used the so-called Bayesian Information Criterion (BIC), choosing that model that had the smallest value of the previous criterion.

Once the model was chosen, a diagnostic study was carried out to evaluate the conditions of applicability of the linear model, among others, the linearity of the predictor variables. This study that was carried out using graphical smoothing procedures of the point clouds of the residuals of the adjusted model.

The interdependence between the predictors was also studied by means of the inflation factor of variance (VIF), considering that values greater than 10 allow to speak of multicollinearity.

Next, the presence of outliers was evaluated by the studentized residuals, declaring an observation as such that corresponding to a residual greater than 3.

Finally, Cook's distance was calculated to detect influential observations; in the case of the existence of such observations, the models with and without such observations were presented.

Data were analyzed using R 3.1.1 software (https://www.R-project.org) and the leaps package version 2.9 (http://CRAN.R-project.org/package=leaps). Graphics were created by means of R software with the ggplot package (http://had.co.nz/ggplot2/book) and Tableau Public software (http://get.tableau.com/es-es/trial/tableau-software).

Criteria for the selection of variables

For the selection of both the variable response and the explanatory variables, the criteria of the works of Bessen (2008), Alcacer (2006), Gittelman (2008), Mejia (2007), Gambardella et al. (2008), and Lee et al. (2012).

The selection of the response variable for the construction of the Predictive Model of the activity

of the variable Grant for PCT national phase entries patent was carried out based mainly on studies that were related to patentability and its indicators (Furman et al., 2002; Hegde and Stampat, 2009) and other factors that have a positive influence on the activity of patent registrations and are considered indicators.

Once the most parsimonious model was chosen to select the explanatory capacity of the model, the determination coefficient was used, a statistic that quantifies the variability part of the response that can be explained by the predictors and that varies between 0 and 100%.

The R software was used for the analysis of the data (R Core Team (2015).) R: A language and environment for statistical computing R Foundation for Statistical Computing, Vienna, Austria URL https: //www.R-project .org), version 3.1.1 and the leaps package (Thomas Lumley using Fortran code by Alan Miller (2009): regression subset selection, R package version 2.9, http://CRAN.R-project.org/package=leaps).

For the elaboration of the Predictive Model, it was selected as response variable Grant for PCT national phase entries patent on which we have constructed the mathematical model and the Explanatory Variables used in this study.

Explanatory Variables or Predictors that were selected

1 rd_p_persqual_.-Total R&D personnel and researchers by sectors of performance, qualification and sex.

2 rd_p_perssci .-R&D personnel and researchers by sectors of performance, sex and fields of science.

3 rd_e_berdfundr2.- Business enterprise R&D expenditure (BERD) by economic activity and source of funds.

4 rd_e_gerdact.-Total R&D expenditure (GERD) by sectors of performance and type of R&D activity

5 humresour_rd_tot.-Human resources in science and technology (HRST) - % of active population

6 gr_do_rd_soufun .- Gross domestic expenditure on R&D (GERD) by source of funds

7 tot_rd_exp.-Total R&D expenditure - % of GDP

8 pt_app_epo.-Patent applications to the European Patent Office

9 rd_exp_sec_higed.-Research and development expenditure, by sectors of performance educacion superior

10 bus_ent_rd_exp.-Business enterprise sector - Research and development expenditure, by sectors of performance

11 hieduc_exp_rd_sec-ejec .-Higher education sector - Research and development expenditure, by sectors of performance

The explanatory or predictive variables were grouped into four sections:

Related to researchers and R & D personnel

1 Total R&D personnel and researchers by sectors of performance, qualification and sex.

2 Total R&D personnel and researchers by sectors of performance, sex and fields of science.

5 Human resources in science and technology (HRST) - % of active population.

11 Higher education sector - Research and development expenditure, by sectors of performance.

These predictors have a citation level of 175,000 results in scholar.google.es time space 2000-2014 analyzed.

B) Related to R & D expenditure

6 Gross domestic expenditure on R&D (GERD) by source of funds

7 Total R&D expenditure - % of GDP.

These predictors have a citation level of 265,000 results in scholar.google.es in the analyzed time.

C) Predicting R & D activity related to patent applications

8 Patent applications to the European Patent Office.

This predictor has a citation level of 3,800,000 results in scholar.google.es.

D) Predictors related to economic activity

3 Business enterprise R&D expenditure (BERD) by economic activity and source of funds

10 Business enterprise sector - Research and development expenditure, by sectors of performance.

These predictors have a citation level of 323.000 results in scholar.google.es

RESULTS

ScienceKnowledge (SK)

The SK indicator for the response and predictor variables was elevated, with a growing increase in their citations. The indicator is based on counting all the priority patent applications filed by a country's inventors, regardless of the patent office in which the application is filed, and can therefore be considered as a complete 'matrix' of all patent counts (De Rassenfosse et al., 2013).

SK results for Variable response.- gran_pct_nat_phas.- The total SK value during the study period was 90750. The most important increase corresponds to 2013-2014, with an increase of 17% (Fig. 1).

SK results for Predictor Variables

Table 1 lists the total SK values for the predictor variables, which were highest for humresour_rd_tot, with 571000 citations, followed by hieduc_exp_rd_sec-ejec with 317000 citations, tot_rd_exp with 266000, and bus_ent_rd_exp with 200000. The lowest values were observed for gr_do_rd_soufun, with 4280 citations, and rd_e_gerdact with 5670.

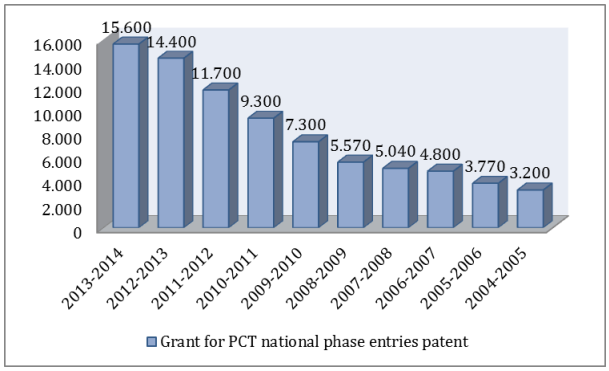

Fig 1a. Grant for PCT national phase entries patent. Increase in interanual %. ScienceKnowledge (SK).

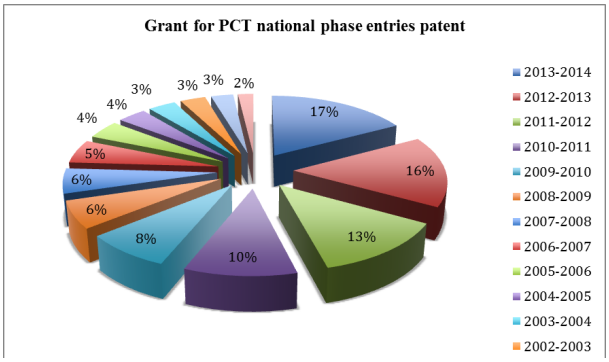

Fig 1b. Grant for PCT national phase entries patent. Increase in interanual %. ScienceKnowledge (SK).

Descriptive analysis of variables

Table 2 reports the mean values, the standard deviations and the three quartiles for the response variable and the predictors. Data for all four response variables and the rd_p_persqual,rd_p_perssci and pt_app_epo predictor variables were highly skewed to the right, due to the extreme values in some countries. Thus, the median value for the variable pat_ep_nipc was 173.00, i.e., half of the countries had a value below 173.00, while three quarters had one below 1963.00, whereas the United Kingdom, France, Japan, and Germany had values above 5000, which had a substantial impact on the overall mean value of the variable. Out of the remaining predictor variables, rd_e_berdfundr2, rd_e_gerdact, gr_do_rd_soufun,tot_rd_exp, rd_exp_sec_higed, bus_ent_rd_exp, and hieduc_exp_rd_sec-ejec were only slightly skewed to the right, while humresour_rd_tot can be considered practically symmetrical, with a mean value of 38.42 and median value of 38.38.

Regression model

The eleven predictor variables were introduced for the regression model.

MODEL

The response variable in this model was gran_pct_nat_phas. The optimal model contained predictor variable: Total R&D personnel and researchers by sectors of performance, sex and fields of science. The regression coefficient was 0.001 for rd_p_perssci ($P<0.05$) and -1.18 for pt_app_epo ($P<0.1$) (Table 3). The negative value indicates a decrease in the response variable with an increase in the predictor variable pt_app_epo. The adjusted coefficient for the two variables was 0.14.

DISCUSSION

The data of the research team have been previously associated with patentability (Sapsalis and Van Pottelsberghe, 2007; Singh, 2008), the present study offers the first demonstration of the number of people involved in the research, including technicians, managers and qualified specialists, it is the most important factor, in the model considered. The high rating of the researchers proved to be more influential compared to human resources in general (humresour_rd_tot), and much more influential compared to previous activi-

Table 1. ScienceKnowledge, total values of predictive responses.

Response predictiva	Total SK
rd_p_persqual	11200
rd_p_perssci	17400
rd_e_berdfundr2	18500
rd_e_gerdact	5670
humresour_rd_tot	571000
gr_do_rd_soufun	4280
tot_rd_exp	266000
pt_app_epo	3570000
rd_exp_sec_higed	11200
bus_ent_rd_exp	200000
hieduc_exp_rd_sec-ejec	317000

Table 2. Descriptive analysis of variables.

Measures of magnitude and heterogeneity					
Variable Response analyzed	**1st Quartile**	**Median**	**3rd Quartile**	**Media**	**Desv. estándar**
Grant for the patent of entries in the National Phases of the PCT	37´27	115´60	664´50	1796´00	4593´39
Explanatory Variables	**1er Cuartil**	**Median**	**3er Cuartil**	Mean	**Estándar deviation**
rd_p_persqual	18290´00	72520´00	121900´00	249400´00	635667´00
rd_p_perssci	18290´00	72520´00	121900´00	249400´00	635667´00
rd_e_berdfundr2	26´71	129´40	446´70	267´50	280´72
rd_e_gerdact	79´60	296´30	868´60	473´30	436´10
humresour_rd_tot	31´61	38´38	45´83	38´42	8´61
gr_do_rd_soufun	39´66	46´22	60´46	48´32	14´45
tot_rd_exp	0´71	1´28	2´17	1´50	0´87
pt_app_epo	6´98	50´56	149´90	89´92	102´44
rd_exp_sec_higed	0´23	0´36	0´47	0´38	0´20
bus_ent_rd_exp	0´30	0´88	1´44	0´99	0´76
hieduc_exp_rd_sec-ejec	0´23	0´36	0´47	0´38	0´20
High asymmetry on the right					
Moderate asymmetry on the right					

ty in patent applications (pt_app_epo).

Our results agree with data previously provided (Jekunen, 2014; Kannankutty et al., 2014; Coupé, 2003), our findings indicate that for the increase of Grant for the patent of entries in the National Phases of the PCT, the qualification of the number of people involved in the research is fundamental, showing interdependence with the quality of the researchers and the financing of patentability.

The application of multivariate linear regression analysis has allowed us to identify variables that affect the activity of Grant for the patent of entries in the National Phases of the PCT and, therefore, indirectly, increase the usefulness of scientific knowledge and allow the investment in R & D to be maximized. In this analysis of the variable Grant for the patent of entries in the National Phases of the PCT from 2000 to 2018, evidence that the quality of researchers, greater experience of the teams of research and greater specialization are determinants for the increase Grant for registration the patents.

Our selection of the response variable was endorsed by the SK results, which all showed an elevated level of citations in relation to patentability and a trend to marked growth. The mean annual growth rate in citations for: Grant for the patent of entries in the National Phases of the PCT was with 17.16%. The relevance of the predictor values selected was also confirmed by the SK results, which were highest for humresour_rd_tot, with 571,000 citations. The predictor variables humresour_rd_tot and hieduc_exp_rd_sec-ejec were selected in previous studies on patentability (Fleming and Sorenson, 2004; Singh, 2008; Cassiman et al., 2008; Sikka et al., 2014).

An optimal model was developed to determine the predictor variable with significant influence on the response variable analyzed. In the model for the response variable grants for PCT national phase entry, contained the predictor variables rd_p_perssci and pt_app_epo; the model residuals showed no outlier, and no country was excluded from the final model.

The coefficient of determination was negative for one of the variables, pt_app_epo (patent applications to the EPO), rd_p_perssciwith he showedhigh statistical significance (P<0. 1), ex-

Table 3. Regression model Model: Grant for the patent of entries in the National Phases of the PCT.

Coefficients	**Estimate**	**Std. error**	**P value**
Intercept	296.9	95.980	0.005
rd_p_perssci	0.001	0.000	0.043
pt_app_epo	-1.178	0.648	0.082
Adjusted R^2			
0.839			

plaining why these two predictor variables together accounted for only 14% of the variability.

Research team data have previously been associated with patentability (Sapsalis and Van Pottelsberghe, 2007; Sanberg and McDevitt, 2013; Singh, 2008; Stevens et al., 2011). However, the present study offers the first demonstration that the number of individuals engaged in research, including technicians, managers and qualified specialists, is the most important factor, entering in model considered. The high qualification of researchers proved to be more influential in comparison to human resources in general (humresour_rd_tot) and much more influential in comparison to previous activity in patent applications (pt_app_epo). Unlike the studies by Miyata (2000) and Reitzig (2004), we detected no direct relationship between funding, either public or private, and the development of patents.

It has previously been reported that the number of staff with a PhD is an influential factor (Reitzig and Puranam, 2009; Rasmussen and Borch, 2004; Coupé, 2003); our findings evidence the interdependence between the quality of researchers and patentability. It has also been proposed that the specific scientific area in question plays a role in the development of patents (Fernández et al., 2008); ours show the interdependence between the quality of researchers and funding for patentability. It has also been proposed that the specific scientific area of research plays a role in the development of patents (Fernández et al., 2008; Finardi, 2011; Zhoua et al., 2016); but our data show that this only acts as a predictive variable when it is related to the quality of human resources, including researchers and technicians.

The application of multivariate linear regression analysis allowed the identification of variables that affect patenting activity and therefore, in an indirect manner, may enhance the usefulness of scientific knowledge and permit full advantage to be taken of investment in R&D. In this analysis of patent applications from 2000 through 2010, the likelihood of patentability was greater with higher quality of researchers, longer experience of research teams, and greater specialization.

The data of the research team have been previously associated with patentability (Sapsalis and Van Pottelsberghe, 2007; Singh, 2008; Upham and Small, 2010); the present study offers the first demonstration that the number of people involved in the research, including technicians, managers and qualified specialists is the most important factor, in the model considered. The high rating of the researchers proved to be more influential compared to human resources in general (humresour_rd_tot) and much more influential compared to previous activity in patent applications (pt_app_epo).

Our results are consistent with previously reported data (Rasmussen and Borch, 2004; Coupé, 2003), our findings for Grant for the patent of entries in the National Phases of the PCT show interdependence with the quality of researchers and the financing of patentability.

The application of multivariate linear regression analysis has allowed us to identify variables that affect the activity of Grant for the patent of entries in the National Phases of the PCT and, therefore, indirectly, increase the usefulness of scientific knowledge and allow the investment in R & D to be maximized. In this analysis of the variable Grant for the patent of entries in the National Phases of the PCT from 2000 to 2018, evidence that the quality of researchers, greater experience of the teams of research and greater specialization are determinants for the increase Grant for registration the patents.

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