

ENTERPRISES PROVIDING ICT TRAINING IN EUROPE

Lucio Laureti, LUM University
Alberto Costantiello, LUM University
Marco Maria Matarrese, LUM University
Angelo Leogrande, LUM University

ABSTRACT

The determinants of enterprises providing ICT training in Europe are analyzed in this article. Data are collected from the European Innovation Scoreboard-EIS of the European Commission for 36 European countries in the period 2000-2019. Data are analyzed with Panel Data with Fixed Effects, Panel Data with Random Effects, Dynamic Panel, WLS and Pooled OLS. Results show that the number of enterprises providing ICT training in Europe is positively associated with “Innovation Index”, “Innovators”, “New Doctorate Graduates”, and “Tertiary Education” and negatively associated with “Government Procurement of Advanced Technology Products”, “Human Resources”, and “Marketing or Organizational Innovators”. In adjunct a cluster analysis is performed by using k-Means algorithm optimized with the Silhouette Coefficient and we find the presence of four clusters. Finally, we use eight different machine learning algorithms to predict the value of the enterprises providing ICT training in Europe. We found that the Simple Tree Regression is the best predictor and that the number of enterprises providing ICT training in Europe is expected to growth of the 5,02%.

Keywords: General, Innovation and Invention, Processes and Incentives, Management of Technological Innovation, Technological Change, Choices and Consequences, Intellectual Property and Intellectual Capital

JEL Classification: O30; O31; O32; O33; O34.

INTRODUCTION

The following article deals with the issue of professional training of employees of companies in the IT sector in Europe. The data used were collected by the European Innovation Scoreboard of the European Commission and refer to the period 2000-2019 for 38 countries. The data were analyzed using the Panel Data models with Fixed Effects, Panel Data with Variable Effects, Dynamic Panel, Pooled OLS, WLS. The formation of human capital is an essential element for the promotion of economic growth, as indicated in the Solow model (Solow, 1956), in the models of endogenous growth (Romer, 1994) and in the context of the Schumpeterian economy (Schumpeter, 1934). In general, the role of knowledge for the economic system has been widely recognized in the vast work of Von Hayek (Von Hayek, 1937). The role of human capital training is a necessary element to implement technological innovation and research and development. Technological innovation based on human capital generates a set of advantages, namely:

- Increase relations between innovative companies and the public sector through co-participation in technological innovation projects (Costantiello et al., 2021);

- Improves employment especially in high innovative firms (Laureti et al., 2022);
- Augments the number of design applications (Leogrande et al., 2021);
- Has a positive impact on venture capitalism (Leogrande, et al., 2021);
- Has a positive impact on human resources (Leogrande & Costantiello, 2021);
- Increases the level of corporate sales (Costantiello et al., 2021);
- Improves the volume of intellectual assets (Costantiello et al., 2021);
- Is positively associated with broadband penetration (Leogrande et al., 2021);
- Is positively associated to financial development at country level (Laureti et al., 2020);
- Requires an environment innovation-friendly (Costantiello et al., 2021).

To achieve these objectives, it is necessary that companies, especially small and medium-sized enterprises, invest in the training of their personnel in the ICT sector. Staff training in ICT and especially in the context of STEM-type disciplines can be made more efficient using learning systems administered in the cloud (Shyshkina, 2018). The issue of employee training acquires particular importance especially in those contexts, such as India, where the abundance of young people does not, however, satisfy the demands of employers. In fact, young people appear to be poorly skilled. Therefore, companies should have incentives to focus on ICT training for young people employed (Malik & Venkatraman, 2017). Training in ICT disciplines is essential to ensure that even newly developing countries such as Kenya can seize the opportunities for economic growth to become middle-income countries (Kimani, 2017). The training of employees in IT fiscal lines and especially in software engineering also plays a significant role in entrepreneurial skills in the ITC sectors. It follows that taking care of employee training in IT disciplines also has a positive impact in terms of improving business, enterprise, and management plans (Hien & Cho, 2018).

Investment in employee training in ICT disciplines has positive impacts on productivity in Ecuador with significant increases in business efficiency growth (Rodríguez-Moreno & Rochina-Barrachina, 2019). Training in companies is not only a useful activity for the development of employees, but on the contrary, it can also be a useful method for improving the lifelong learning activity of management and top functions as well (Hollová et al., 2017). The training of employees in digital skills appears to be relevant both within private companies and within the public sector. The benefits of ICT employee training are the growth of business opportunities (Hofmann & Ogonek, 2018). However, it must be considered that the ability of companies to increase productivity to a certain extent also depends on the degree of digitalization of the public administration. The issue of employee training in IT disciplines at the corporate level has also been addressed by the Egyptian government. The Egyptian government has invested to support companies in IT training for employees (de Waal et al., 2017). Employee training in the IT sector appears to be particularly relevant for older employees. In fact, elderly employees have little confidence in the possibility of acquiring IT skills even when they are involved in corporate training processes (Wang et al., 2020). In this regard, it is necessary to act on the motivations of elderly employees to increase the effectiveness of corporate IT training. Furthermore, the lack of attention to information technology training in developing countries significantly limits the adoption of managerial models oriented towards digitization in both the public (Sarker et al., 2018) and private sectors. IT training of human resources in companies is associated with a significant growth in employee productivity (Fajar & Soeling, 2017). Employee training in the use of ICT is also relevant for companies specializing in sales services (Torres et al., 2020). It should also be borne in mind that for many developing or newly developing countries, it is necessary to invest in the training of company personnel in the IT disciplines to increase the ability to compete internationally in the digital economy (de Brito et al., 2018). The investment in the IT training of employees is also relevant for the introduction of efficient management models such as for example for the implementation of E.R.P. (Fernandez et al., 2018). The effectiveness of personnel training models in IT disciplines created by companies can be improved using virtual training tools (Hosain, 2017). The issue of employee training in ICT disciplines is so relevant that some companies set up Corporate

Universities to administer courses to human resources to increase the skills of corporate human capital (Scarso, 2017).

The article continues as follows: the second paragraph presents and discusses the econometric model used for the last observed variable, the third paragraph refers to the application of the k-Means clustering algorithm optimized with the Silhouette coefficient, the fourth paragraph presents 'comparative analysis of eight different algorithms used for prediction through machine learning techniques, the fifth paragraph concludes.

The Econometric model

We estimated the following model:

$$\text{EnterprisesProvidingICTTraining}_{it} = a_1 + b_1(\text{GovernmentProcurementOfAdvancedTechnologyProducts})_{it} + b_2(\text{HumanResources})_{it} + b_3(\text{InnovationIndex})_{it} + b_4(\text{MarketingOrOrganisationalInnovators})_{it} + b_5(\text{NewDoctorateGraduates})_{it} + b_6(\text{TertiaryEducation})_{it}$$

Where $i=36$ and $t=2000-2019$. We analyze data with Panel Data with Random Effects, Panel Data with Fixed Effects, WLS, Dynamic Panel, Pooled OLS.

We find that the level of Enterprises Providing ICT Training is positively associated to:

- **Innovation Index:** It is a general indicator of a country's ability to innovate. There is therefore a positive relationship between the general orientation of a country towards innovation and the ability of companies to offer IT training to employees. Obviously, if a country has a very high degree of innovation, then there is a very high possibility that even companies will recognize the role of corporate training in the IT sector. In fact, in countries that have a high level of innovation, companies that manage to increase the value of human capital through the increase in computer knowledge also have a greater chance of competing and earning higher profits. In fact, in an overall innovation-oriented context, it is likely that there are many public and private incentives for companies that choose to focus on the IT training of their employees. It therefore follows that the growth of a country's degree of innovation is positively associated with the investment that companies make in ICT training for employees.
- **Innovators:** it is a variable calculated as the sum of the percentage of small and medium-sized enterprises that make product innovations out of the total of small and medium-sized enterprises added to the percentage of small and medium-sized enterprises that make process innovations out of the total of small and medium-sized enterprises. This variable is therefore able to highlight the percentage of small and medium-sized enterprises able to innovate. There is a positive relationship between innovators and business investment in employee IT training. This positive relationship is since to innovate companies need to focus on corporate human capital and on the ability of employees to correctly use the IT tools applied to technological innovation. It follows therefore that the countries that have innovative small and medium-sized enterprises are also characterized by the presence of training courses in the ICT sector that are carried out in companies for employees. The aim of training employees through the growth of IT skills is therefore necessary to increase the ability of small and medium-sized enterprises to compete in environments oriented towards process and product innovation in a highly competitive context.
- **New Doctorate Graduate:** is an indicator consisting of the relationship between the number of doctorates in science, technology, engineering, and mathematics-STEM on the total population aged between 25 and 34 years. There is a positive relationship

between the number of companies offering ICT training to their employees and the percentage of PhDs in STEM disciplines. This positive relationship can be understood considering that if a country has a very high percentage of doctorates in STEM disciplines, then it also has a greater ability to innovate and produce knowledge within companies, even small and medium-sized ones. It follows that the orientation of small and medium-sized enterprises is significantly oriented towards the knowledge economy with attention to science and technology. Countries with a higher number of doctorates in STEM disciplines are also characterized by companies that are more sensitive to investment in the training of their employees in ICT disciplines.

- **Tertiary Education:** It is an indicator that takes into consideration the percentage of the population who have a qualification higher than secondary education out of the total population aged between 24 and 35 years. Tertiary education refers to people who have a research doctorate or a master's degree or a postgraduate professional qualification. There is a positive relationship between the presence of people with tertiary education and the investment of companies in IT training for employees. In countries where human capital has a higher level of training, there is also an orientation of companies towards the professional education that is administered to employees in the company. In fact, if the degree of technical-scientific and professional culture is very high then the possibility of maximizing company training tends to grow and companies could have greater advantages also in terms of profit and competitiveness through the training of employees in the ICT sector.

We find that the level of Enterprises Providing ICT Training is negatively associated to:

- **Government procurement of advanced technology products:** It is an indicator that measures a country's ability to promote technological innovation through public procurement. The indicator varies in a range from 1 to 7. There is a negative relationship between the value of the impact of public spending with respect to technological innovation and the ability of companies to invest in the ICT training of their employees. This negative relationship can be better understood considering that indeed the capacity of public spending to have a positive impact on technological innovation is very limited. Countries that have very advanced technological innovation systems tend to produce this innovation not through public spending but rather through the activation of private production systems. Although certainly the State through public spending can play a very important role in determining technological innovation and research and development, it is also true that generally the most innovative countries tend to produce such innovations through private market organizations.
- **Human Resources:** It is a measure that takes into consideration the sum of the percentage of doctoral students plus the percentage of people who have a tertiary education out of the total population aged between 25 and 34 years. In countries where the sum of people with a doctorate and people with tertiary education is increasing, the value of business investment in employee ICT training tends to decrease. This condition can be considered very particular and means that the workforce already has a high level of training thanks to the university system and therefore this condition reduces the training of companies in employee training. That is, in European countries where the workforce has a very strong STEM orientation associated with significant investments in tertiary education, there is a reduction in the professional ICT investment made by companies for their employees. However, it must be considered that this condition is very rare and characterizes only the most advanced European countries. In fact, especially in Southern Europe and Eastern Europe, the degree of tertiary education added to the presence of STEM doctorates tends to be reduced compared to the analogous value in

Northern Europe.

- **Marketing or organizational innovators:** is the percentage of small and medium-sized enterprises that have made organizational or marketing innovations out of the total of small and medium-sized enterprises recorded at national level. Specifically, innovation through marketing or organizational solutions is considered as a form of non-technological innovation. There is therefore a negative relationship between firms' investment in non-technological innovation and firms' inability to provide training to their employees in ICT disciplines. This negative relationship can be easily understood considering that if companies are able to obtain organizational, productive and profit advantages thanks to non-technological innovations; they obviously have less incentives to invest in the training of their workforce in the IT sector. However, it must be considered that non-technological innovation can be considered as a weak form of innovation even if it can produce economic and financial benefits in the short term. However, in the long run, only a process of technological innovation that is adequately supported by a research and development process can sustain sustainable economic growth.

Clustering Using the Unsupervised k-Means Algorithm Optimized Through the Silhouette Coefficient

A clustering is proposed below using the k-Means algorithm optimized through the Silhouette coefficient. Specifically, since the k-Means algorithm is associated with an unsupervised clustering, a value of the Silhouette coefficient was selected such as to maximize the number of clusters by ensuring that none of the elements of each single clusters had a negative value of the Silhouette coefficient. This choice was made to give a representation as broad as possible of the heterogeneity of the observed variable or to also highlight the marginal differences between the various clusters analyzed. the data used refer to European countries in the period between 2014 and 2021 for 35 Countries are Austria, Bosnia and Herzegovina, Belgium, Bulgaria, Cyprus, Czechia, Germany, Denmark, Estonia, Greece Spain, Finland, France, Croatia, Hungary, Ireland, Iceland, Italy, Lithuania, Luxembourg, Latvia, Montenegro, North Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Sweden, Slovenia, Slovakia, Turkey, United Kingdom.

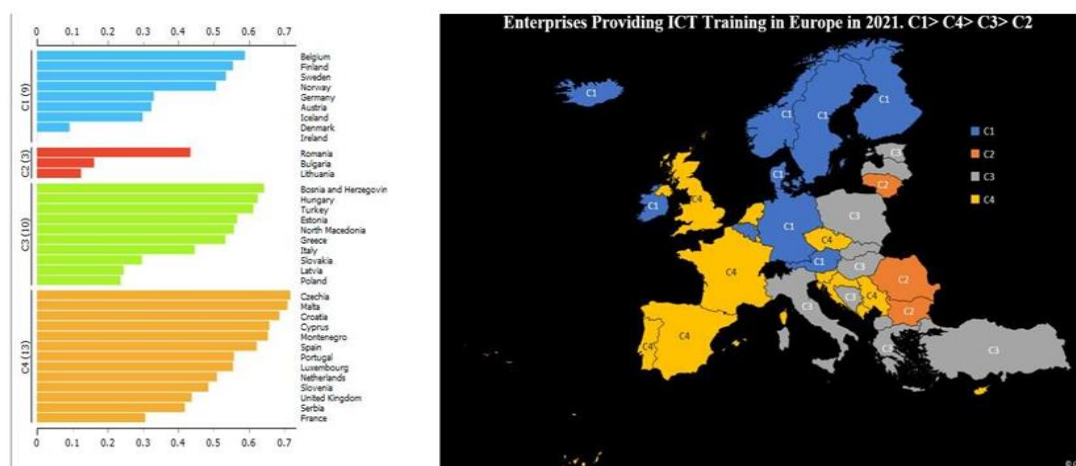


FIGURE 1
CLUSTERING CARRIED OUT USING THE UNSUPERVISED K-MEANS ALGORITHM OPTIMIZED THROUGH THE SILHOUETTE COEFFICIENT TO MAXIMIZE THE NUMBER OF CLUSTERS SUCH THAT NONE OF THE ELEMENTS OF EACH CLUSTER HAS A SILHOUETTE COEFFICIENT VALUE LESS THAN ZERO.

Through the analysis carried out, it was possible to obtain the following clusters, namely:

- Cluster 1: Belgium, Finland, Sweden, Norway, Germany, Austria, Iceland, Denmark, Ireland;
- Cluster 2: Romania, Bulgaria, Lithuania;
- Cluster 3: Bosnia, Hungary, Turkey, Estonia, North Macedonia, Greece, Italy, Slovakia, Latvia, Poland;
- Cluster 4: Czechia, Malta, Croatia, Cyprus, Montenegro, Spain, Portugal, Luxembourg, Netherlands, Slovenia, United Kingdom, Serbia, France.

It is possible to verify that the median value of the observed variable for the nations of cluster 1 is equal to 166.67, for cluster 4 it is equal to 126.67, for cluster 3 equal to 70.00 and for cluster 2 equal to 13.33. It therefore follows that the ordering of the clusters is indicated below, that is: $C1 > C4 > C3 > C2$. It appears that the value of the average of the observed variable for the various countries analyzed by the European Union is equal to 106.67. It follows therefore that two clusters have a median value higher than the average of the entire distribution, i.e. cluster 1 with a value of 166.67 and cluster 4 with a value of 126.67. On the contrary, there are two clusters that have a value of the median of the observed variable lower than the average of the distribution, that is cluster 3 with a value of 70 and cluster 2 with a value of 13.33. In particular, the value of the median of cluster 3 is equal to 65.62% of the value of the average and the value of cluster 2 is equal to 12.50%. The result is therefore an evident disparity between European countries in the value of the training offered by companies to their employees in the ICT sector. The difference therefore appears evident between the countries of Central and Northern Europe which have high values of company training in the IT sector as opposed to the countries of Southern and Eastern Europe which have lower values except for Spain and Portugal. As is evident, there is therefore a real divide between Central-Northern Europe on the one hand and South-Eastern Europe on the other. This gap is also very serious because it reflects a more structural delay in the themes of technological innovation and research and development. In this regard, it is necessary that policy makers intervene to create the conditions so that companies can invest effectively in the training of their employees on ICT issues, especially through adequate tax incentives.

Machine Learning and Prediction

Eight different machine learning algorithms were used below to predict the value of the number of companies engaged in IT training for their employees in Europe. The data used refer to 35 countries for the period 2014-2021. The database used is the European Innovation Scoreboard of the European Commission. The algorithms were trained with 70% of the dataset data while the remaining 30% was used for the actual prediction. Specifically, the algorithms were compared in a performance ranking based on the ability to maximize the R-squared and minimize four different types of static errors, namely "*Mean Absolute Error*", "*Mean Squared Error*", "*Root Mean Squared Error*", "*Mean Signed Difference*". Following the analysis carried out, the following scores were obtained, namely:

1. Simple Regression Tree with a payoff of 6;
2. ANN-Artificial Neural Network with a payoff value of 9;
3. Three Regression Ensembles with a payoff value of 17;
4. Random Forest Regression with a payoff value of 19;
5. PNN-Probabilistic Neural Network with a payoff value of 27;
6. Polynomial Regression with a payoff value of 28;
7. Linear Regression with a payoff value of 34;
8. Gradient Boosted Trees Regression with a payoff value of 40.

By applying the Simple Regression Tree algorithm it is therefore possible to make the following predictions for the countries considered:

- Bosnia with an increase from an amount equal to 71.237 up to a value of 96.841 equal to an absolute value of 25.60 units equivalent to 35.94%;
 - Belgium with an increase from an amount of 186,223 units up to a value of 195,161 or equal to a value of 8,938 units equal to a value of 4,799%;
 - France with an increase from an amount equal to 104.368 up to a value of 119.556 units or equal to a variation of 15.188 units equal to a value of 14.552%;
 - Ireland with an increase from an amount equal to 162.634 up to a value of 195.161 or equal to a value of 32.527 units or equal to a value of 20.00%;
 - Iceland with an increase from an amount of 170,669 units up to a value of 195,161 units or equal to an amount of 24,462 units equal to a value of 14.330%;
 - Montenegro with an increase from an amount equal to 90.323 up to a value of 96.841 units or equal to a value of 6.518 units equal to an amount of 7.21%;
 - North Macedonia with a decrease of a value equal to 42.67 up to a value equal to 41.11 or equal to an amount of -1.565 equal to a value of 3.66%;
 - Malta with a decrease from an amount equal to 159.543 up to a value of 135.551 units or equal to a value of -23.992 units equal to a variation of -15.03%;
 - Poland with a decrease from an amount equal to 90.659 up to a value of 47.11 or equal to an amount of -43.549 equal to a value of 48.03%;
 - Serbia with an increase from a total of 72,446 units up to a value of 117,272 units or equal to a variation of 44,826 units equal to a value of 61.87%;
 - Slovenia with a decrease from an amount equal to 136,895 units up to a variation of 135,551 units or equal to a value of -1,344 units equal to a value of 0.981%;
 - United Kingdom with a decrease from an amount equal to 181.72 up to a value of 167.876 units or equal to a change of -13.844 units equal to an amount of -7.6%;
- Overall, on average, the value of the variable analyzed for the countries considered is expected to grow from an amount of 122,451 units up to a value of 128,599 units, or equal to a value of 6,147 units equal to a value of 5.02%.

| Results of predictions through the Simple Regression Tree | | | | |
|---|----------|------------|--------------------|-------------------|
| Countries | 2021 | Prediction | Absolute Variation | Percentage Change |
| Bosnia | ★ 71,24 | ★ 96,84 | ★ 25,60 | ★ 35,94 |
| Belgium | ★ 186,22 | ★ 195,16 | ★ 8,94 | ★ 4,80 |
| France | ★ 104,37 | ★ 119,56 | ★ 15,19 | ★ 14,55 |
| Ireland | ★ 162,63 | ★ 195,16 | ★ 32,53 | ★ 20,00 |
| Iceland | ★ 170,70 | ★ 195,16 | ★ 24,46 | ★ 14,33 |
| Montenegro | ★ 90,32 | ★ 96,84 | ★ 6,52 | ★ 7,22 |
| North Macedonia | ★ 42,68 | ★ 41,11 | ★ -1,57 | ★ -3,67 |
| Malta | ★ 159,54 | ★ 135,55 | ★ -23,99 | ★ -15,04 |
| Poland | ★ 90,66 | ★ 47,11 | ★ -43,55 | ★ -48,04 |
| Serbia | ★ 72,45 | ★ 117,27 | ★ 44,83 | ★ 61,88 |
| Slovenia | ★ 136,90 | ★ 135,55 | ★ -1,34 | ★ -0,98 |
| United Kingdom | ★ 181,72 | ★ 167,88 | ★ -13,84 | ★ -7,62 |
| Mean | ★ 122,45 | ★ 128,60 | ★ 6,15 | ★ 5,02 |

FIGURE 2
RESULTS OF PREDICTIONS THROUGH THE SIMPLE REGRESSION TREE
MACHINE LEARNING ALGORITHM

CONCLUSION

The determinants of enterprises providing ICT training in Europe are analyzed in this article. Data are collected from the European Innovation Scoreboard-EIS of the European Commission for 36 European countries in the period 2000-2019. The analysis of the literature carried out in the first paragraph takes into consideration both the role of technological innovation for economic growth and also the impact of IT training of personnel in companies for increasing productivity. Specifically, the scientific literature highlights the ability of corporate training to increase the performance of companies. Furthermore, the Human Resource Management models applied to information and knowledge companies in general are always associated with the training of employees in ICT.

The second paragraph presents the econometric model for estimating the value of IT training in companies in Europe. Data are analyzed with Panel Data with Fixed Effects, Panel Data with Random Effects, Dynamic Panel, WLS and Pooled OLS. Results show that the number of enterprises providing ICT training in Europe is positively associated with “*Innovation Index*”, “*Innovators*”, “*New Doctorate Graduates*”, “*Tertiary Education*” and negatively associated with “*Government Procurement of Advanced Technology Products*”, “*Human Resources*”, and “*Marketing or Organisational Innovators*”. The third paragraph presents a case of application of clustering algorithms to the observed variable. The cluster analysis is performed by using k-Means algorithm optimized with the Silhouette Coefficient and we find the presence of four clusters. Furthermore, we use eight different machine learning algorithms to predict the value of the enterprises providing ICT training in Europe. We found that the Simple Tree Regression is the best predictor and that the number of enterprises providing ICT training in Europe is expected to grow by 5.02%.

Finally, in the light of the analysis conducted, it appears that if European policy makers intend to increase the degree of digitalization of businesses, to create an entrepreneurial system structurally oriented towards technological innovation, then they must allocate economic and financial resources to support programs that companies implement for the ICT training of their employees.

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