

## PROSPECTS FOR INNOVATION PERFORMANCE ON EUROPEAN LEVEL

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**Abstract:** *In 2004, the European Commission implemented the Decision No 1608/2003/EC of the European Parliament and of the Council concerning the production and development of Community statistics on innovation. This triggered the awareness of the role of innovation and R&D on national and European level and thus the opportunity to step towards in-depth monitoring innovation performance through various indicators. The paper aims to investigate the trends in the selected innovation indicators (i.e., public funding, expenditures and innovation activities, types of innovation and products introduced, hampered innovation activities) to outline the development direction on the enterprise level using the Community innovation survey data for the 2002–2016 period. Using the basic time series analysis, the paper evaluates the progress according to the European Strategy on research and innovation. Furthermore, using the autocorrelation and autoregression methods, the paper also outlines the future direction in innovation performance on European level.*

**Key words:** innovation, performance, progress, future direction, European Union, Community innovation survey

### 1. Introduction

In 2010, European Commission (EC) presented the strategy for smart, sustainable and inclusive growth known as Europe 2020. It focused on the need for transformation as a response to the recent economic crisis, which negatively influenced the European economic and social progress. To reinforce economic progress, Europe 2020 outlined three main priorities regarding smart, sustainable and inclusive growth. In this context, it emphasized knowledge and innovation as important forces for successful economic development (Unspecified 2010; Rončević 2019).

The implementation of Europe 2020 followed the provisions of the Treaty establishing European Community (European Union 2002), and in particular Article 157 thereof, according to which the Community and the Member States are to provide the conditions for the competitive Community's industry. Following the aim of this paper, we focus on the part, which refers to the exploitation of the industrial potential that science, technology and innovation policies have for Member States.

As pointed by EC, innovation is a prerequisite for Europe's sustainable growth, which is influenced by several systemic factors set by the regulatory framework. To foster the innovations, one of the important actions outlined by EC, is the reduction of the main administrative burdens set by the EU legislation. This means that innovation and regulatory environment should be interacting to set an optimal level of regulations in innovation domain. To set an innovation-friendly regulatory framework, the Better Regulation Agenda and the third strand of the Investment Plan for Europe have already constituted mutually connected instruments. These include further improvement of the existing and future regulations design focusing on their impact on innovation, achievement of the best possible balance between regulatory environment and technological and scientific progress, overall assessment of the impact that regulations have on innovations, and search for innovation-friendly approaches for the future (European Commission 2016).

To support and monitor the performance of these regulations and policies, in 2004 the European Commission implemented the Decision No 1608/2003/EC of the European Parliament and of the Council concerning the production and development of Community statistics on innovation. This triggered activities to build foundations for governing the process of providing R&D and innovation statistics, which would ensure the usability and comparability of the data.

In providing these statistics, an important role has been attributed to the Community Innovation Survey (CIS), which has been carried out in some European states since 1992. Being driven mainly by academics, CIS provided data that were of high value primarily for researching innovation in conjunction with economic theories. With the implementation of the Decision No 1608/2003/EC of the European Parliament and of the Council, the content and implementation of CIS has gradually shifted from academics to policy analysts and national statistical agencies with Eurostat being the coordinator of changing the standard CIS questionnaire. Furthermore, in order to ensure comparable statistics on R&D and innovation, the implementation of Commission Regulation No 1450/2004 has determined the use of CIS to

provide innovation indicators, thus also being incorporated into the European law (Arundel and Smith 2013).

Today, CIS is considered the largest innovation survey in the world regarding both, the number of participating countries and the number of responding enterprises. It follows the standard definitions of R&D from the Frascati Manual (OECD 2015), which provides methodological guidelines for collecting, using and reporting data on research and experimental development. It is also based on the Oslo Manual (OECD 2005), which outlines the guidelines for collecting and interpreting innovation data. The newest edition of the Oslo Manual was released in 2018 (OECD 2018) and represents the foundation for future preparation and implementation of CIS (Arundel and Smith 2013).

The main aim of the paper is to evaluate the trends in general innovation indicators, i.e., the number of innovative enterprises, their source of funding (public vs. non-public) and enterprises' innovation expenditures, and to expose prospects for innovation performance on European level. Furthermore, the overview of the main factors hampering innovation activities, the paper aims also to outline main obstacles that enable the enterprises to be more successful in innovations.

The following chapter describes data and methods used to meet the main aims of the paper, which is followed by the presentation and interpretation of analysis results. In conclusion, we summarize our key findings and propose ideas, which should be considered in the area of innovation regulation.

## **2. Data and methods**

To answer to our research question, we used Community innovation survey data for the 2004–2016 period. Namely, since 2004 the area of statistics on Community innovation is continuously regulated, both in terms of concepts unifications as well as and the compulsory transmission of data by the Member States. Consequently, the data are of better quality in terms of their validity, reliability, as well as comparability.

We used Eurostat database to download the data from Community innovation survey<sup>5</sup> for the observed period. To follow innovation

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<sup>5</sup> The statistical unit is the enterprise, which is defined as “the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision making, especially for the allocation of its current resources. It may carry out one or more activities at one or more locations and it may be a combination of legal units, one legal unit or part of a

performance, we used the following indicators: (1) total number of enterprises in the population, (2) number of product and/or process innovative enterprises<sup>6</sup>, (3) number of product and/or process innovative enterprises that received any public funding, and (4) total innovation expenditure (in thousand Euros) of product and/or process innovative enterprises. All of these are presented as time series data.

We firstly presented the selected indicators for the observed period, which allowed us to outline the development trends thereof. These were also used to calculate annual growths as well as average annual growth rate (AAGR) and compound annual growth rate (CAGR).

Following the demonstrated trends, we further investigated the correlations of individual time series with their past values. To do so, we used autocorrelation analysis, which represents the correlation of a time series with itself at differing time lags. The autocorrelations are calculated as normalized version of autocovariance function (Shumway and Stoffer 2017):

$$r_k = \frac{c_k}{c_0} = \text{Cor}(x_t, x_{t+k}) \quad (\text{Eq.1})$$

where  $x_t$  is the observed time series with  $n$  observations,  $c_0$  is the autocovariance of the time series at lag 0 and equals the variance of the time series, and  $c_k$  is the autocovariance function for some lag  $k$ , that is:

$$c_k = \frac{1}{n} \sum_{t=1}^{n-k} (x_t - \bar{x})(x_{t+k} - \bar{x}) \quad (\text{Eq.2})$$

Following the normalized autocovariance function, we calculated the autocorrelation function (ACF) for each individual time series, which represents a set of correlations between the time series  $x_{t+k}$  and its past values  $x_t$  for lag values  $k = 0, \pm 1, \pm 2$ , and so on. The value of  $r_k$  ranges from  $-1$  to  $1$ . To present the results of autocorrelation analysis, we used graphical representation of ACF using correlation plots. The x-axis represents a time lag ( $k$ ), and y-axis represents the value of autocorrelation. These presented autocorrelation coefficients correspond to one lag value  $k$ . When  $k = 0$ , the value of autocorrelation ( $r_0$ ) equals 1, since it refers to the correlation of a time series  $x_t$  with itself. When  $k = 1$ , the value of autocorrelation ( $r_1$ ) measures the association between  $x_t$  and  $x_{t-1}$ , when  $k = 2$ , the value of

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legal unit." (Council Regulation (EEC) No 696/93 of 15 March 1993, OJ No L76 of 3 March 1993)

<sup>6</sup> Note, that the category of "product and/or process innovative enterprises" includes all innovative enterprises, i.e., enterprises that implemented new or significantly improved production process, goods, services, marketing concept or strategy, and/or organizational method. These are referred to as product and/or process innovative enterprises, regardless of organizational or marketing innovation (including enterprises with abandoned/suspended or on-going innovation activities).

autocorrelation ( $r_2$ ) measures the association between  $x_t$  and  $x_{t-2}$ , and so on. Blue dotted lines represent the approximate 95% confidence intervals, which are calculated as

$$-\frac{1}{n} \pm \frac{2}{\sqrt{n}} \quad (\text{Eq. 3})$$

where  $n$  is the number of data points used in the calculation of the ACF. The approximate 95% confidence intervals serve as the threshold used to identify statistically significant values of autocorrelations.

Following the findings based on ACF analysis, we further performed autoregression (AR) analysis, which is actually an extension of linear regression modelling. When analyzing a time series, the AR analysis regresses the time series against itself. We can present the AR model of order  $p$  as:

$$x_t = c + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \dots + \phi_p x_{t-p} \quad (\text{Eq.4})$$

where  $c$  is a constant,  $\phi_i$  ( $i=1,2,\dots,p$ ) represent the estimated parameters, and  $p$  determines the order of the model, which is expressed by the optimal number of lags  $k$ . We can perceive the AR model similarly to the multiple regression model with lagged values of time series  $x_t$  as predictors.

According to the results of regression and autocorrelation analyses, we finally estimated expected future trends for the observed indicators in two ways. We first used estimated regression models, which enabled us to calculate the predictions for the observed indicators as a function of time. Secondly, we also used estimated AR models to predict future trends for the observed indicators as a function of past data of the same time series. In both cases, the predictions were estimated using ordinary least squares (OLS) method.

### 3. Results

To evaluate the progress of innovation performance, we first present the population of enterprises divided into innovation and non-innovation enterprises from 2004 to 2016.

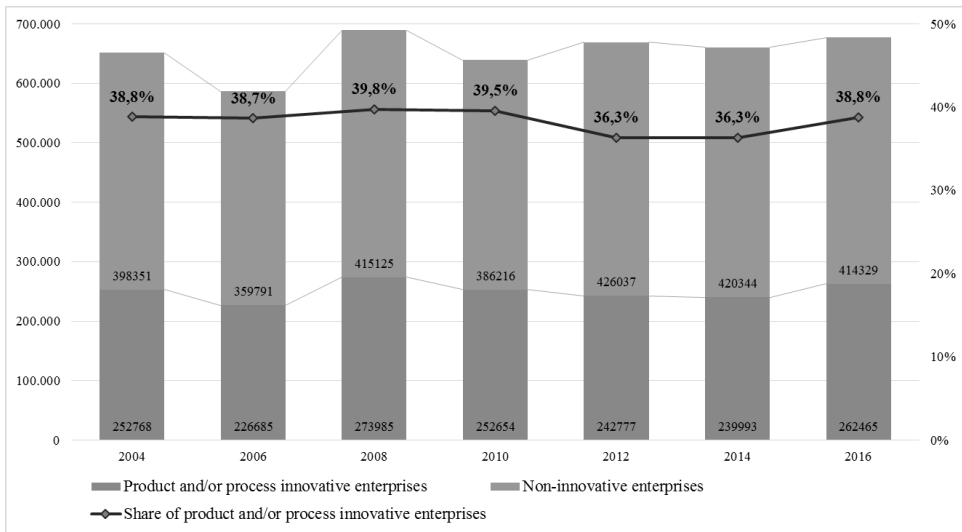


Figure 1. Number of innovative and non-innovative enterprises, and the share of innovative enterprises in the population in 2004–2016.

The data in Figure 1 show some minor fluctuation in the number of enterprises in the population. On the other hand, the data also show consistently lower share of innovative enterprises compared to non-innovative ones. Share of innovative enterprises in the observed period ranges from 36,3 % to 39,8 %, exhibiting AAGR of only 1% and CAGR of 0,5%. Focusing on the innovative enterprises, we divided them according to whether they received any public funding or not.

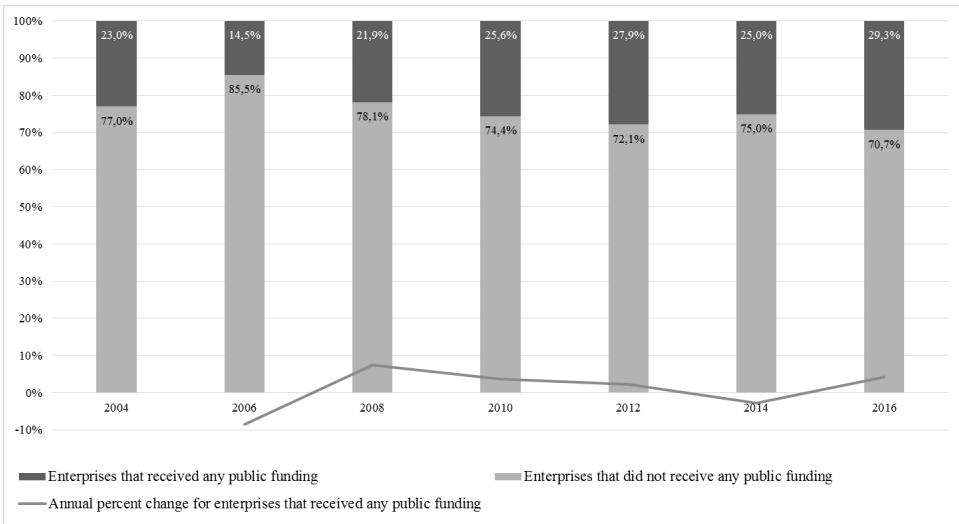


Figure 2. Share of innovative enterprises that received any public funding vs. share of innovative enterprises that did not receive any public funding, and annual percent change for innovative enterprises that received any public funding in 2004–2016.

Following the data in Figure 2, we notice that the share of enterprises that received any public funding decreased for 8,7% in 2006 as compared to 2004, but started to increase again from 2008 onwards. A minor decrease of 2,8 % can again be perceived in 2014, but in 2016 the share of innovative enterprises that received any public funding increased for 4,2%. The data exhibit AAGR of 11,3% and CAGR of 4,0%.

In addition to funding, innovative enterprises also exhibit expenditures, which are directly or indirectly associated with innovations and are presented in Figure 3.

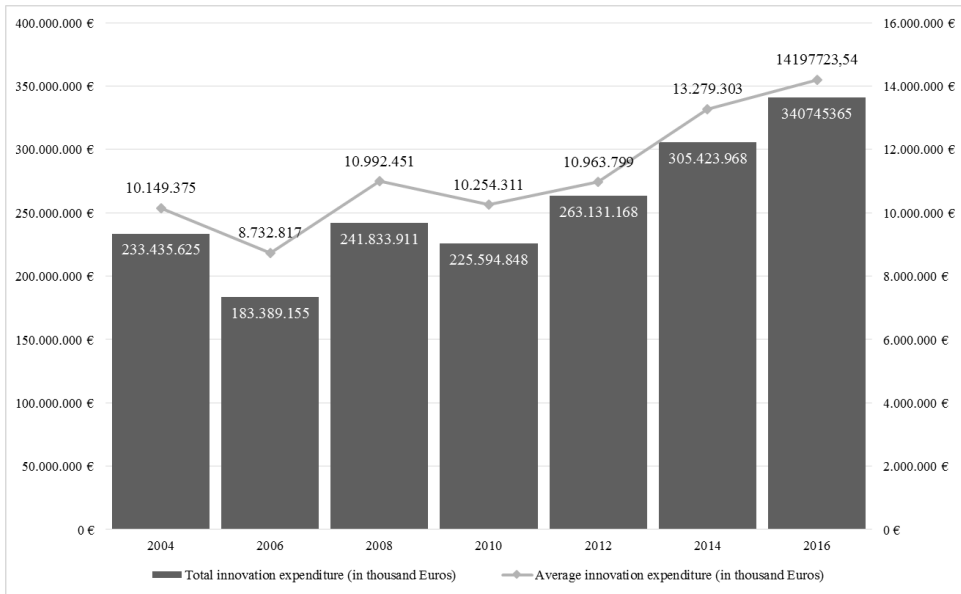


Figure 3. Total and average innovation expenditure in thousand Euros in 2004–2016.

We can observe a similar trend in total and average innovation expenditures, and the number of innovative enterprises in the population (see Figure 1). It is obvious that decreased number of innovative enterprises means also lower expenditure on innovation and vice versa. Namely, when the number of innovative enterprises drops, there remains fewer entities spending on innovation. Following the observed trends, data exhibit AAGR of almost 8,0% and CAGR of 9,3%.

Finally yet importantly, we also focused on the factors hampering the innovation activities. In Figure 4, we present main factors that innovative enterprises outlined to be highly important in terms of hampering the innovation activities. Note that the data refer to 2004, 2010 and 2016, as these data are only collected in every second round of CIS implementation, i.e., every four years.



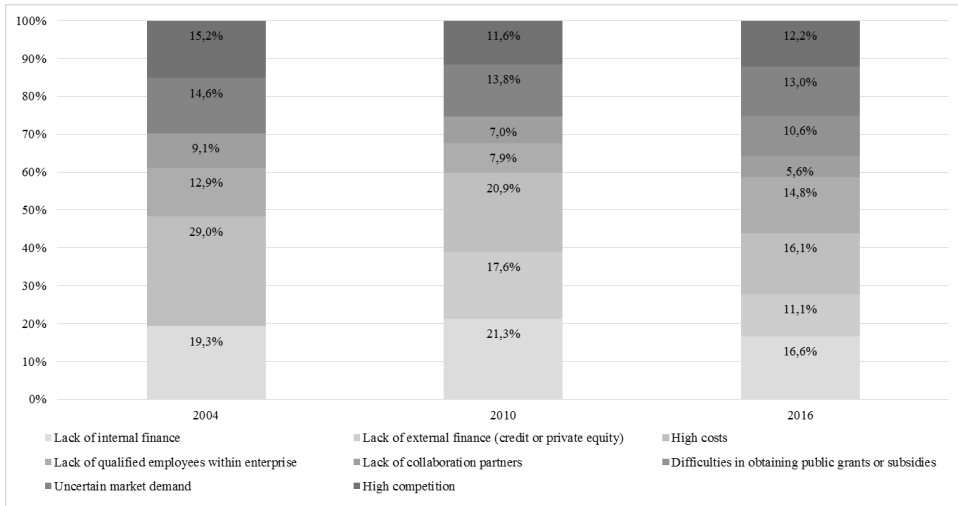


Figure 4. Main highly important factors hampering innovation activities in 2004–2016.

The data show that innovative enterprises as highly important factors hampering innovation activities expose lack of internal finance, lack of external finance, high costs, lack of qualified employees within enterprise, lack of collaboration partners, difficulties in obtaining public grants or subsidies, and uncertain market demands. Looking at these factors, we can divide them into two main groups, i.e., factors whose importance in hampering innovation activities has somewhat declined from 2004 to 2016, and factors whose importance in hampering innovation activities is still high or even higher in 2016 as compared to 2010 and 2004. As it turns out, lack of qualified employees within enterprise is the only factor that significantly gained on the importance in hampering innovation activities. Although in 2010 a share of innovative enterprises for which lack of qualified employees represented an obstacle for implementing innovation activities dropped as compared to the share in 2004, but in 2016, their share almost doubled as compared to 2010. As regards to other presented hampering factors, the data show that the share of innovative enterprises for which these factors represented an obstacle for implementing innovation activities in 2016 dropped as compared to 2010 as well as to 2004.

In addition to growths and shares (Figures 1, 2 and 3), we also tested the data regarding the association between time-specific data points in each individual indicator. However, note, that the association for hampering

factors is not assessed, since the data are measured for three separate years only. Hereafter we present the results of autocorrelation analysis for product and/or process innovative enterprises, enterprises that received any public funding, and total and average innovation expenditures.

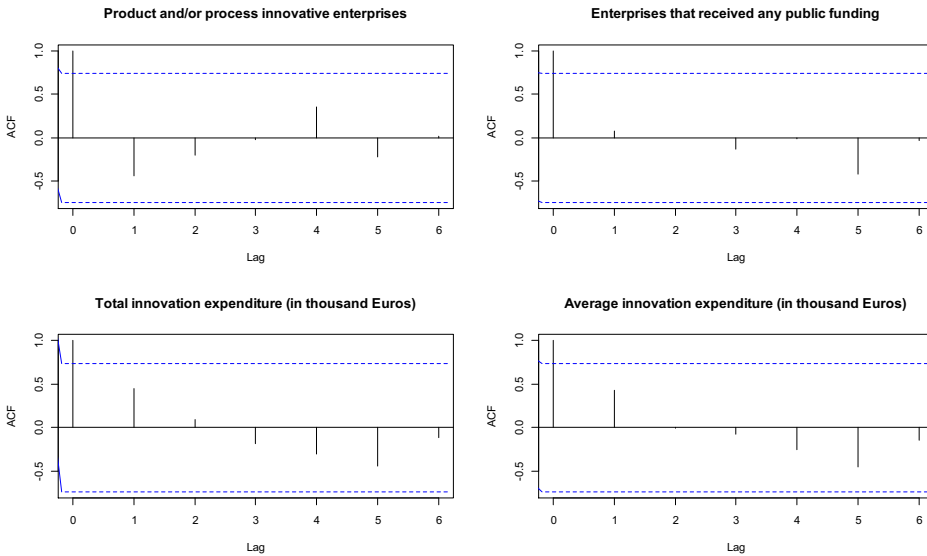


Figure 5. Autocorrelation functions (ACFs) for product and/or process innovative enterprises, enterprises that received any public funding, total innovation expenditure and average innovation expenditure in 2004–2016.

According to Figure 5, in case of all four indicators, when time lag equals 0, the value of autocorrelation equals 1. That is, the correlation is perfect, since it represents the correlation of individual time series with itself. In case of the number of product and/or process innovative enterprises, the value of autocorrelation at time lag 1 is negative, indicating that the number of these enterprises in the 2004–2016 period is negatively correlated with the number of the same enterprises between in the 2004–2014 period. When observing the number of enterprises that received any public funding, the value of autocorrelation at time lag 1 is otherwise positive, but close to zero. In cases of both, total and average innovation expenditures, the value of autocorrelation at time lag 1 is positive, which indicates that innovation expenditure in the 2004–2016 period is positively correlated with the innovation expenditure in the 2004–2014 period.

However, in case of all four indicators, the values of autocorrelations are not significant (they do not reach the blue dashed line on the graph, which represents a threshold for the values to be statistically significant). This finding points to the fact that each individual time series is not related to its past values.

Although there is no obvious tendency of association observed in case of the observed indicators, we conducted AR analysis to predict future trends for each indicator. These are presented in Figure 6.

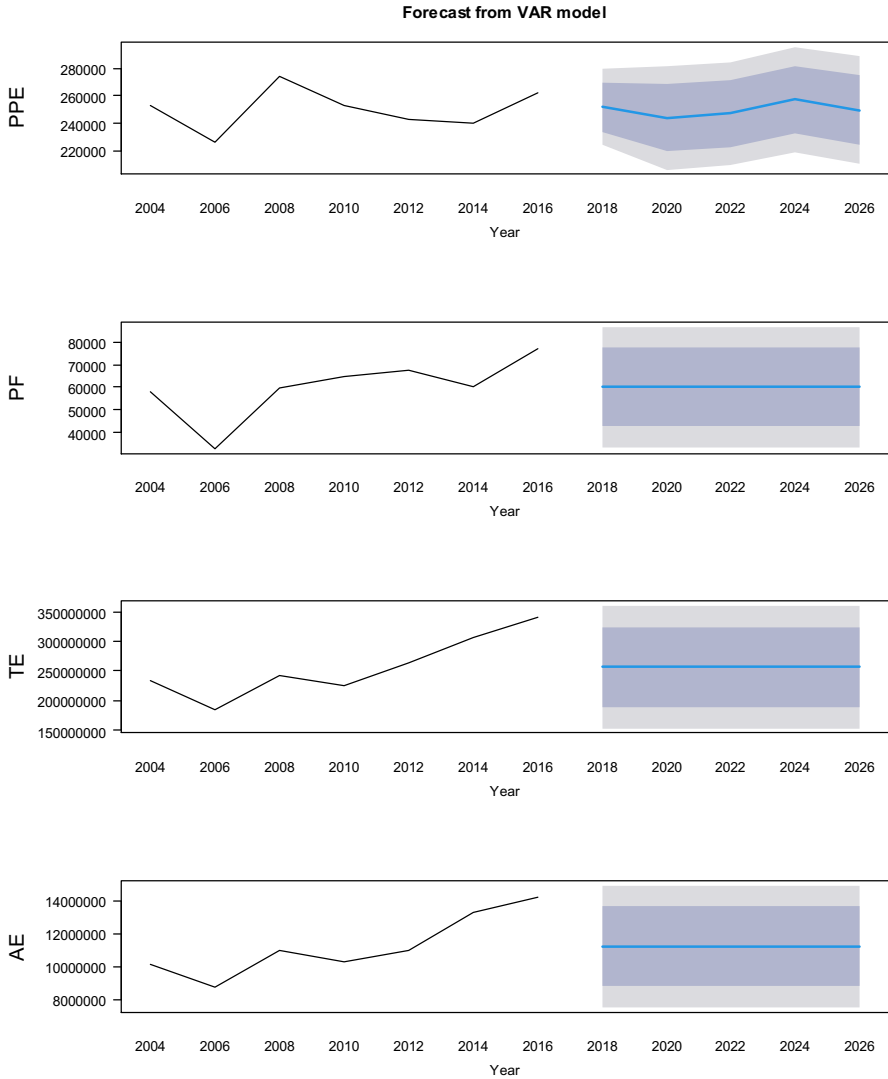


Figure 6. Predicted values for product and/or process innovative enterprises (PPE), enterprises that received any public funding (PF), total innovation expenditure (TE) and average innovation expenditure (AE) based on AR models (2004–2016 historical, 2008–2026 predicted).

The left side of the figure shows the actual data for the observed 2004–2016 period, and the right side represents the predictions for the next 10-year period based on each individual autoregression model. The predicted values for each individual indicators are presented as lines, and the shaded areas represent 80% and 95% confidence intervals thereof.

As it turns out, in the coming 10-year period, we can expect some fluctuations in the number of innovative enterprises, whereas the shares of innovative enterprises that received any public funding will not change much. On the other hand, as regards to total and average innovation expenditures, it is expected that these will settle down at 256.222.006 and 11.224.254 thousand Euros respectively.

#### **4. Conclusion**

Europe's sustainable growth largely depends on the innovation, which undergoes a lasting regularization process. The data used in our study show that in the 2004–2016 period, the main effort was directed towards achieving qualitative rather than quantitative improvements in reaching an optimal level of regulations in innovation domain. Namely, the share of innovative enterprises in the population of all European enterprises did not change significantly in the observed period and their share is about 38%. There was also lower share of those innovative enterprises that received any public funding as compared to the ones that did not received any public funding in the observed 2004–2016 period. However, the share of publicly funded innovative enterprises from 2004 to 2016 has grown for 11% on average. Regarding innovation expenditure, this indicator follows the numbers of innovative enterprises, meaning that in the years for which higher share of innovative enterprises has been observed, innovation expenditures were higher as compared to the years in which the share of innovative enterprises dropped.

These findings lead us to some important features regarding innovation domain. Although in European population the share of innovative enterprises remains almost unchanged, obtaining public funding is more accessible. This is most likely due to an increase in public funding, but the finding can presumably be attributed to greater informative of companies in the field of obtaining public funds.

Furthermore, the review of factors hampering innovation activities shows that the innovation domain is clearly expanding, since innovative enterprises to a lesser extent outline the problems regarding acquiring collaboration partners as one of the main hampering factors. But there is still a need for

regulation and improvements in European educational and employment systems, since there is a shortage of qualified employees (especially within innovative enterprises). In fact, more and more innovative enterprises exposes this as one of the highly important hampering factors.

Although there has already been done much in setting the most optimal regulatory framework in innovation domain, there is still a room for improvements. From this point, we propose and encourage further work in this area, as well as to further explore available data on innovations since they are a real treasure trove of information.

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