ATLANTIS PRESS
*Advances in Social Science, Education and Humanities Research, volume 441*
**6th International Conference on Social, economic, and academic leadership (ICSEAL-6-2019)**

# Leadership in Innovation: A Case of the High-Tech Sector in the Krasnoyarsk Krai

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**Abstract** This paper aims at analyzing the determinants of leadership in innovation using a case study of the high-tech sector in the Krasnoyarsk region of the Russian Federation. The effectiveness of innovation is assessed through the analysis of patent applications, granted patents and trademark applications. Our results show the degree of influence on the number of patents such factors as public R&D spending, the number of employees in the high tech industry, spending on education, the number of employees in science and technology, the level of exports. Most of the above factors can be considered as determining in the field of innovation efficiency.

***Keywords:*** *innovations, leadership, high-tech sector, Krasnoyarsk region, patents*

## 1 Introduction

One would probably agree that the definition of leading innovative determinants of a high-tech industry is important for the regional economy for several reasons:

- high-tech products are the fastest growing segment of trade;
- a significant amount of imports to the Russian Federation is represented by high-tech products (the share of high-tech goods in the total volume of Russian imports in 2016 amounted to 61.3%);
- the development of high-tech manufacturing sectors is a driver of economic growth;
- the high-tech sector of the economy has a high investment potential, as it develops or uses the most advanced technologies.

As a main opportunity for assessing leadership in innovation in a high-tech industry, a methodology can be used that relates the results of innovations to the number of patents issued (for inventions, utility models, industrial designs, computer programs or databases), as well as the number of issued certificates of registration of goods signs that can characterize the effectiveness of labor and entrepreneurial activities in the field of high technology (Khalili 2016; Elrehail et al. 2018). Based on this assumption, a series of econometric tests was carried out to determine the innovative determinants of the high-tech sector of the Krasnoyarsk Krai. The influence of a number of factors was analyzed, such as: investments in research and development in the technological field, education costs, budget allocations (or expenses) for R&D human resources in R&D, human resources in higher professional education, and the level of export of high-tech products.

The study period covers 2008-2018 and 61 municipal entities of the Krasnoyarsk Krai. It was decided to save for analysis the data of all municipalities of the region, which is the primary reason for the imbalance of the sample (there are missing data in the study panel). For the analysis, a correlation-regression analysis using panel data was selected. Using the panel data methodology involves considering fixed and random effects. The choice in favor of a model with either fixed or random effects was made based on the Hausman test.

## 2. Innovative determinants of the high-tech industry

Innovations consist of introducing innovations that increase the efficiency of certain processes, there are many attempts to determine the essence of innovative determinants, but at the moment there is no single definition (Martínez-Román and Romero 2017; Le and Lei 2019). Although the term "high technology" is very often used in literature and scientific research, there is also no clear definition of it (Nguyen et al. 2018).

In general, "high technologies" can be divided into two separate groups, the first, where the emphasis is on the technical complexity of the final product, and the second, where the emphasis is on determining the initial level of research and development in connection with the industry in which "high technologies" are used. Technology-oriented research is a valuable tool for integrating resources into innovative processes. Thus, the determination of the determinants of innovation in high-tech industry (the contribution of innovation) is of importance (see e.g. Tavassoli 2015).

The determining factors of innovation in the high-tech industry are numerous. Literature defines such key characteristics of high-tech innovations as human capital and access to appropriate financial and support resources to ensure synergies. In addition, these classic influence factors characterizing the conditions of efficiency show the importance of endogenous research and infrastructure for regional as well as national innovation potential, and the development of high-tech business clusters (Hiadlovsky et al. 2018).

Factors determining the effectiveness of innovative activities are often analyzed at the national level and rarely at the regional level. A more comprehensive analysis at the regional level is carried out by studying the determinants of regional innovation through the production function, taking into account five categories as explanatory variables: national and regional social economic environment, innovative firms, higher education institutions and R&D. We focus on internal factors of influence, such as government spending on R&D, the number of employees in the high-tech industry, expenses on education, the number of workers in science and technology, and the level of exports.

## 3. Data, methodology and results

The initial data for the study were taken from an automated information system for monitoring municipalities (AIS 2020), as well as annual reports on the activities of Rospatent (2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018; 2019) with annual intervals and cover the period from 2008 to 2018. The dependent variables for analysis are the number of applications for the grant of patents per 1000 people (hereinafter "pa"), the number of patents granted per 1000 people. (hereinafter "pg") and the number of issued certificates of registration of trademarks per 1000 people (hereinafter "ctm").

The explanatory variables are (Baesu et al. 2015): education expenses as a percentage of the gross regional product GRP (hereinafter "*eegrp"*), education expenses as a percentage of budget expenditures (hereinafter "*eepe"*), budget appropriations (or expenses) for R&D as a percentage of total expenses (hereinafter "*gboard"*), expenses for R&D as a percentage of ВРП (hereinafter "*rdegrp"*), expenses for R&D per capita (hereinafter "*rdecap"*), human resources involved in R&D as a percentage of the working population (hereinafter "*rdpap"*), GRP per capita (hereinafter "*grpcap"*), human resources in higher professional education as a % of the working population (hereinafter "*hrstap"*), human resources in higher vocational education as a percentage of the total population (hereinafter "*hrsttp"*), and export level as a percentage of GRP (hereinafter *"expgrp"*).

Descriptive statistics of the variables and the correlation matrix for the main panel of the study (the number of patent applications and its determinants) are presented in Table 1. It can be noted that the level of correlation of *eegrp* and *eepe*, as well as the level of correlation between *hrstap* and *hrsttp* is very high. the conclusion that they are alternative indicators. Thus, in order to avoid errors in the calculations, alternative indicators should not be included in one model. Instead, use them to verify the reliability of the resulting model (Wang et al. 2018). Based on the data presented in Table 1, we can conclude that there is a direct correlation between the dependent variable and the explanatory ones, there is only one indicator - the level of export negatively correlates with such indicators as the number of applications for granting patents and R&D expenses.

**Table 1.** Correlation matrix and descriptive statistics

| Correlation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variables | pa | eegrp | eepe | gboard | rdegrp | rdecap | rdpap | grpcap | hrstap | hrsttp | expgrp |
| pa | 1,000 | | | | | | | | | | |
| eegrp | 0,304 | 1,000 | | | | | | | | | |
| eepe | 0,043 | 0,604 | 1,000 | | | | | | | | |
| gboard | 0,558 | 0,281 | -0,019 | 1,000 | | | | | | | |
| rdegrp | 0,677 | 0,371 | -0,023 | 0,670 | 1,000 | | | | | | |
| rdecap | 0,620 | 0,357 | 0,008 | 0,516 | 0,772 | 1,000 | | | | | |
| rdpap | 0,634 | 0,293 | -0,031 | 0,501 | 0,753 | 0,787 | 1,000 | | | | |
| grpcap | 0,472 | 0,299 | -0,026 | 0,469 | 0,613 | 0,692 | 0,617 | 1,000 | | | |
| hrstap | 0,463 | 0,374 | 0,252 | 0,377 | 0,528 | 0,539 | 0,542 | 0,468 | 1,000 | | |
| hrsttp | 0,502 | 0,439 | 0,317 | 0,431 | 0,554 | 0,558 | 0,541 | 0,452 | 0,827 | 1,000 | |
| expgrp | -0,027 | -0,137 | 0,034 | -0,241 | -0,016 | 0,150 | 0,198 | 0,186 | 0,289 | 0,234 | 1,000 |
| Summary statistics | | | | | | | | | | | |
| Mean | 14,364 | 4,703 | 10,503 | 1,088 | 1,255 | 306,360 | 0,821 | 8,535 | 30,456 | 21,879 | 47,448 |
| SD | 21,627 | 1,028 | 2,061 | 0,401 | 0,797 | 322,650 | 0,423 | 0,823 | 7,034 | 6,264 | 24,201 |
| Min | 0,018 | 2,340 | 5,058 | 0,306 | 0,198 | 4,410 | 0,189 | 6,012 | 13,500 | 9,450 | 17,370 |
| Max | 115,110 | 7,929 | 18,576 | 1,962 | 3,717 | 1247,400 | 2,034 | 10,161 | 49,590 | 35,190 | 163,620 |

Source: Own results

Since the initial data for the analysis are unbalanced, it would be incorrect to immediately draw up a linear dependence equation, it is necessary to conduct a Fisher test, which shows that only a part of the variables selected for analysis are stationary (Table 2).

**Table 2.** Panel unit root test

| Fishcr-typc test | pa | eegrp | eepe | gboard | rdegrp | rdecap | rdpap | grpcap | hrstap | hrsttp | expgrp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inverse chi-squared - P (p-value) | 65,586 (0,026) | 49,572 (0,119) | 70,491 (0,000) | 45,373 (0,485) | 59,772 (0,077) | 16,269 (0,850) | 58,778 (0,094) | 93,245 (0,000) | 35,598 (0,774) | 24,489 (0,842) | 42,177 (0,604) |

Source: Own results

Since the considered data set contains some heterogeneity, mainly due to factors not taken into account in the model, it is necessary to use the panel data model with fixed effects, the fixed effects approach avoids the problem of unaccounted variables - it reflects the effect of all variables as observed, and unobservable. The panel data model with fixed effects provides unbiased and consistent estimates; it is believed that each analyzed object is “unique” and cannot be considered as the result of random selection from the general population. This approach is used at the national level, regional, as well as in industries, large enterprises (Ruosha 2016). The resulting equation of dependence is presented below:

$$Y_{i,t} = \beta_0 + \beta_1 X_{it} + \alpha_i + \varepsilon_{it} \quad (1)$$

where: $Y_{i,t}$ is the dependent variable (*pa, pg, ctm*); $\beta_0$ is the intercept; α - represents all the stable characteristics; $X_{it}$ - represents the vector of independent variables; $\beta_1$ are the coefficients; $\varepsilon_{it}$ is the error.

In a situation where unobserved determinants do not correlate with a dependent variable, to obtain the most objective estimates, it is also necessary to consider a panel data model with random effects, it is assumed that unspecified variables are one of the components of errors. The panel data model with random effects is described by the equation:

$$Y_{i,t} = \beta_0 + \beta_1 X_{it} + \alpha_i + \varepsilon_{it} + \mu_{it} \quad (2)$$

where: $Y_{i,t}$ is the dependent variable (*pa, pg, ctm*); $\beta_0$ is the intercept; α - represents all the stable characteristics; $X_{it}$ - represents the vector of independent variables; $\beta_1$ are the coefficients; $\varepsilon_{it}$ is the within-entity error; $\mu_{it}$ represents between-entity errors.

Using the Houseman test, it is necessary to confirm or refute the hypothesis that there is no correlation between individual effects and regressors in order to make a choice in favor of using a panel data model with random effects, or in favor of a model with fixed effects. The first version of the test includes an analysis of the influence of determinants on the number of patent applications *(pa)* and covers the period 2008-2018. The second test examines the factors affecting the number of patents granted (pg) and covers the period 2008-2018. Finally, the last option covers the period 2008-2018. and shows the main factors affecting the number of issued trademark registration certificates *(ctm).*

For each analysis variant, three different models are evaluated, confirming the reliability of the results. The first model is the base model, in the second model the control variable *eegrp* is replaced by *eepe*, in the third model the control variable *hrstap* is replaced by *hrsttp*. Alternative variables are supposed to provide similar information, have a high degree of correlation with the baseline, and therefore provide a reliability check.

First, the analysis of the number of patent applications was carried out (Table 3). In all cases, the Houseman test results recommend using a panel data model with fixed effects. The cost of education per gross regional product (GRP) and the cost of R&D per capita are negatively correlated with the number of patent applications. At the same time, the number of researchers as a percentage of the able-bodied population has a positive effect on this indicator. The effect of the remaining explanatory variables is not significant.

**Table 3.** Result for the patents applications (*pa*)

| Variables | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Fixed | Random | Fixed | Random | Fixed | Random |
| constant | 25,992 | -16,596 | 19,026 | -19,701 | -14,508 | -37,692 |
| eegrp | -3,536 | -1,726 | -3,290 | -1,526 | | |
| eepe | | | | | 0,569 | 0,615 |
| gboard | 4,968 | 4,191 | 4,531 | 4,163 | 3,559 | 2,946 |
| rdecap | -0,032 | -0,023 | -0,285 | -0,021 | -0,032 | -0,022 |
| rdpap | 16,983 | 25,839 | 17,325 | 25,920 | 18,702 | 26,622 |
| grpcap | -1,667 | 2,301 | -0,802 | 2,837 | 0,439 | 3,404 |
| hrstap | | | 0,246 | -0,002 | 0,129 | -0,118 |
| hrsttp | 0,489 | 0,161 | | | | |
| expgrp | 0,052 | -0,105 | 0,054 | -0,100 | 0,092 | -0,068 |
| $R^2$ | 0,009 | 0,465 | 0,003 | 0,459 | 0,009 | 0,462 |
| F (p-values) | 4,122(0,00) | | 3,843 (0,00) | | 3,258 (0,00) | |
| Wald chi2 | | 40,059 (0,00) | | 39,591 (0,00) | | 38,988 (0,00) |
| Hausman test (recommended) | Prob>chi2 = 0.02 (Fixed effects model) | | Prob>chi2 = 0.00 (Fixed effects model) | | Prob>chi2 = 0.00 (Fixed effccts model) | |

Source: Own results

**Table 4.** Result for the granted patents (pg)

| Variables | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Fixed | Random | Fixed | Random | Fixed | Random |
| constant | -9,123 | -19,429 | 2,023 | -18,147 | -2,019 | -19,820 |
| eegrp | | | -0,678 | 0,332 | -0,529 | 0,449 |
| eepe | 0,309 | 0,335 | | | | |
| gboard | 2,918 | 2,784 | 4,250 | 4,223 | 3,789 | 4,162 |
| rdecap | -0,017 | -0,012 | -0,022 | -0,016 | -0,018 | -0,013 |
| rdpap | 10,858 | 17,604 | 11,730 | 18,601 | 7,300 | 18,379 |
| grpcap | 0,079 | 1,366 | -0,821 | 0,902 | -0,257 | 1,210 |
| hrstap | 0,222 | 0,062 | | | 0,279 | 0,130 |
| hrsttp | | | 0,486 | 0,276 | | |
| expgrp | 0,053 | -0,055 | 0,056 | -0,052 | 0,047 | -0,054 |
| $R^2$ | 0,156 | 0,543 | 0,098 | 0,564 | 0,056 | 0,039 |
| F (p-values) | 3,222(0,00) | | 2,261 (0,01) | | 1,878(0,03) | |
| Wald chi2 | | 29,788(0,00) | | 33,250 (0,00) | | 31,924 (0,00) |
| Hausman test (recommended) | Prob>chi2 = 0.00 (Fixed effects model) | | Prob>chi2 = 0.00 (Fixed effects model) | | Prob>chi2 = 0.10 (Fixed effects model) | |

Source: Own results

The second set of tests considers the number of patents granted as a dependent variable. The results of the analysis of the number of patents granted are similar to the results of the analysis of patent applications, except that the cost of education is negatively correlated with this variable, the number of R&D employees and researchers as a percentage of the working population make a positive contribution to the innovative development of the high-tech industry. For all ratings, it is recommended to use a model with fixed effects.

The last series of tests analyzes the determining factors for the number of issued certificates of registration of trademarks in the field of high-tech production (Table 5). Compared to previous analysis options, a completely different situation is observed. On the one hand, all explanatory variables are significant, except for education costs. Government spending on R&D and R&D expenditures per capita have a positive effect on the registration of new trademarks. The number of workers in the field of science and technology and the level of export in relation to GRP also have a positive effect. However, unlike previous results, R&D personnel as a percentage of the working-age population have a negative impact. In addition, the level of economic development negatively affects the emergence of new trademarks. This means that the less developed territories of the Krasnoyarsk Krai present great potential for certification of their products.

**Table 5.** Result for the trademark applications (ctm)

| Variables | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Fixed | Random | Fixed | Random | Fixed | Random |
| constant | 10,822 | -104,760 | -7,739 | -113,040 | -26,343 | -121,410 |
| eegrp | 4,139 | 4,628 | 5,001 | 5,063 | | |
| eepe | | | | | 2,466 | 1,598 |
| gboard | 70,011 | 43,074 | 70,614 | 43,731 | 67,878 | 45,297 |
| rdecap | 0,185 | 0,212 | 0,204 | 0,221 | 0,203 | 0,218 |
| rdpap | -96,660 | -72,531 | -102,150 | -76,230 | -96,480 | -72,729 |
| grpcap | -32,391 | -13,563 | -32,904 | -14,184 | -31,212 | -13,104 |
| hrstap | | | 4492,800 | 2,571 | 4899,600 | 3093,300 |
| hrsttp | 5,516 | 3,100 | | | | |
| expgrp | 3,208 | 3,294 | 3198,600 | 3,281 | 2,993 | 3,070 |
| $R^2$ | 0,274 | 0,395 | 0,299 | 0,405 | 0,281 | 0,378 |
| F (p-values) | 36,270 (0,00) | | 35,820(0,00) | | 38,340(0,00) | |
| Wald chi2 | | 264,780(0,00) | | 264,060(0,00) | | 279,900(0,00) |
| Hausman test (recommended) | Prob>chi2 = 0.00 (Fixed effects model) | | Prob>chi2 = 0.00 (Fixed effects model) | | Prob>chi2 = 0.00 (Fixed effects model) | |

Source: Own results

Our study indicates that the number of patent applications or patents granted, the level of education, economic development and the level of export do not have a significant impact on the innovative development of the high-tech sector in the Krasnoyarsk Krai. The level of innovative development in the high-tech sector is positively affected by the amount of labor resources and research in the field of R&D. The level of R&D expenditures per capita has a negative effect. Conversely, the number of applications for trademarks is positively affected: the level of R&D expenses per capita, as well as the number of scientific and technical personnel.

## 4. Conclusions

Overall, one can see that the high-tech sector is of particular importance, providing the prerequisites for economic growth, as well as to stimulate import substitution. In this context, it is important to assess its leadership and the value of potential determinants that can affect the productivity of the innovation process, such as education costs, budget allocations, R&D expenses, human resources involved in R&D, etc.

The panel analysis of the municipalities of the Krasnoyarsk Krai, using the fixed and random effects model, demonstrates that the number of employees and researchers in the field of R&D has a leading and positive effect on patent developments, while the cost of R&D has the opposite effect. However, when we talk about new trademarks, the costs of research and development and human resources in the field of science and technology come to the fore. The level of export in the high-tech sector, in turn, has a positive effect on innovative production, although economic development has these negative consequences.

The results of the study can be divided into two categories. The first category determines the determinants of the number of patent applications and granted patents. From the entire list of explanatory variables, only two main factors of innovative production were found. According to the results of the study, the personnel involved in research and development have a positive impact on the sphere of high-tech production. These conclusions can be considered contradictory, since a large number of R&D employees also leads to an increase in R&D expenses. Nevertheless, we can assume that more and more people involved in scientific research contribute to the generation of new ideas.

The second category of results relates to the determinants of the emergence of new high-tech trademarks. In this case, R&D expenses have a positive impact, encourage new ideas in business and are the cause of commercial advantages. In addition, the number of workers in science and technology is important for such an innovative production. However, the results of the study, even in combination with data from other studies, should be interpreted with caution, for several reasons:

First, the statistics found are not complete for all municipalities in the Krasnoyarsk Territory. In order to avoid comparing heterogeneous data, the linear interpolation method was used, however, the statistics were not completely balanced. Secondly, some of the variables were not stationary. Thirdly, the linearity of the estimation equations was taken as the basis, while real interactions can be nonlinear. Thus, at this stage, it seems impossible to avoid considering some variables with potential similar effects, such as R&D personnel and human resources of science and technology.

## Acknowledgments

The project "Formation of mechanisms for selection and support of competitive high-tech businesses for structural changes in the economic system of the resource region and promotion in the world commodity markets" was funded by Krasnoyarsk Regional Fund of Science,

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