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The Role of Broadband Price Index in Fostering Economic Growth and Digitization in Europe

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Abstract

This study analyzes the determinants of the "*Broadband Price Index"* in Europe. The data used refers to 28 European countries between 2016 and 2021. The database used is the Digital, Economy, and Society Index-DESI of the European Commission. The data were analyzed using the following econometric techniques, namely Panel Data with Random Effects, Panel Data with Fixed Effects, Pooled OLS, WLS and Dynamic Panel. The value of the "*Broadband Price Index*" is positively associated with the DESI Index and "Connectivity", while it is negatively associated with "*Fixed Broadband Take Up*", "*Fixed Broadband Coverage*", "*Mobile Broadband*", "*e-Government*", "*Advanced Skills and Development*", "*Integration of Digital Technology*", "*At Least Basic Digital Skills*", "*Above Basic Digital Skills", and "At Least Basic Software Skills*". A cluster analysis was carried out below using the k-Means algorithm optimized with the Silhouette coefficient. The analysis revealed the existence of three clusters. Finally, an analysis of the machine learning algorithms was carried out to predict the future value of the "*Broadband Price Index*". The result shows that the most useful algorithm for prediction is the Artificial Neural Network-ANN, with an estimated value equal to an amount of 9.21%.

JEL Classification: O30; O31, O32; O33; O36.

Keywords: Innovation, and Invention; Processes and Incentives; Management of Technological Innovation and R&D; Diffusion Processes; Open Innovation.

1. Introduction

The following analysis takes into consideration the value of the "*Broadband Price Index*" in Europe. The data analyzed refers to the DESI-Digital Economy and Society Index for 28 European countries between 2016 and 2021. The data was used using econometric methodologies, also using clustering and techniques for machine learning. The analysis of the "Broadband Price Index" is relevant to increasing the degree of digitization in Europe, with positive impacts in terms of economic growth. Reducing the price of broadband is also an essential element in reducing the digital divide and enabling a wider diffusion of digital technologies in Europe.

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The creation of the ICT infrastructure, the implementation of broadband and the increase in internet users have an impact on per capita income in the medium to long term [1]. Burlacioiu, et al. (2018) [2] analyze the role of digital and broadband technologies in Romania using data from the DESI database between 2017 and 2018. The authors verified that connectivity in Romania has reached high values compared to the European average, even if the human capital endowment turns out to be undersized. The authors suggest investing in human capital training to improve the ability to implement new digital technologies at the levels of the leading European countries, i.e., Denmark, Sweden, Finland, and the Netherlands. The digital economy remains a widely discussed topic. However, the lack of a unanimous scientific definition and detailed research on this economic model complicates the understanding of digital technologies. It is essential that each government analyze the model and focus on improving the digital economy to ensure that the country remains digitally competitive in the world. Česnauskė (2019) [3] investigates the digitization and societal performance of the Baltic countries using the DESI-Index. The author shows that Estonia has a lower connectivity value than the other Baltic countries. Latvia leads the ranking of the Baltic countries for connectivity value despite having lower values compared to other Baltic countries in terms of human capital and integration of digital technology components. The authors highlight the need to intervene through economic policy tools to improve both connectivity through broadband and the value of human capital. Obviously, the interventions designed to improve connectivity tend to have a very significant impact in terms of the broadband price index. Tocan et al. (2021) [4] analyze the case of broadband penetration in Romania and note the positive results that the country has achieved in terms of diffusion, coverage, and distribution of broadband compared to the European average. However, the measured value of the broadband price index appears to be high in Romania - equal to an amount of 92 - compared to the European average, equal to a value of 64.

Moldabekova et al. (2021) [5] analyze the relationship between investment in digitalization and logistics performance by integrating data from the DESI-Index of the European Union with data from the LPI index of the World Band. The authors highlight the fact that the growth in the spread of broadband and connectivity has a positive impact in terms of logistic performance. Policymakers wishing to increase the added value produced in the logistics sector should therefore also act with investments in digitization and in the creation of broadband networks, thus generating an impact in terms of the broadband price index. Balacescu & Babucea (2018) [6] refer to the paradoxical condition of Romania with reference to the existing relationship between broadband coverage and the number of internet users in the country. It appears from the data of the Digital, Economy, and Society Index-DESI that Romania is in second place in terms of internet speed even if it is in last place in terms of internet usage. This condition could also be due to the value of the broadband price index, which in Romania tends to be higher than the value of the European average. Ovando Chico et al. (2018) [7] analyze the case of the relationship between institutional reforms in the telecommunications sector, broadband development, and digital divide in Mexico. The authors verified that the political reforms in the telecommunications sector launched in Mexico have had positive effects in terms of reducing the digital divide. In fact, the penetration of broadband had a very significant impact for each percentile of straight. However, the results show that poor and financially vulnerable Mexican's face forms of exclusion from digitization. Obviously, the use of the internet also requires economic policies that can act on the broadband price index to make internet access economically sustainable for the population. Finally, for the population with low incomes it is possible to create bonuses and incentives that can allow them to have access to internet centers or to purchase the necessary equipment for surfing the internet.

Alderete (2017) [8] highlights the role of broadband for economic growth in Latin America. The author shows the existence of a positive relationship between the spread of broadband and the increase in the Gross Domestic Product in Latin American countries. However, it should be added to the authors' considerations that the value of the broadband price index also has a significant impact. In fact, in the presence of more competitive markets in relation to internet services, it is possible to offer the population the possibility of accessing the internet at reduced prices, with significant advantages in terms of broadband diffusion and growth in the level of digitization. Subekhi & Hadibrata (2020) [9] present a case study on the impact of the price, quality, and image of the Alfamart company on users' customer satisfaction. Alfamart is a broadband provider in Indonesia. The authors show that price, quality, and even brand image have a positive effect in terms of customer satisfaction. In this regard, it is necessary to underline the role of the price dimension as a tool to redeem the broadband accessible to the population and to create the conditions for a market segmentation that can allow for the distinction and clustering of customers based on their willingness to pay and on the quality of the products requested.

Ali (2020) [10] highlights the role of broadband in rural areas of the United States in the context of smart working. In fact, the Covid-19 pandemic has significantly increased the number of workers who have carried out their activity in smart working. However, this possibility was not an option for Americans living in rural areas due to the lack of investments necessary to create broadband networks in the interior of the United States that investment in broadband networks in rural areas has been insufficient and has prevented Americans from practicing smart working effectively. To the criticisms of the author, it is possible to add considerations relating to the prices of the broadband network. In fact, in mature and efficient markets, as the local markets of the USA should be, the price variable also has a very significant impact in determining the ability of the population to access the internet and use online navigation services for work.

Dettling (2017) [11] highlight the relationship between the spread of the internet and the employment of married women in the United States. The author shows that the growth in the availability of fast internet has impacted the employment of married women by a value of 4.1 percentage points. Especially married women with high schooling have the greatest advantages deriving from the spread of the internet. However, in addition to what is indicated by the author, it is also necessary to consider the amount of the broadband price. In fact, reduced broadband price index values could make it possible to have a further impact on the participation in work of married women, also having the possibility to act more effectively on the socio-economic reasons of the digital divide.

Gong (2020) [12] analyzes the case of the distribution of broadband services in Malaysia. The author verifies the existence of at least three different digital divides: generational, gender and social economic. If on the one hand the generational digital divide has decreased, on the other hand the digital divide of gender and economic-social is still present. The distribution of the internet and internet services in Malaysia tends to increase with income. To resolve the issue of the digital divide from an economic and social point of view, the author suggests to policy makers to introduce economic policies capable of reducing the price of broadband in Malaysia to increase the distribution of the internet among the population. The transition to artificial intelligence, 5G and advanced robotics should be accompanied and partly preceded by an extensive digitization which, thanks to low prices, will allow for an increase in the use and diffusion of broadband in Malaysia.

Cakrabuana & Ali (2019) [13] takes into consideration the price, the quality, and the information factors to evaluate the customer satisfaction value of the customers of a company operating in the broadband internet services sector. In particular, the authors interviewed about 200 users of the broadband service provider MyRepublic. MyRepublic is an internet service operator active in Indonesia. The results show that the price, the quality of the service and the quality of the information have a very significant value in terms of customer satisfaction. This analysis highlights the role of some determinants such as the price of internet services in determining customer satisfaction. However, it is necessary to consider that the value of the price of internet services has a very significant impact from a macro-economic point of view due to the ability to reduce the digital divide and increase the degree of overall digitization of the economy with positive effects in terms of production capacity and Gross domestic product.

The differentiation of broadband prices has a positive impact in terms of broadband diffusion even if this value must also be commensurate with the presence and distribution of the network infrastructures [14]. In this regard, the author suggests to policy makers to increase investments in the distribution of internet network infrastructures to create the conditions for a competitive broadband market capable of generating differentiated prices for consumers. Briglauer & Gugler, (2017) [15] underline the value of the development of internet networks for the economic growth of 27 European countries in the period between 2003 and 2015. The results show that a mixed structure of basic broadband, fast broadband, and super-fast broadband the greatest benefits in terms of economic growth. However, it must be considered that the possibility of spreading the Internet more widely in Europe also depends on the prices of the service or on the value measured by the Broadband Price Index.

Katz & Callorda (2018) [16] address the issue of the relationship between digitalization, broadband network services and economic growth in the countries of Latin America and the Caribbean countries. The authors consider the role of internet networks and infrastructures both to remove the digital divide and to promote a broader level of digitization capable of generally greater economic growth. However, to the considerations made by the authors it is also necessary to add the analysis of the value of the price of broadband supply as a tool to promote the spread of the internet and the growth of digital skills among the population. In fact, if it is certainly true that internet infrastructures are a necessary tool to achieve the conditions of economic growth in the digitalization economy, it is also true that the size of the price of internet services has a significant impact on the digitization choices of families and businesses above all. Considering the economic and social gaps present in Latin America and the Caribbean countries.

Dkhil & Jebsi (2020) [17] consider the role of regulation as a determinant of investments in the broadband network. The authors build a large dataset with 107 countries in a period between 2004 and 2015. The results show that the relationship between regulation and investments in the broadband network takes the form of a U-curve or at some point further growth of regulation tends to reduce the development of investment in broadband networks. However, it should be noted that the authors did not carry out any analysis on the impact of prices on broadband investment. In fact, broadband prices have a very significant impact in determining the profit conditions of companies investing in broadband, even in the presence of regulation. Baker et al. (2021) [18] address the issue of the relationship between the digital divide and the regulation of the telecommunications sector in the US during the phases of the Covid-19 pandemic. However, it should be emphasized that there is also a question relating to broadband prices and that therefore the objective of achieving high levels of digitalization and the diffusion of broadband can also be solved by creating a market that is competitive and able to reduce broadband prices for the population. The price of the broadband, together with the creation of the infrastructures necessary for the internet connection, also in the framework of legislation that is positively oriented to the growth of the telecommunications sector, can together allow to resolve the issue of internet access for people who have low incomes and living in rural areas.

Mayer et al. (2020) [19] consider the relationship between broadband deployment and economic growth. The authors check for a negative relationship between broadband penetration and broadband speed. The authors suggest that policy makers invest in broadband speed in those countries where broadband penetration is low. However, these results are in any case connected to the degree of economic development and economic growth considered at the national level. However, the authors fail to analyze the price determinants of user choice for broadband speed. In fact, in general, fast broadband tends to have wider market prices than the normal internet network. In the event of low broadband penetration, lowering the price value could be an incentive to improve internet adoption by the population.

Ghosh (2017) [20] analyze the case of the relationship between broadband penetration and economic growth. The authors check for a positive relationship between broadband penetration and economic growth. Furthermore, the authors also focus their attention on 3G/4G services to verify broadband penetration. The results show that the impact of economic policies aimed at promoting 3G/4G is about three times higher than the impact value. Economic policies aimed at promoting broadband. Finally, the authors verify that there is a positive relationship between the reduction in the price of broadband and economic growth. The reduction in the price of broadband can promote greater innovation and growth of the entrepreneurial culture. Mass use of broadband also has significant effects in terms of political polarization [21]. In fact, the authors analyzed internet access in the United States in the period between 2004 and 2008. The authors verified that the growth of broadband and the increase of internet connections is positively associated with an increase in political polarization in use of social networks. In fact, the greater the capacity of the population to easily access social media through broadband, the greater the orientation towards political polarization. In this sense, the price of broadband services is essential to allow greater participation of the population in social media. It follows that where broadband is available at low prices there is a greater political polarization of the population through social networks.

The development of broadband services can also give rise to an increase in exports for companies that are knowledge intensive and have a positive impact on the creation of an environment that is positively aimed at technological innovation [22]. However, these effects appear to be high in the presence of a market system capable of reducing the value of broadband prices to facilitate a wider digitization in businesses, households, and institutions.

The distribution of fixed broadband is positively associated with the growth of digitization at European level [23]. However, the possibility of using fixed broadband as a driver of digitization also depends on broadband prices. In fact, more accessible broadband prices can make it possible to create a wider market for internet connection services with positive effects on economic growth and digital entrepreneurship.

Technologically it is possible to classify the internet infrastructure in Local Area Network, Metropolitan Area Network and Wide Area Network [24]. The network infrastructure can be characterized by different typologies such as: star connection, tree layout, node meshing, point-to-point connection [25]. Fully optical devices such as WDM Wavelength Division Multiplexer can develop fixed line technology [26]. In this sense, the price dimension can be very relevant to guide the choice of technologies that are efficient and convenient with a positive impact in terms of reduction of the broadband price index. The use of fully optical networks can increase broadband speed [27] and have positive effects in terms of broadband price index by creating new markets for users. The use of fully optical networks improves broadband [28] efficiency by enabling wider digitization. Such technological improvements in an open market context can lead to increased competition with a positive impact in terms of reducing the price of broadband.

The article continues as follows: the second paragraph presents the estimated econometric model, the third paragraph contains the cluster analysis, the fourth paragraph presents the analysis of machine learning algorithms for prediction, and the fifth paragraph concludes. Finally, Appendix I contains the summary of the results of the analyses presented.

2. The Econometric Model

The results of the econometric models developed to estimate the value of the "*Broadband Price Index*" are presented below. The data analyzed refer to the Digital Society and Economy Index-DESI of the European Union. The data refer to 28 countries in the period between 2016 and 2021. The data produced was analyzed using the methods Panel Data with Random Effects, Panel Data with Fixed Effects, Pooled OLS, WLS, and Dynamic Panel.

$$
\begin{aligned}
BroadbandPriceIndex_{it} &\\
= a_{it} &+ b_1(FixedBroadbandTakeUp)_{it} + b_2(FixedBroadbandCoverage)_{it}\\
&+ b_3(MobileBroadband)_{it} + b_4(eGovernment)_{it} + b_5(AdvancedSkillsAndDevelopment)_{it}\\
&+ b_6(Connectivity)_{it} + b_7(Integration\ of\ Digital\ Technology)_{it}\\
&+ b_8(DESIAggregate\ score)_{it} + b_9(At\ least\ Basic\ Digital\ Skills)_{it}\\
&+ b_{10}(AboveBasicDigitalSkills)_{it} + b_{11}(AtLeastBasicSoftwareSkills)_{it}
\end{aligned}
$$

$Where\ i = 28\ and\ t = 6.$

The analysis of the econometric model showed that the "*Broadband Price Index*" value is negatively associated with the following variables:

- *Fixed broadband take-up:* The Fixed Broadband Take Up value is made up of the sum of three different elements: "*Overall Fixed Broadband Take Up*", "*At Least 100 Mbps Fixed Broadband Take Up*", "*At Least 1 Gbps Take-Up*". There is a negative relationship between the "*Fixed Broadband Take Up*" value and the Broadband Price Index value. That is, the growth in the value of the fixed broadband network is positively associated with the reduction in the value of the "*Broadband Price Index*". This negative relationship may be since where broadband distribution growth occurs; the market tends to be more efficient. The growth in the number of competitors and broadband internet service providers allows countries to grow in the number of internet connections at a decreasing price.

$$FixedBroadbandTakeUp_{it} = a_1 + b_1(OverallFixedBroadbandTakeUp)_{it} + b_2(AtLeast100MbpsFixedBroadbandTakeUp)_{it} + b_3(AtLeast1GbpsTakeUp)_{it}$$

$Where\ i = 28\ and\ t = 6.$

- *Fixed broadband coverage:* the "*Fixed Broadband Coverage*" value is a composite indicator consisting of the following elements: "*Fast Broadband NGA Coverage*" and "*Fixed Vet High-Capacity Network VHCN Coverage*". It is possible to represent this relationship in an extended form, that is:

$$FixedBroadbandCoverage_{it} = a_1 + b_1(FastBroadbandNGACoverage)_{it} + b_2(FixedVeryHighCapacityNetworkVHCNCoverage)_{it}$$

$Where\ i = 28\ and\ t = 6.$

The value of the "*Fixed Broadband Coverage*" is negatively associated with the value of the "*Broadband Price Index*". This negative relationship is since with the growth in the value of broadband coverage there is also a condition of growth in the market from the point of view of internet providers and services. In fact, in general, with the growth of broadband coverage, the market for internet services tends to be characterized by a certain maturity and this condition allows for the introduction of those elements of competitiveness that are positively associated with a reduction in prices. The spread of broadband internet services therefore allows more offering companies to enter the market by offering products at lower prices and thus allowing a downward orientation of market prices. This condition of price reduction is therefore a condition associated with the development of the market in terms of providers.

- *Mobile broadband:* Mobile Broadband is made up of a set of variables namely "*4G Coverage*", "*5G Readiness*", "*5G Coverage*", "*Mobile Broadband Take Up*". There is a negative relationship between the "Mobile Broadband" value and the "Broadband Price Index" value. This relationship can best be understood by because the growth and expansion of the mobile broadband network market is positively associated with the broadband price index. In fact, the growth of the mobile market tends to be associated with a reduction in bandwidth prices since internet services are being offered by an increasing number of companies. The reduction in the price of broadband occurs because of the development of markets with an increase in the number of companies offering internet connection products. The growth in competition is generally positively associated with a reduction in the prices of internet connection services. It follows therefore that the further development of the mobile broadband market will increasingly tend to lower broadband prices. It therefore follows that if the policy maker should regulate the markets to ensure that there is greater competition in the offer of internet services to ensure that the prices of broadband are reduced and are accessible for businesses, institutions, and families. Below is a representation in extended form of the variable of interest:

$$MobileBroadband_{it} = a_1 + b_1(4GCoverage)_{it} + b_2(5GReadiness)_{it} + b_3(5GCoverage)_{it} + b_4(MobileBroadbandTakeUp)_{it}$$

$Where\ i = 28\ and\ t = 6$

- *e-Government:* is a composite variable consisting of the following elements: "*e-Government users*", "*Pre-filled forms*", "*Digital public services for citizens*", "*Digital public services for businesses*", "*Open data*". There is a negative relationship between the value of e-government and the value of the "Broadband Price Index". In other words, in European countries where e-government is more developed there is also a reduction in the price of broadband for families, businesses and institutions. It should be considered that the countries that have the highest levels of e-government are also the countries that have the most developed markets for broadband, both fixed and mobile. It follows therefore that the public administration also plays a very important role in determining the trend of the broadband price index. It follows that especially in Northern European countries that have the highest levels of e-government efficiency, such as Sweden and Finland, the overall price of broadband tends to be reduced.

Therefore the policy maker must take into consideration the role of the public administration as a driver for the development of the broadband market also with a view to creating the conditions for reducing the price of broadband to improve the conditions of access to internet services by businesses and households. Below is a representation in extended form of the variable of interest:

$$eGovernemnt_{it} = a_1 + b_1(eGovernment)_{it} + b_2(PreFilledForms)_{it} + b_3(DigitalPublicServicesForCitizens)_{it} + b_4(OpenData)_{it}$$

$Where\ i = 28\ and\ t = 6$

- *Advanced Skills and Development*: is a composite variable made up of the sum of "*ICT Specialists*", "*Female ICT Specialists*", "*Enterprise Providing ICT Training*", "*ICT Graduates*". Advanced Skills and Development is a composite variable made up of the sum of "ICT Specialists", "Female ICT Specialists", "Enterprise Providing ICT Training", "ICT Graduates". The analysis shows the presence of a negative relationship between the value of IT skills and the value of fixed broadband. This negative relationship may be since ITC specialists are generally more widespread in markets that have a higher level of sophistication and evolution of the market from the point of view of digitization. And given that generally in the markets that are more developed it is more likely that there will be more companies offering internet connection services. This competitiveness among companies operating in the provision of internet services has a positive impact in terms of lowering the prices of broadband. Below is a representation in extended form of the variable of interest:

$$AdvancedSkillsAndDevelopment_{it} = a_1 + b_1(ICTSpecialists)_{it} + b_2(FemaleICTSpecialists)_{it} + b_3(EnterpriseseProvidingICTTraining)_{it} + b_4(ICTGraduates)_{it}$$

$Where\ i = 28\ and\ t = 6$

However, it is also possible to indicate the equation in a more extended form:

$$AdvancedSkillsAndDevelopment_{it} = a_1 + b_1(SMEsWithAtLeastABasicLevelOfDigitalIntensity)_{it} + b_2(ElectronicInformationSharing)_{it} + b_3(SocialMedia)_{it} + b_4(BigData)_{it} + b_5(Cloud)_{it} + b_6(AI)_{it} + b_7(ICTForEnvironmentalSustainability)_{it} + b_8(eInvoices)_{it} + b_9(SMEsSellingOnline)_{it} + b_{10}(eCommerceTurnover)_{it} + b_{11}(SellingOnlineCrossBorder)_{it}$$

$Where\ i = 28\ and\ t = 6$

- *Integration of Digital Technology:* the value of the *"Integration of Digital Technology"* variable is based on the value of the following variables*: "Digital Intensity", "Digital Technologies for Business", "e-Commerce".* There is therefore a negative relationship between the value of the "*Integration of Digital Technology*" and the value of the "*Broadband Price"*. This negative relationship tends to be since in general the "*Integration of Digital Technology*" variable tends to grow for those markets that have a high degree of computerization at a national level. In fact, where digitization grows, there is also a greater growth in market digitization, with greater broadband penetration, and a higher and more widespread degree of IT skills. Generally, in these markets there is also a greater degree of competitiveness among the providers of internet connection services and the growth of the competitiveness tends to be associated with a reduction in the price of broadband. It follows therefore that in the markets where the technological and IT skills are greater, the digitization market is more evolved, with an increase in competitiveness and a reduction in the price of the broadband network.

$$IntegrationOfDigitalTechnology_{it} = a_1 + b_1(DigitalIntensity)_{it} + b_2(DigitalTechnologiesForBusinesses)_{it} + b_3(eCommerce)_{it}$$

$Where\ i = 28\ and\ t = 6$

However, it is also possible to indicate the equation in a more extended form:

$$IntegrationOfDigitalTechnology_{it} = a_1 + b_1(SMEsWithAtLeastABasicLevelOfDigitalIntesity)_{it} + b_2(ElectronicInformationSharing)_{it} + b_3(SocialMedia)_{it} + b_4(BigData)_{it} + b_5(Cloud)_{it} + b_6(AI)_{it} + b_7(ICTForEnviromentSustainability)_{it} + b_8(eInvoice)_{it} + b_9(SMEsSellingOnline)_{it} + b_{10}(eCommerceTurnover)_{it} + b_{11}(SellingOnlineCrossBorder)_{it}$$

$Where\ i = 28\ and\ t = 6$

- *At least Basic Digital Skills:* it is a measure that evaluates digital skills by classifying them as "*basic*" or "*above the bases*". In particular, four different types of elements are taken into consideration: "*Information*", "*Communication*", "*Problem Solving*" and "*Software for Content Creation*". In this case the assigned value is marked as "*at least Basic*". There is a negative relationship between the value of the "*At least Basic Digital Skills*" variable and the value of the "*Broadband Price Index*". It follows that in European countries where the value of technology and information skills is at least at a basic level, the price of broadband tends to decrease. As a result, even countries with a low level of digital skills tend to be characterized by an efficient internet service offering market capable of reducing broadband prices for users or families, businesses and institutions. Consequently, the degree of market efficiency in creating the conditions for fast digitization at low prices can also occur in connection with a human capital that has a sufficient level of technological competence. This condition does not want to underestimate the role of high-level IT skills, but on the contrary to highlight that these markets are able to reach levels of efficiency in the offer of low-priced services even in the presence of sufficiently skilled human capital in ICT.

- *Above basic digital skills:* it is a measure that evaluates digital skills by classifying them as "*basic*" or "*above the bases*". In particular, four different types of elements are taken into consideration: "*Information*", "*Communication*", "*Problem Solving*" and "*Software for Content Creation*". In this case the assigned value is marked as "*above the bases*". There is a negative relationship between the value of "*Above basic digital skills*" and the value of "*Broadband Price Index*". This negative relationship means that the growth of digital skills above average values also leads to a reduction in the price of broadband. This negative relationship highlights the relationship between the value of human capital knowledge, the degree of market competition and also the price of broadband. In fact, it is necessary to consider that where digital skills are widespread and of a high level in general, the markets for the provision of internet connection services, both fixed and mobile, are highly evolved with the presence of a high degree of competitiveness capable of reducing market prices. It therefore follows that the negative relationship between "*Above basic digital skills*" and "*Broadband Price Index*" can be better understood considering that "*Above basic digital skills*" is a variable indicative of the degree of digitalization and competitiveness of the market with positive advantages in terms of offer of internet services and price reductions for households and businesses.
- *At least basic software skills:* it is a measure that evaluates digital skills by classifying them individuals who, in addition to having used basic software features such as word processing, have used advanced spreadsheet functions, created a presentation or document integrating text, pictures and tables or charts, or written code in a programming language. There is a negative relationship between the value of the "*At least basic software skills*" and the value of the "*Broadband Price Index*". This relationship is negative and is due to the fact that the presence at national level of software skills is positively associated with efficient digital markets. Generally, efficient markets are also characterized by a very large number of internet connection service providers capable of generating competitive prices. Competitive prices make it possible to increase the degree of further digitization and the spread of broadband. Therefore the presence of a negative relationship between "*At least basic software skills*" and the value of the "*Broadband Price Index*" and this relationship can be better understood considering that "*At least basic software skills*" is an indicator of an efficient digital market which is associated with a growing degree of competitiveness with reduced broadband prices.
- The analysis of the econometric model (Figures 1 and 2) showed that the "*Broadband Price Index*" value is positively associated with the following variables:

Results of the econometric analysis											
Variables		***Pooled OLS***		***Fixed Effects***		***Random Effects***		***WLS***		***Dynamic Panel***	
		Coefficiente	***p-value***	***Coefficiente***	***p-value***	***Coefficiente***	***p-value***	***Coefficiente***	***p-value***	***Coefficiente***	***p-value***
	const	-2,55E-05		-0,00033277	***	-0,00019029	**	-1,52E-05			
Fixed broadband take-up	A1	-1,00001	***	-1,00002	***	-1,00001	***	-1,00001	***	-0,998065	***
Fixed broadband coverage	A2	-1	***	-1,00001	***	-1,00001	***	-1	***	-0,998564	***
Mobile broadband	A3	-1	***	-1,00001	***	-1,00001	***	-1	***	-0,999377	***
e-Government	A5	-0,0777937	***	-0,0914576	***	-0,0878383	***	-0,0679361	***	-0,90564	***
Advanced Skills and Development	A11	-0,0777942	***	-0,0914605	***	-0,0878384	***	-0,067937	***	-0,903951	***
Connectivity	A16	3,68884	***	3,6342	***	3,64868	***	3,72826	***	0,389202	***
Integration of Digital Technology	A17	-0,311174	***	-0,365873	***	-0,351369	***	-0,271744	***	-3,61168	***
Aggregate score	A19	0,311175	***	0,365848	***	0,351358	***	0,271744	***	3,61077	***
At least Basic Digital Skills	A44	-0,0388977	***	-0,0457297	***	-0,0439214	***	-0,0339672	***	-0,446808	***
Above basic digital skills	A45	-0,0388981	***	-0,0457348	***	-0,043924	***	-0,0339694	***	-0,452969	***
At least basic software skills	A46	-0,0388913	***	-0,0457155	***	-0,0439044	***	-0,0339643	***	-0,458353	***
Broadband price index(-1)	A4(-1)									0,239005	***

Figure 1. Results of the econometric analysis

- *Connectivity:* It is a composite variable made up as follows: *"Fixed Broadband Take-Up", "Fixed Broadband Coverage", "Mobile Broadband", "Broadband Prices".* In explicit form:

$$Connectivity_{it} = a_1 + b_1(FixedBroadbandTakeUp)_{it} + b_2(FixedBroadbandCoverage)_{it} + b_3(MobileBroadband)_{it} + b_4(BroadbandPrices)_{it}$$

$Where\ i = 28\ and\ t = 6$

Or even in a more extended form:

$$Connectivity_{it} = a_1 + b_1(OverallFixedBroadbandTakeUp)_{it} + b_2(AtLeast100MbpsFixedBroadbandTakeUp)_{it} + b_3(AtLeast1GbpsTakeUp)_{it} + b_4(FastBroadbandNGACoverage)_{it} + b_5(FixedVeryHighCapacityNetworkVHCNCoverage)_{it} + b_6(4GCoverage)_{it} + b_7(5GReadiness)_{it} + b_8(5GCoverage)_{it} + b_9(MobileBroadbandTakeUp)_{it}$$

$Where\ i = 28\ and\ t = 6$

- *DESI Aggregate score:* It is an index made up of "*Human Capital*", "*Connectivity*", "*Integration of Digital Technology*", "*Digital Public Services*".

$$DESI_{it} = a_1 + b_1(HumanCapital)_{it} + b_2(Connectivity)_{it} + b_3(IntegrationOfDigitalTechnology)_{it} + b_4(DigitalPublicServices)_{it}$$

$Where\ i = 28\ and\ t = 6.$

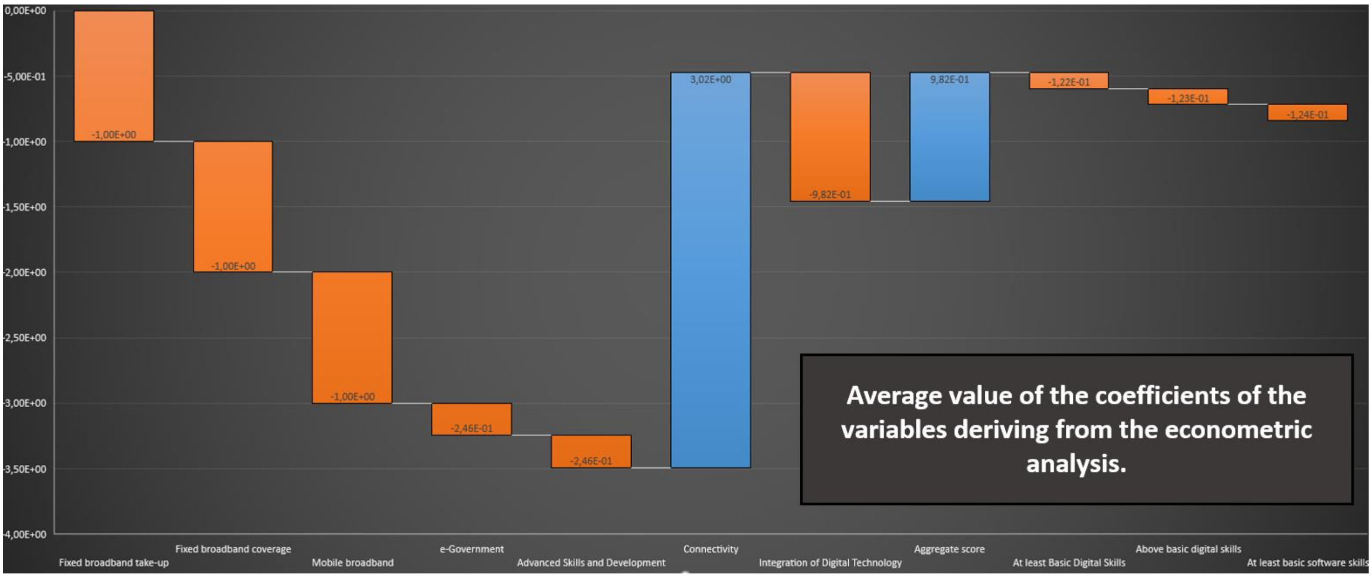

Figure 2. Average value of the coefficients of the variables deriving from the econometric analysis

3. Clustering with k-Means Algorithm

The k-Means algorithm optimized with the Silhouette coefficient is used below to identify the presence of clusters within the data. Since the k-Means algorithm is representative of an unsupervised clustering type, the Silhouette coefficient must also be used. In fact, the role of the Silhouette coefficient consists precisely in the ability to assign a value to the clusters. The Silhouette coefficient varies between -1 and 1. Generally, the choice of the optimal number of clusters takes place in maximizing the Silhouette coefficient, i.e. for positive values as close to 1. Finally, it must be considered that the Silhouette coefficient can be applied both to the cluster as a whole and to the individual elements of the cluster. The cluster analysis with reference to the "*Broadband Price Index*" variable through the optimization of the Silhouette Coefficient has highlighted the presence of three different clusters, namely:

- ***Cluster 1:*** *Malta, Croatia, Denmark, Slovenia, Hungary, Slovakia, European Union, Sweden, Czechia, Netherlands;*
- ***Cluster 2:*** *Greece, Ireland, Spain, Portugal, Cyprus, Belgium;*
- ***Cluster 3:*** *Latvia, Lithuania, Finland, Austria, Germany, France, Poland, Italy, Romania, Bulgaria, Luxembourg, Estonia.*

The median value of the "*Broadband Price Index*" variable in the countries of cluster 1 is equal to a value of 5.03, in the countries of cluster 2 it is 3.6, in the countries of cluster 3 it is equal to a value of 6.87. Therefore, the following ordering of clusters derives, namely: C3>C1>C2. The data therefore show that most of the countries where broadband is cheaper are the countries of Cluster 2, namely: Spain, Portugal, Ireland, Cyprus, Belgium, and Greece. However, cluster 3 which is the most numerous with a number of participating countries equal to 12 and which coincides with central-southern Europe and part of Eastern Europe has a higher broadband price index value. Certainly, to increase the degree of digitization of the European Union and therefore generate the positive effects in terms of human capital and economic growth, it is necessary to further invest in broadband and create a competitive market especially for the most populous European countries such as France, Germany, Italy, and Poland. In fact, the market competition between the various providers makes it possible to create the conditions for a reduction in broadband prices and therefore increases the probability of creating an increase in the internet connections of households and businesses (Figure 3).

Reducing the price of broadband is an essential element especially in the context of economic policies aimed at reducing the digital divide and to allow companies and institutions to offer digital services to the population. In fact, services such as those connected to e-government, telemedicine, require developed markets where the price of access to broadband is more accessible to allow greater participation of the population.

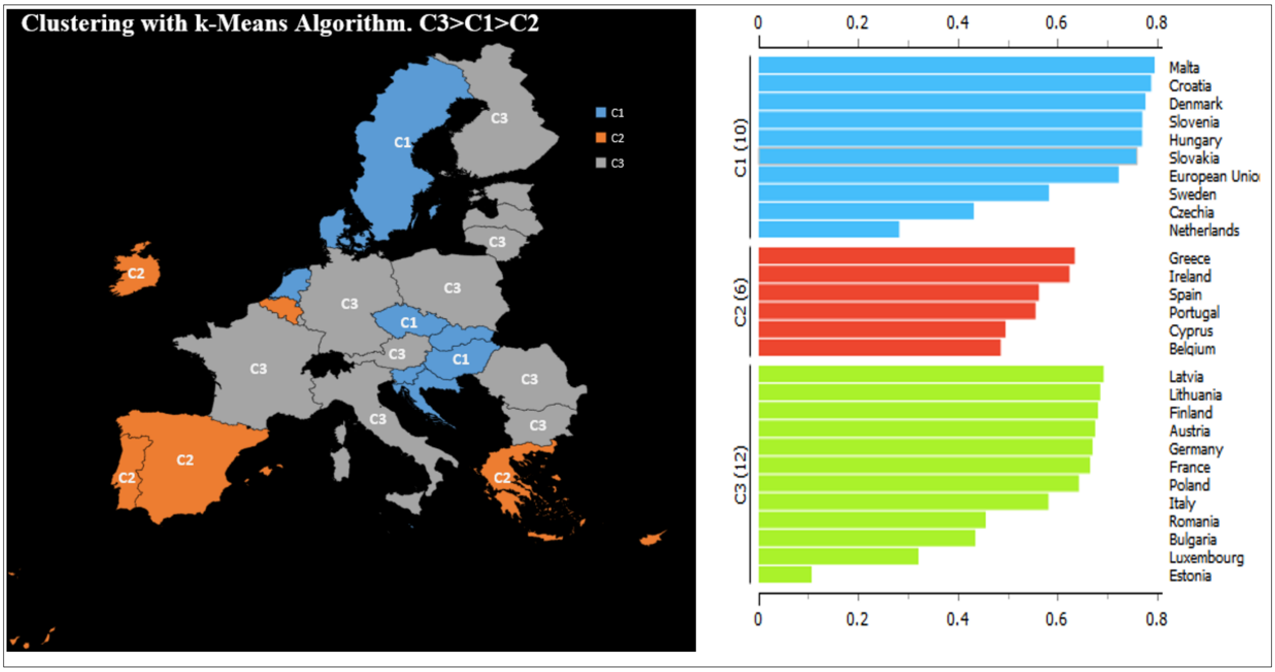

Figure 3. Broadband price index in Europe

4. Machine Learning and Predictions

Eight different machine learning algorithms were used below to predict the value of the "*Broadband Price Index*" between the countries considered. Specifically, eight different machine learning algorithms were analyzed to predict the "*Broadband Price Index*". The choice was made by maximizing R-square and minimizing errors such as "*Mean Absolute Error*", "*Mean Squared Error*", "*Root Mean Squared Error*", "*Mean Signed Difference*". The algorithms were trained with 70% of the data while the remaining 30% of the data was used for the actual prediction (Figure 4). The following is the ordering of algorithms:

- *Ann-Artificial Neural Network* with a payoff value of 10;
- *Gradient Boosted Trees* with a payoff value of 13;
- *Random Forest Regression* with a payoff value of 16;
- *Simple Regression Tree* with a payoff value of 18;
- *Probabilistic Neural Network-PNN* with a payoff value of 21;
- *Tree Ensemble Regression* with a payoff value of 27;
- *Polynomial Regression* with a payoff value of 35;
- *Linear Regression* with a payoff value of 40.

Through the application of the ANN-Artificial Neural Network, the prediction for the values was carried out as indicated below, that is:

- *Bulgaria* with a decrease from an amount of 7.082 up to a value of 6.467 or equal to a variation of -0.615 equal to a value of -8.687%;
- *Germany* with a decrease from an amount of 6.705 up to a value of 6.526 or equal to a variation of -0.179 equal to a value of -2.66%;
- *Greece* with an increase from an amount of 3.76 up to a value of 5.989 or equal to a value of 2.226 equal to a value of 59.175%;
- *Hungary* with an increase from an amount of 5.234 up to a value of 6.288 or equal to a variation of 1.054 equal to a value of 20.136%;
- *Ireland* with an increase from an amount of 5.089 up to a value of 5.926 or equal to a variation of 0.837 units equal to a value of 16.437%;

- *Luxembourg* with a variation from an amount equal to a value of 6.221 units up to a value of 6.450 units or equal to a value of 0.229 units equal to a value of 3.688%;
- *Malta* with an increase from an amount of 4,320 units up to a value of 6,271 units or equal to a variation of 1,951 units equal to a value of 45.147%;
- *Slovakia* with a decrease from an amount of 7,036 units up to a value of 6,217 units equal to a value of -0,819 units equal to a value of -11.642%;
- *Slovenia* with an increase from an amount of 6.213 units up to a value of 6.288 units equal to a value of 1.211%.

The average value of the prediction for the countries considered is expected to increase from an amount of 5,740 units up to a value of 6,269 units or equal to a variation of 0.529 units equal to a value of 9.212%.

Results of the prediction with the Artificial Neural Network-ANN algorithm.

Country	*2021*	*Normalization*	*Absolute Variation*	*%*
Bulgaria	7,082	6,467	-0,615	-8,687
Germany	6,705	6,526	-0,179	-2,666
Greece	3,763	5,989	2,226	59,175
Hungary	5,234	6,288	1,054	20,136
Ireland	5,089	5,926	0,837	16,437
Luxembourg	6,221	6,450	0,229	3,688
Malta	4,320	6,271	1,951	45,147
Slovakia	7,036	6,217	-0,819	-11,642
Slovenia	6,213	6,288	0,075	1,211
Mean	5,740	6,269	0,529	9,212

Results of predictions made with machine learning

Algorithm	R^2	Mean absolute error	Mean squared error	Root mean squared error	Mean signed difference
ANN	0,23835	0,10391	0,01825	0,13508	0,03757
PNN	-0,51173	0,15689	0,04619	0,21491	0,03431
Gradient Boosted Trees	-0,12268	0,13083	0,02991	0,17296	0,02846
Random Forest Regression	0,57442	0,15674	0,03189	0,17857	0,11131
Tree Ensemble Regression	0,14052	0,21461	0,05996	0,24486	0,08586
Linear Regression	-4,01000	0,53277	0,35562	0,59634	0,45343
Polynomial Regression	-1,59000	0,33260	0,21356	0,46212	0,12150
Simple Regression Tree	0,28746	0,18251	0,05560	0,23579	0,00419

Figure 4. Results of machine learning algorithms for prediction

5. Conclusions

This article analyses the determinants of the "*Broadband Price Index"* in Europe. The data used refer to 28 European countries between 2014 and 2021. The database used is the Digital, Economy and Society Index-DESI of the European Commission.

The data were analyzed using the following econometric techniques, namely Panel Data with Random Effects, Panel Data with Fixed Effects, Pooled OLS, WLS and Dynamic Panel. The value of the "*Broadband Price Index*" is positively associated with the DESI Index, and "*Connectivity*" while it is negatively associated with "*Fixed Broadband Take Up*", "*Fixed Broadband Coverage*", "*Mobile Broadband*", "*e-Government*", "*Advanced Skills and Development*", "*Integration of Digital Technology*", "*At Least Basic Digital Skills* ", "*Above Basic Digital Skills* "," *At Least Basic Software Skills* ".

Analysis of the literature highlights the role of broadband pricing in fostering economic growth and digitization in Europe. Broadband is an important driver for the development of European economies, especially in inland areas. Furthermore, the development of broadband, and above all the reduction of the price of broadband, is also an essential tool for reducing the digital divide. In fact, the reduction of inequality in internet access also requires the development of markets for competitive providers capable of reducing the price of broadband. However, the value of regulation as a means of promoting broadband in Europe must also be considered. There are therefore elements of economic, institutional, technological and market policy that can support the spread of broadband with positive effects in reducing the price of broadband.

A cluster analysis was carried out below using the k-Means algorithm optimized with the Silhouette coefficient. The analysis revealed the existence of three clusters. The cluster analysis highlights the need to reduce the price of broadband especially in the most populous countries such as Italy, France, Germany, and Poland.

Finally, an analysis of the machine learning algorithms was carried out to predict the future value of the "*Broadband Price Index*". The result shows that the most useful algorithm for prediction is the Artificial Neural Network-ANN with an estimated value equal to an amount of 9.21%.

Finally, it is necessary to consider that the price of broadband is a strategic factor to allow the development of digitization in Europe with positive effects in terms of added value and economic growth. It therefore follows that the policy maker interested in increasing the degree of digitization of European countries should intervene to create a competitive market for internet service providers, also through institutional and regulatory reforms, in such a way as to reduce the price of broadband with positive in terms of reducing the digital divide and increasing economic growth.

6. Declarations

6.1. Author Contributions

Conceptualization, A.L., N.M., G.C., and A.M.; methodology, A.L.; software, G.C.; validation, N.M., G.C. and A.M.; formal analysis, A.L.; investigation, N.M.; resources, G.C.; data curation, A.M.; writing—original draft preparation, A.L.; writing—review and editing, N.M.; visualization, G.C.; supervision, A.M.; project administration, A.L. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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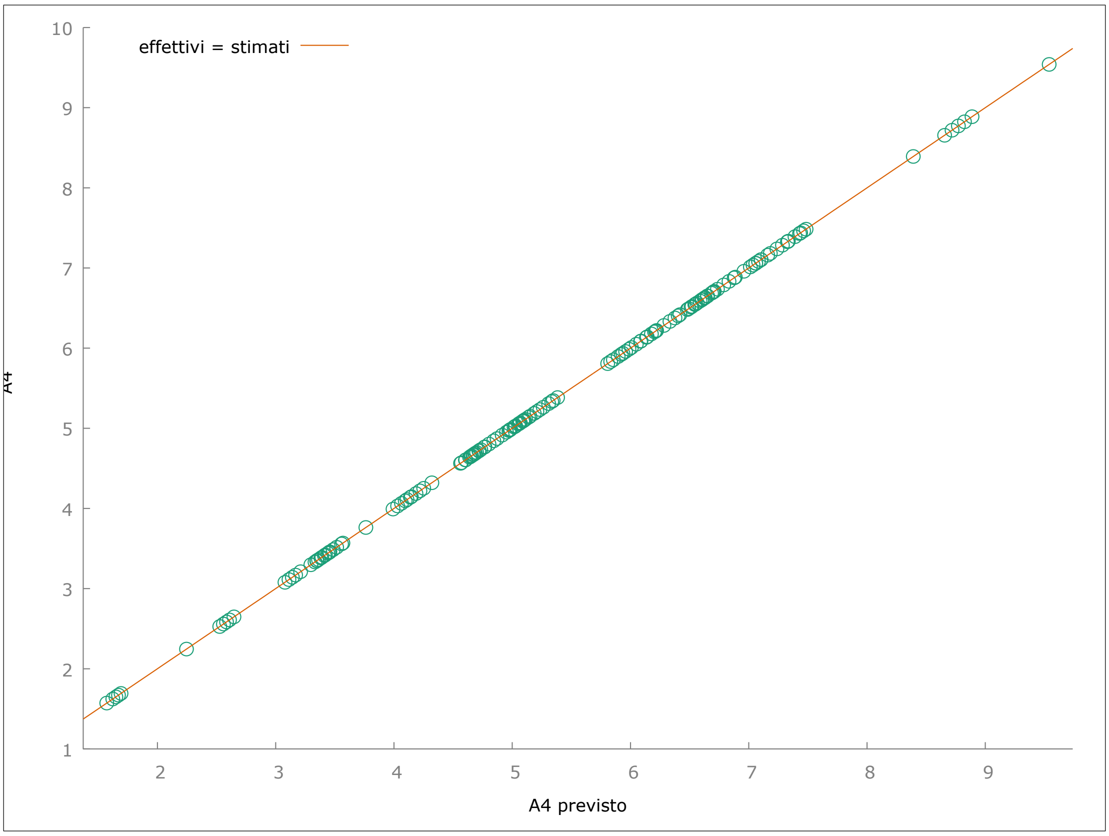
Appendix I

Model 45: Pooled OLS, using 168 observations
Including 28 cross section units
Time series length = 6
Dependent variable: A4

	Coefficient	*Std. Error*	*t ratio*	*p-value*	
Constant	−2,54751e-05	3,55200e-05	−0,7172	0,4743	
A1	−1,00001	2,78453e-06	−3,591e+005	<0,0001	***
A2	−1,00000	3,06891e-06	−3,258e+005	<0,0001	***
A3	−1,00000	3,06006e-06	−3,268e+005	<0,0001	***
A5	−0,0777937	0,0276097	−2,818	0,0055	***
A11	−0,0777942	0,0276098	−2,818	0,0055	***
A16	3,68884	0,110440	33,40	<0,0001	***
A17	−0,311174	0,110439	−2,818	0,0055	***
A19	0,311175	0,110439	2,818	0,0055	***
A44	−0,0388977	0,0138054	−2,818	0,0055	***
A45	−0,0388981	0,0138045	−2,818	0,0055	***
A46	−0,0388913	0,0138041	−2,817	0,0055	***

Media var. dependent	5,353242	SQM var. dependent	1,638071
Residual sum of squares	3,08e-07	E.S. Regression	0,000044
R^2	1,000000	Corrected R^2	1,000000
F(11, 156)	2,06e+10	P-value(F)	0,000000
Log-likelihood	1451,396	Akaike's criterion	−2878,792
Schwarz's criterion	−2841,304	Hannan-Quinn	−2863,578
rho	−0,045461	Durbin-Watson	1,721840

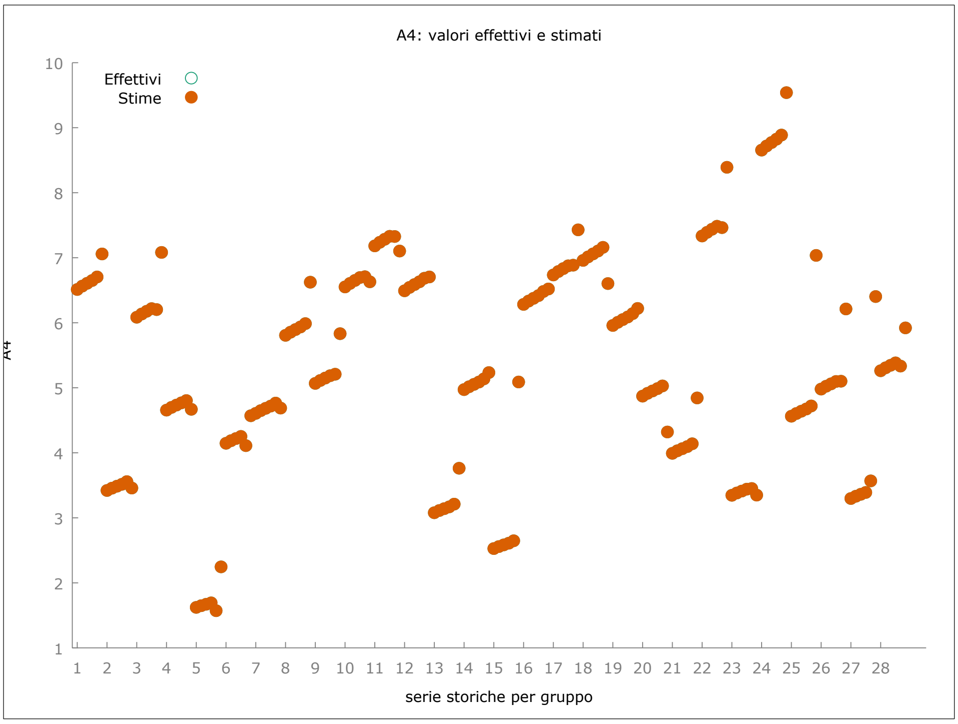


Model 46: Fixed effects, using 168 observations
Including 28 cross section units
Time series length = 6
Dependent variable: A4

	Coefficient	*Std. Error*	*t ratio*	*p-value*	
Constant	−0,000332772	0,000113072	−2,943	0,0039	***
A1	−1,00002	1,23544e-05	−8,094e+004	<0,0001	***
A2	−1,00001	1,12490e-05	−8,890e+004	<0,0001	***
A3	−1,00001	1,15138e-05	−8,685e+004	<0,0001	***
A5	−0,0914576	0,0281229	−3,252	0,0015	***
A11	−0,0914605	0,0281227	−3,252	0,0015	***
A16	3,63420	0,112495	32,31	<0,0001	***
A17	−0,365873	0,112493	−3,252	0,0015	***
A19	0,365848	0,112492	3,252	0,0015	***
A44	−0,0457297	0,0140612	−3,252	0,0015	***
A45	−0,0457348	0,0140617	−3,252	0,0015	***
A46	−0,0457155	0,0140621	−3,251	0,0015	***

Media var. dependent	5,353242	SQM var. dependent	1,638071
Residual sum of squares	2,31e-07	E.S. Regression	0,000042
R^2 LSDV	1,000000	Intra-group R^2	1,000000
LSDV F(38, 129)	6,58e+09	P-value(F)	0,000000
Log-likelihood	1475,613	Akaike's criterion	−2873,226
Schwarz's criterion	−2751,392	Hannan-Quinn	−2823,780
rho	−0,223542	Durbin-Watson	2,071623

Test conjunction on regression
Test statistics: F(11, 129) = 1,2494e+009
con p-value = P(F(11, 129) > 1,2494e+009) = 0
Test for the difference from the intercepts group
Null hypothesis: Groups have a common intercept
Test statistics: F(27, 129) = 1,59653
con p-value = P(F(27, 129) > 1,59653) = 0,0445235

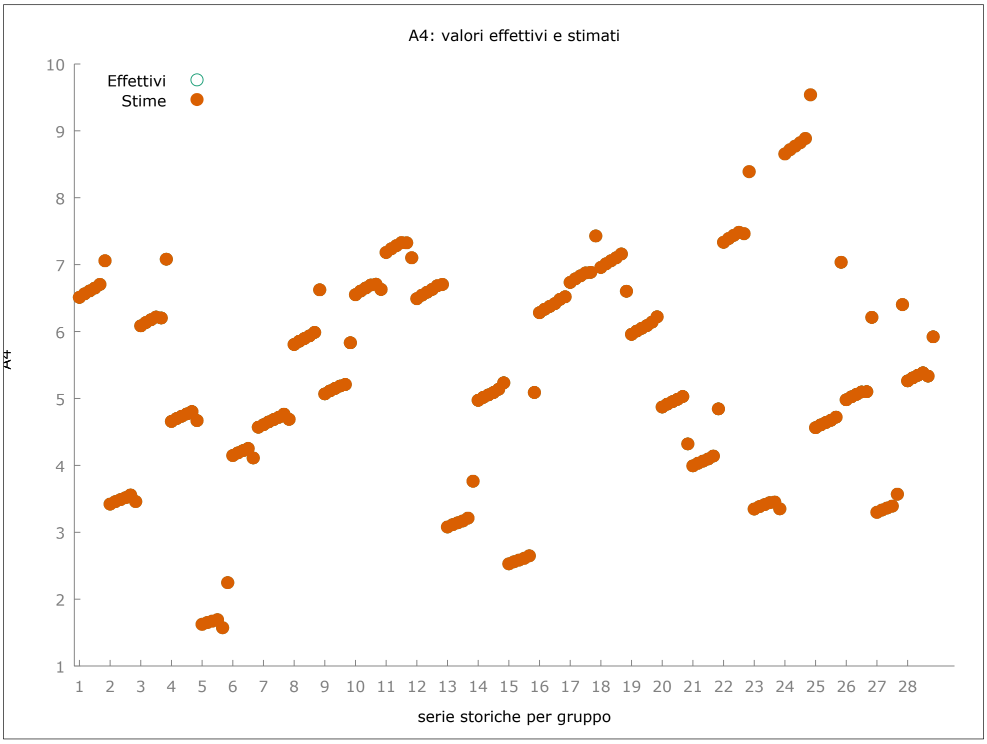


Model 47: Random Effects (GLS), using 168 observations
With Nerlove transformation
Including 28 cross section units
Time series length = 6
Dependent variable: A4

	Coefficient	***Std. Error***	***z***	***p-value***	
Constant	−0,000190293	7,61386e-05	−2,499	0,0124	**
A1	−1,00001	7,99645e-06	−1,251e+005	<0,0001	***
A2	−1,00001	7,41928e-06	−1,348e+005	<0,0001	***
A3	−1,00001	7,50651e-06	−1,332e+005	<0,0001	***
A5	−0,0878383	0,0262564	−3,345	0,0008	***
A11	−0,0878384	0,0262562	−3,345	0,0008	***
A16	3,64868	0,105028	34,74	<0,0001	***
A17	−0,351369	0,105026	−3,346	0,0008	***
A19	0,351358	0,105026	3,345	0,0008	***
A44	−0,0439214	0,0131280	−3,346	0,0008	***
A45	−0,0439240	0,0131283	−3,346	0,0008	***
A46	−0,0439044	0,0131285	−3,344	0,0008	***

Media var. dependent	5,353242	SQM var. dependent	1,638071
Residual sum of squares	4,43e-07	E.S. Regression	0,000053
Log-likelihood	1420,924	Akaike's criterion	−2817,849
Schwarz's criterion	−2780,361	Hannan-Quinn	−2802,634
rho	−0,223542	Durbin-Watson	2,071623

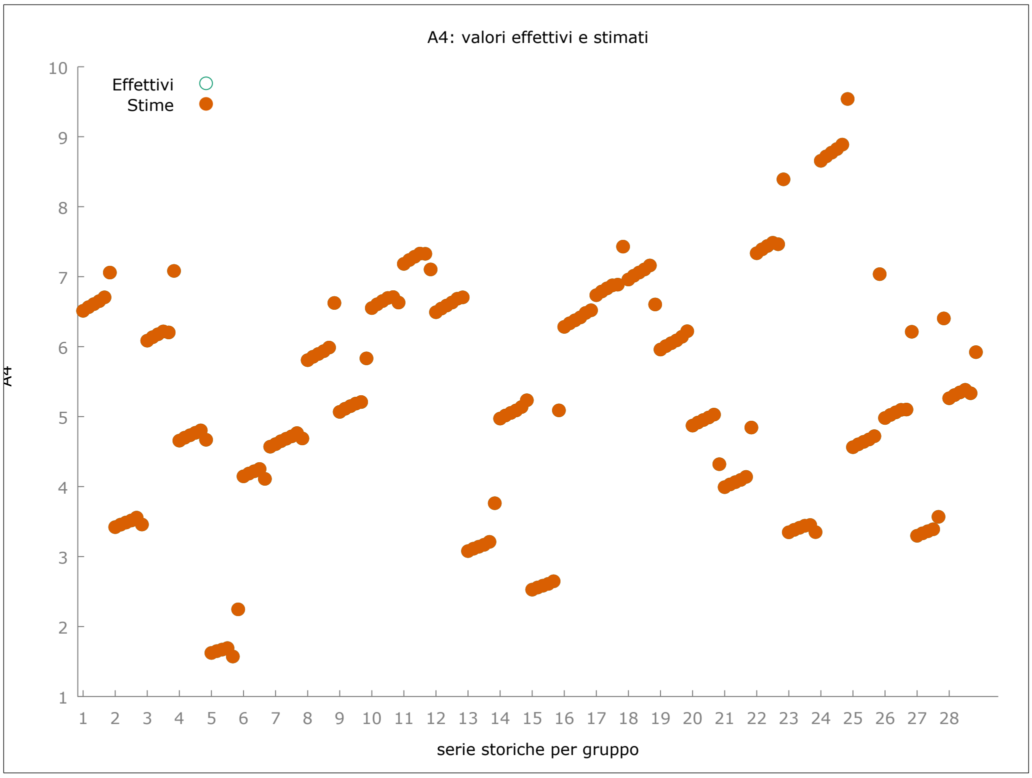
Variance 'between' = 4,93619e-009	*Breusch–Pagan test*
Variance 'within' = 1,37515e-009	Null hypothesis: Variance of the unit-specific error = 0
Theta used for transformation = 0,789356	Asymptotic test statistic: Chi-square(1) = 0,13071
Test conjunction on regression	con p-value = 0,717697
Asymptotic test statistics: Chi-square(11) = 2,73654e+010	
con p-value = 0	*Hausman test*
	Null hypothesis: GLS estimates are consistent
	Asymptotic test statistic: Chi-square(1) = 10,5166
	con p-value = 0,4846



Model 48: WLS, using 168 observations
Including 28 cross section units
Dependent variable: A4
Weights based on error variance per unit

	Coefficient	*Std. Error*	*t ratio*	*p-value*	
Constant	−1,51871e-05	2,91926e-05	−0,5202	0,6036	
A1	−1,00001	2,31550e-06	−4,319e+005	<0,0001	***
A2	−1,00000	2,56660e-06	−3,896e+005	<0,0001	***
A3	−1,00000	2,44085e-06	−4,097e+005	<0,0001	***
A5	−0,0679361	0,0249298	−2,725	0,0072	***
A11	−0,0679370	0,0249298	−2,725	0,0072	***
A16	3,72826	0,0997202	37,39	<0,0001	***
A17	−0,271744	0,0997196	−2,725	0,0072	***
A19	0,271744	0,0997194	2,725	0,0072	***
A44	−0,0339672	0,0124655	−2,725	0,0072	***
A45	−0,0339694	0,0124646	−2,725	0,0072	***
A46	−0,0339643	0,0124641	−2,725	0,0072	***

Statistics based on weighted data:			
Residual sum of squares	164,5329	E.S. Regression	1,026985
R^2	1,000000	Corrected R^2	1,000000
F(11, 156)	3,24e+10	P-value (F)	0,000000
Log-likelihood	−236,6300	Akaike's criterion	497,2600
Schwarz's criterion	534,7476	Hannan-Quinn	512,4743
Statistics based on original data:			
Media var. dependent	5,353242	SQM var. dependent	1,638071
Residual sum of squares	3,12e-07	E.S. Regression	0,000045

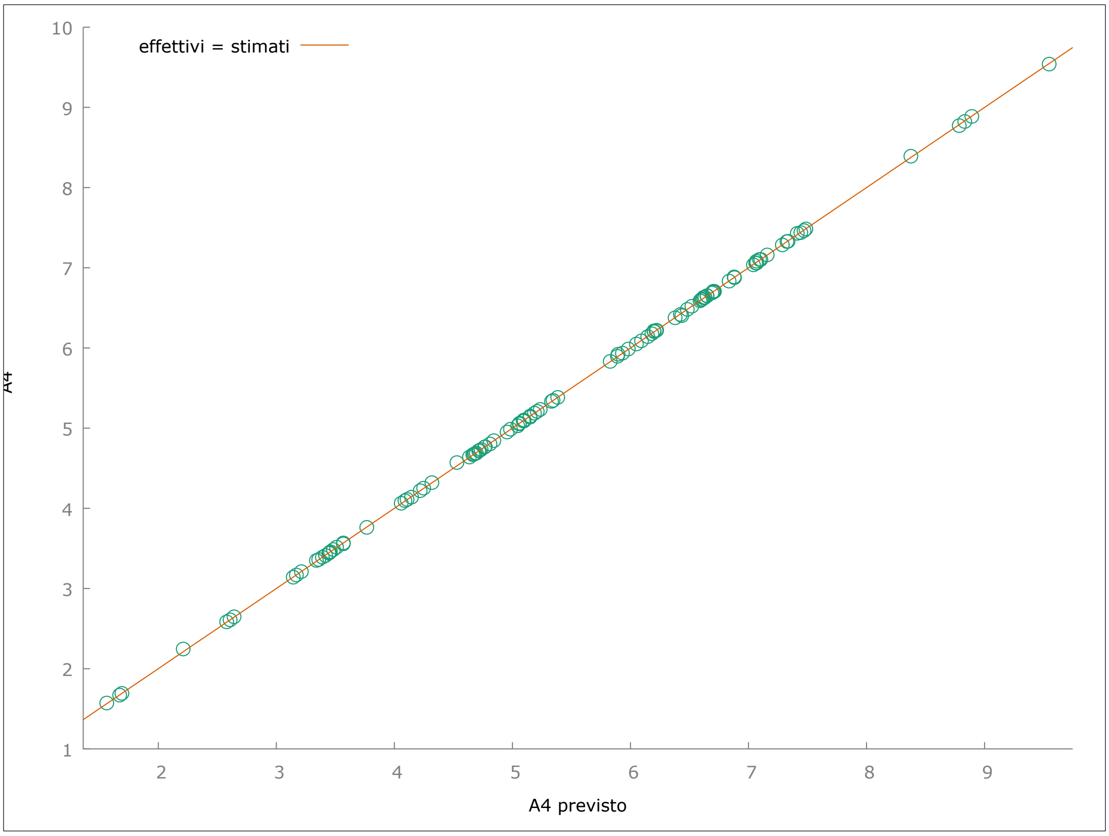


Model 49: One step dynamic panel, using 112 observations
Including 28 cross section units
Dependent variable: A4

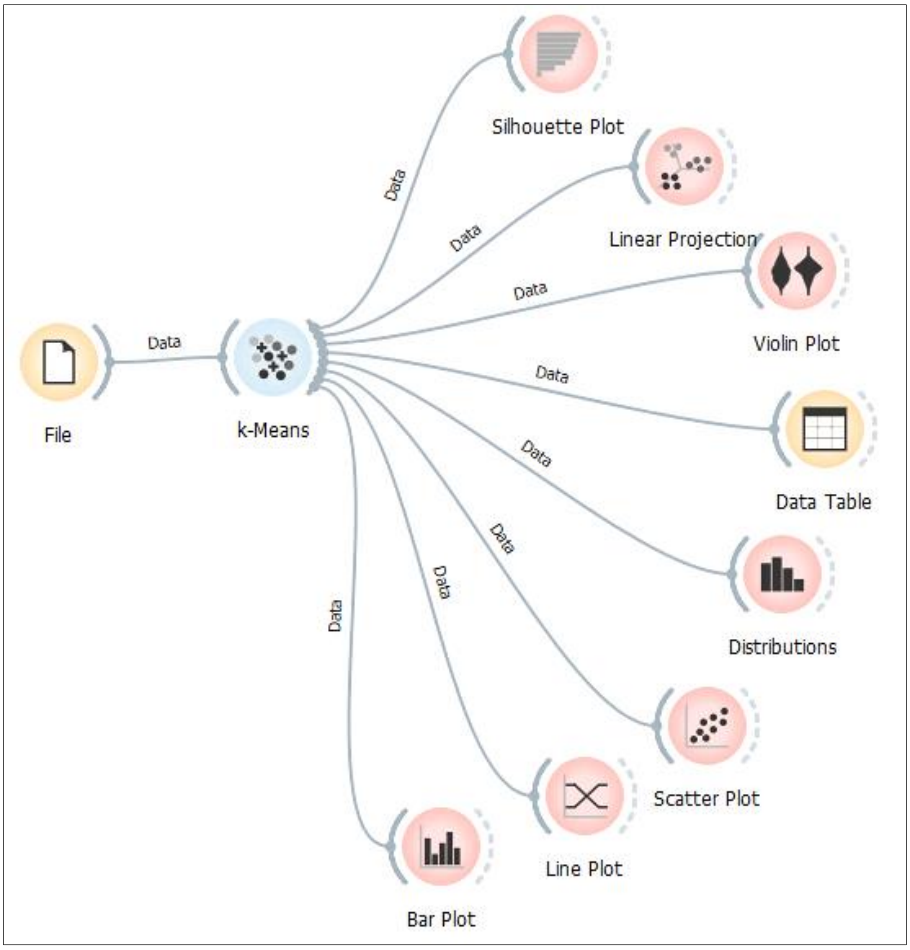
	Coefficient	*Std. Error*	*z*	*p-value*	
A4(-1)	0,239005	0,0850060	2,812	0,0049	***
A1	−0,998065	0,00424900	−234,9	<0,0001	***
A2	−0,998564	0,00438576	−227,7	<0,0001	***
A3	−0,999377	0,00426284	−234,4	<0,0001	***
A5	−0,905640	0,00380660	−237,9	<0,0001	***
A11	−0,903951	0,00389062	−232,3	<0,0001	***
A16	0,389202	0,00180944	215,1	<0,0001	***
A17	−3,61168	0,0143777	−251,2	<0,0001	***
A19	3,61077	0,0146408	246,6	<0,0001	***
A44	−0,446808	0,00328644	−136,0	<0,0001	***
A45	−0,452969	0,00197713	−229,1	<0,0001	***
A46	−0,458353	0,00641147	−71,49	<0,0001	***

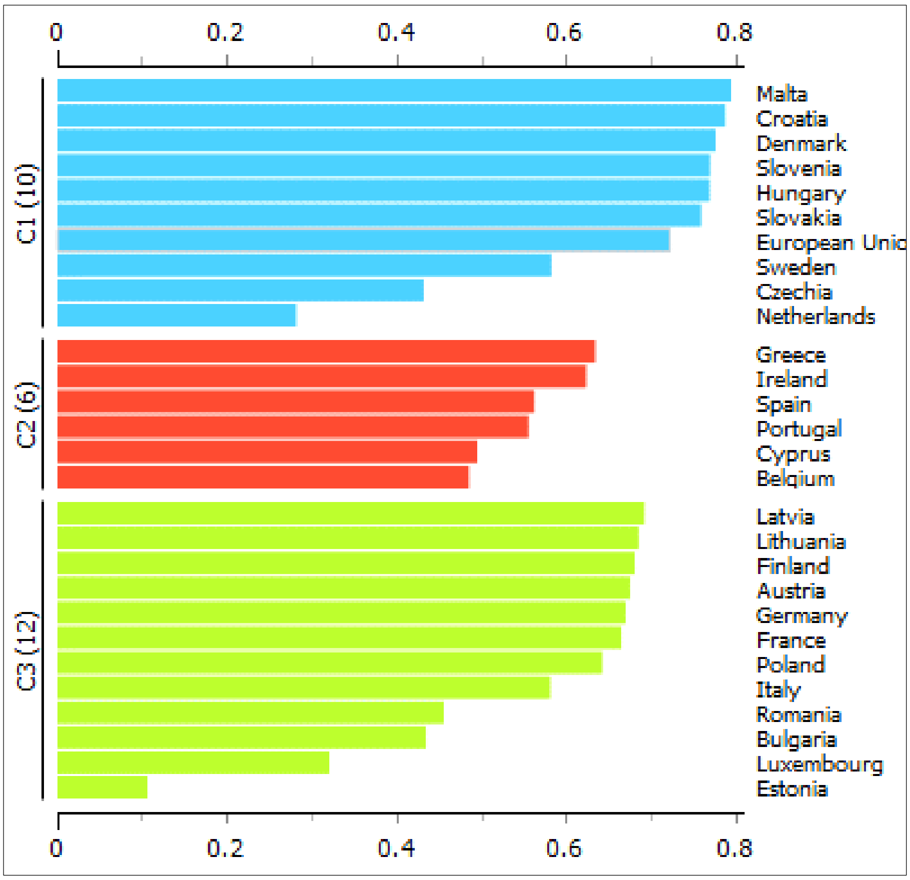
Residual sum of squares	0,007960	E.S. Regression	0,008431

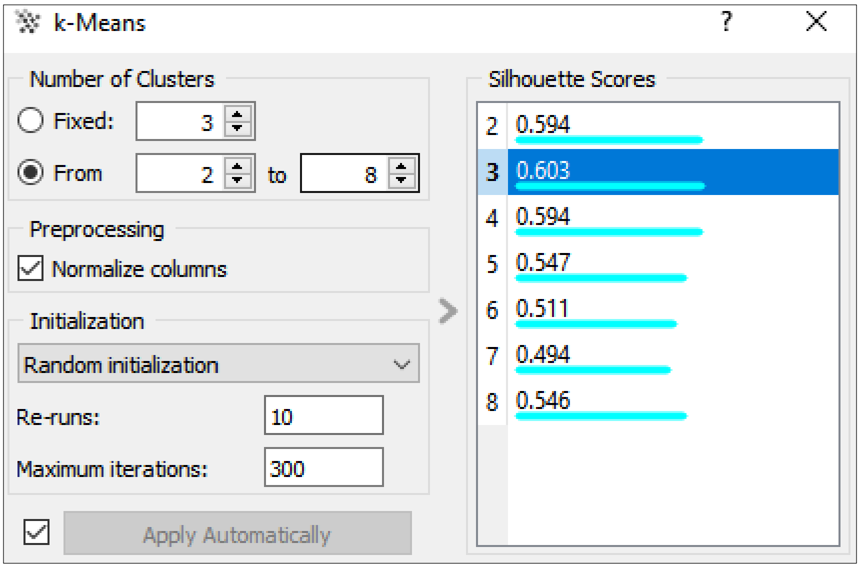
Number of instruments = 21
Error test AR(1): z = 3,67292 [0,0002]
Error test AR(2): z = 0,607257 [0,5437]
Sargan over-identification test: Chi-square (9) = 60,8957 [0,0000]
Wald Test (conjoined): Chi-square (0) = NA



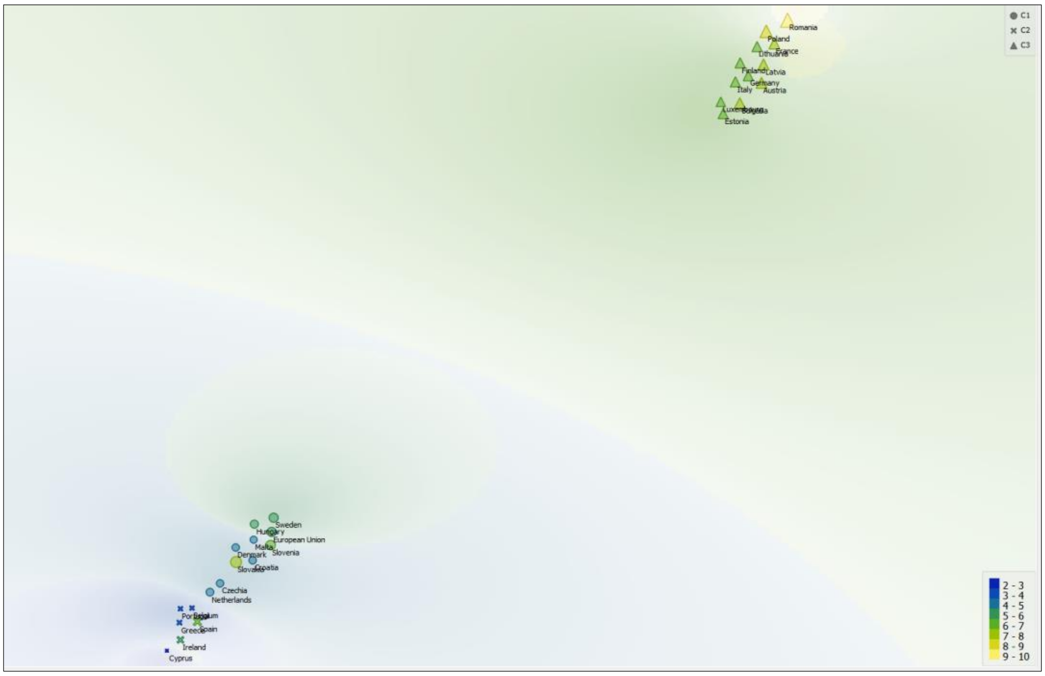
Clusterization

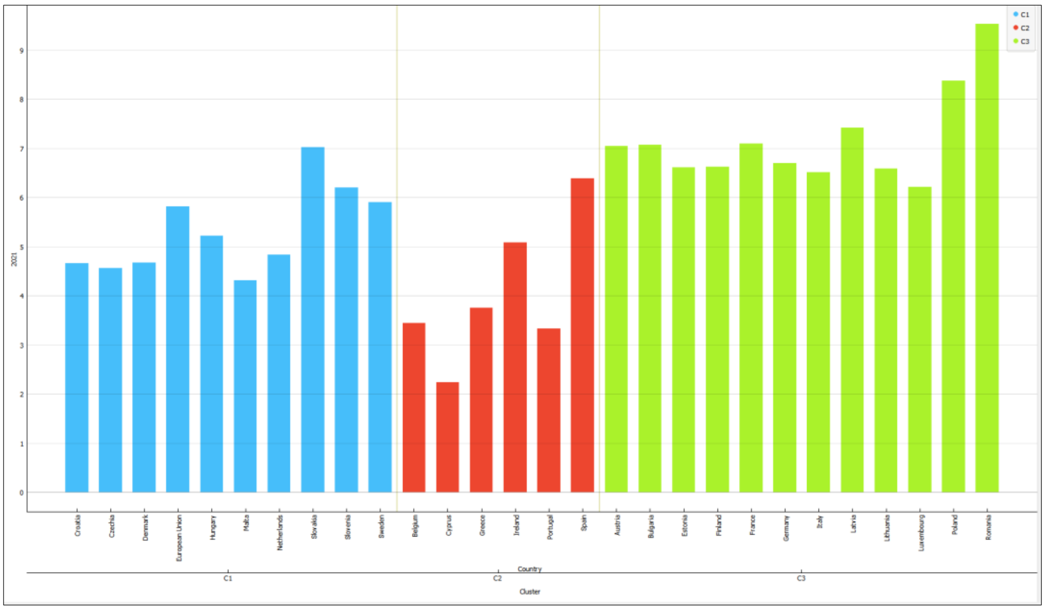


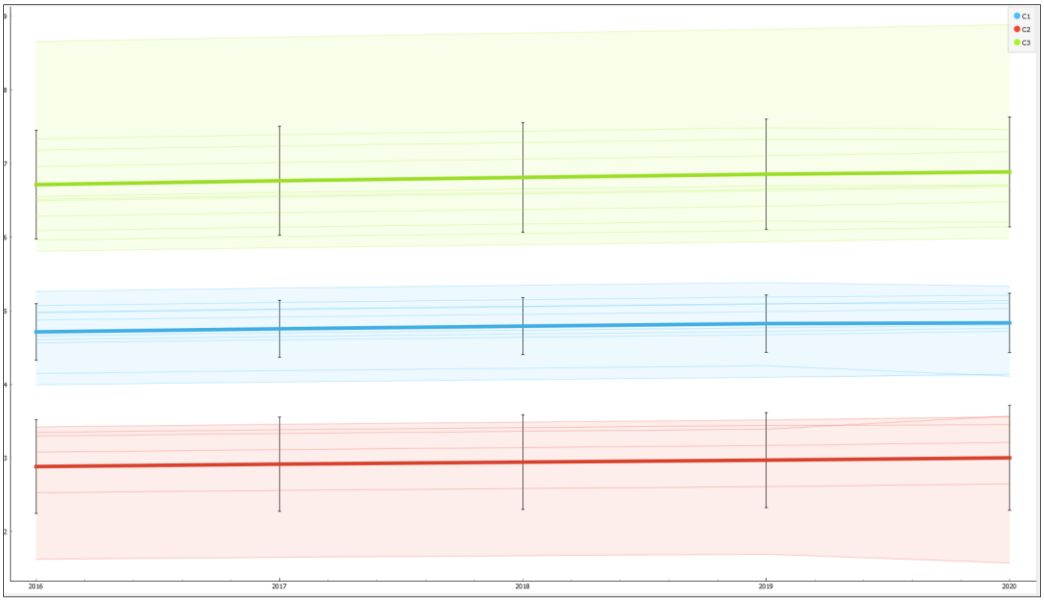


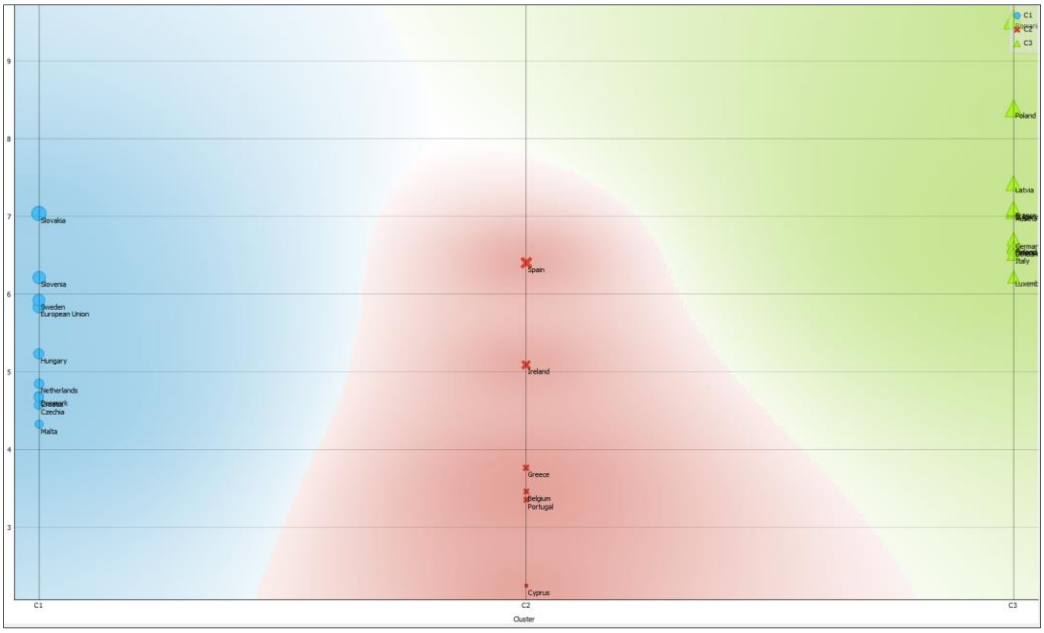


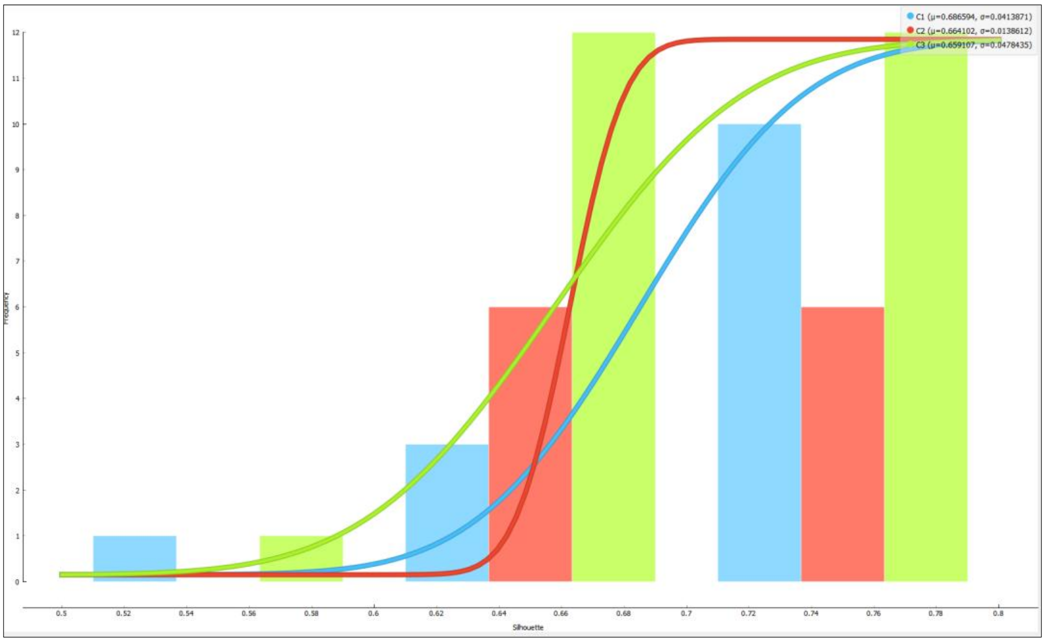
	2021	Country	Cluster
4	4.66909	Croatia	C1
6	4.57054	Czechia	C1
7	4.68792	Denmark	C1
9	5.83236	European Union	C1
14	5.23408	Hungary	C1
20	4.32046	Malta	C1
21	4.8441	Netherlands	C1
25	7.03613	Slovakia	C1
26	6.21279	Slovenia	C1
28	5.92152	Sweden	C1
2	3.45833	Belgium	C2
5	2.24581	Cyprus	C2
13	3.76252	Greece	C2
15	5.08944	Ireland	C2
23	3.3496	Portugal	C2
27	6.40344	Spain	C2
1	7.05883	Austria	C3
3	7.08221	Bulgaria	C3
8	6.62402	Estonia	C3
10	6.63011	Finland	C3
11	7.10359	France	C3
12	6.70476	Germany	C3
16	6.51996	Italy	C3
17	7.42956	Latvia	C3
18	6.60305	Lithuania	C3
19	6.22059	Luxembourg	C3
22	8.39121	Poland	C3
24	9.53991	Romania	C3

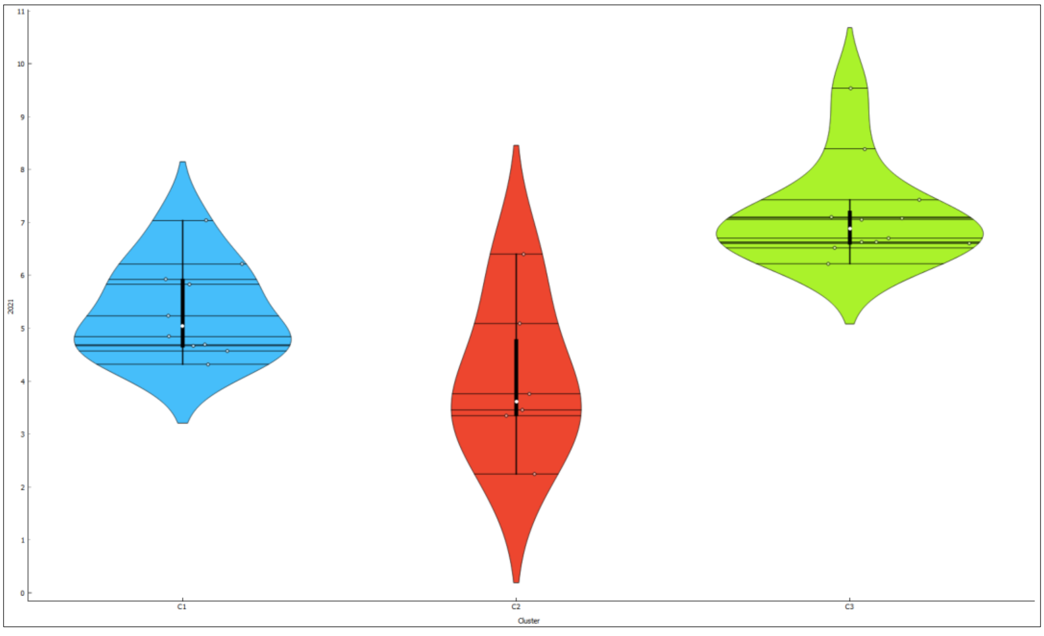

C1
C2
C3
Romania
Poland
France
Lithuania
Finland
Latvia
Germany
Italy
Austria
Estonia
Sweden
Hungary
European Union
Malta
Slovenia
Denmark
Croatia
Czechia
Netherlands
Greece
Spain
Ireland
Cyprus
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10

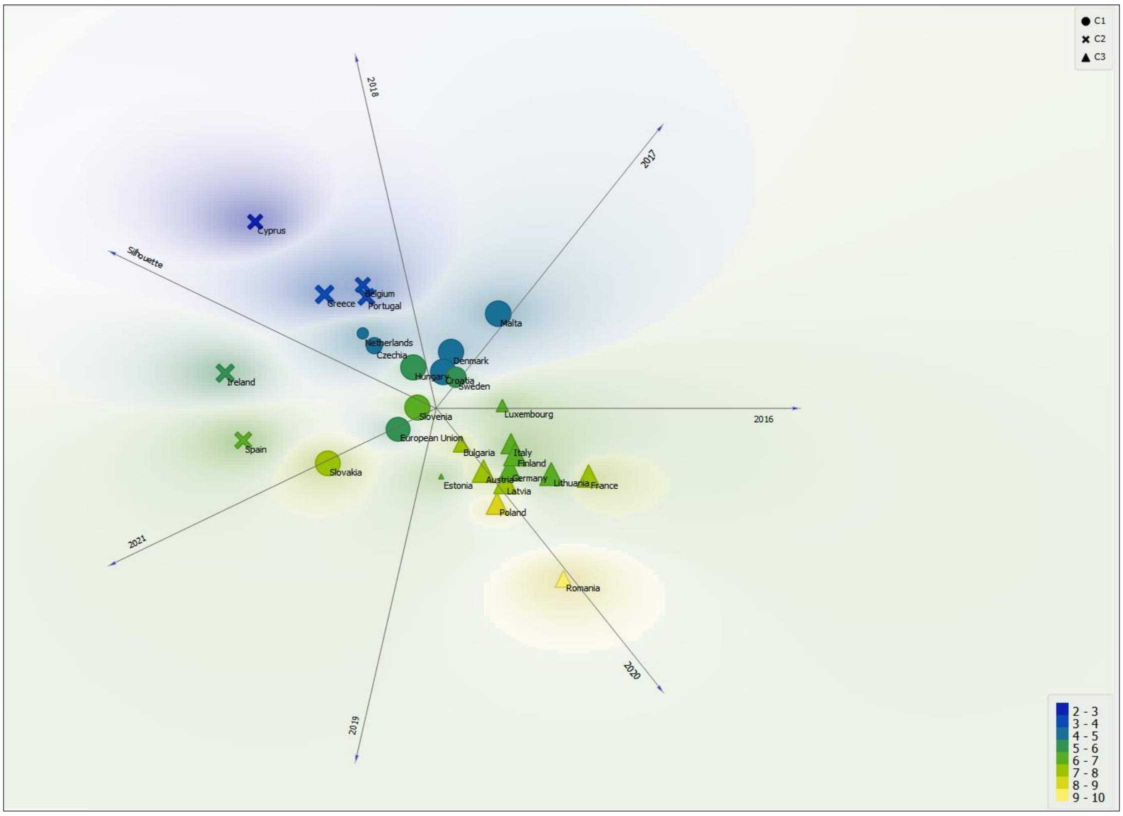

C1
C2
C3
2021
Croatia
Czechia
Denmark
European Union
Hungary
Malta
Netherlands
Slovakia
Slovenia
Sweden
Belgium
Cyprus
Greece
Ireland
Portugal
Spain
Austria
Bulgaria
Estonia
Finland
France
Germany
Italy
Latvia
Lithuania
Luxembourg
Poland
Romania
Country
Cluster


C1
C2
C3
2016
2017
2018
2019
2020


C1
C2
C3
Slovakia
Slovenia
Sweden
European Union
Hungary
Netherlands
Czechia
Malta
Spain
Ireland
Greece
Belgium
Portugal
Cyprus
Poland
Latvia
Italy
Cluster


C1 (μ=0.686594, σ=0.0413871)
C2 (μ=0.664102, σ=0.0138612)
C3 (μ=0.659107, σ=0.0478435)
Frequency
Silhouette

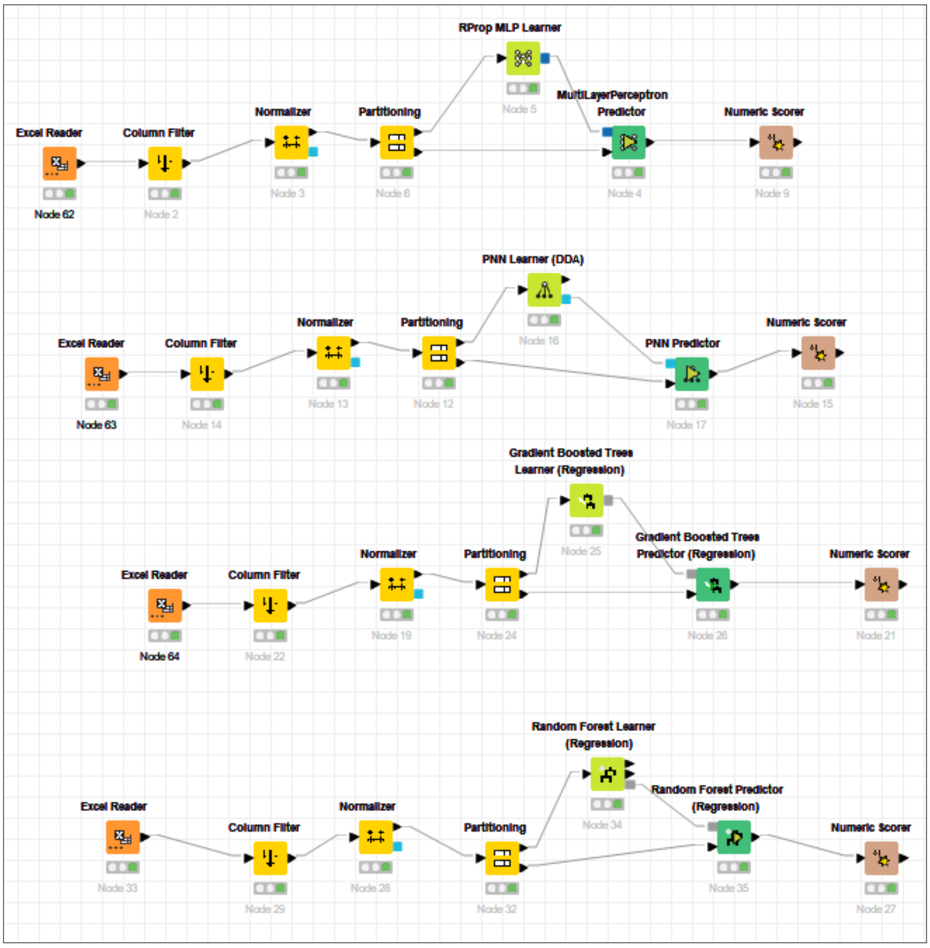

2021
C1
C2
C3
Cluster

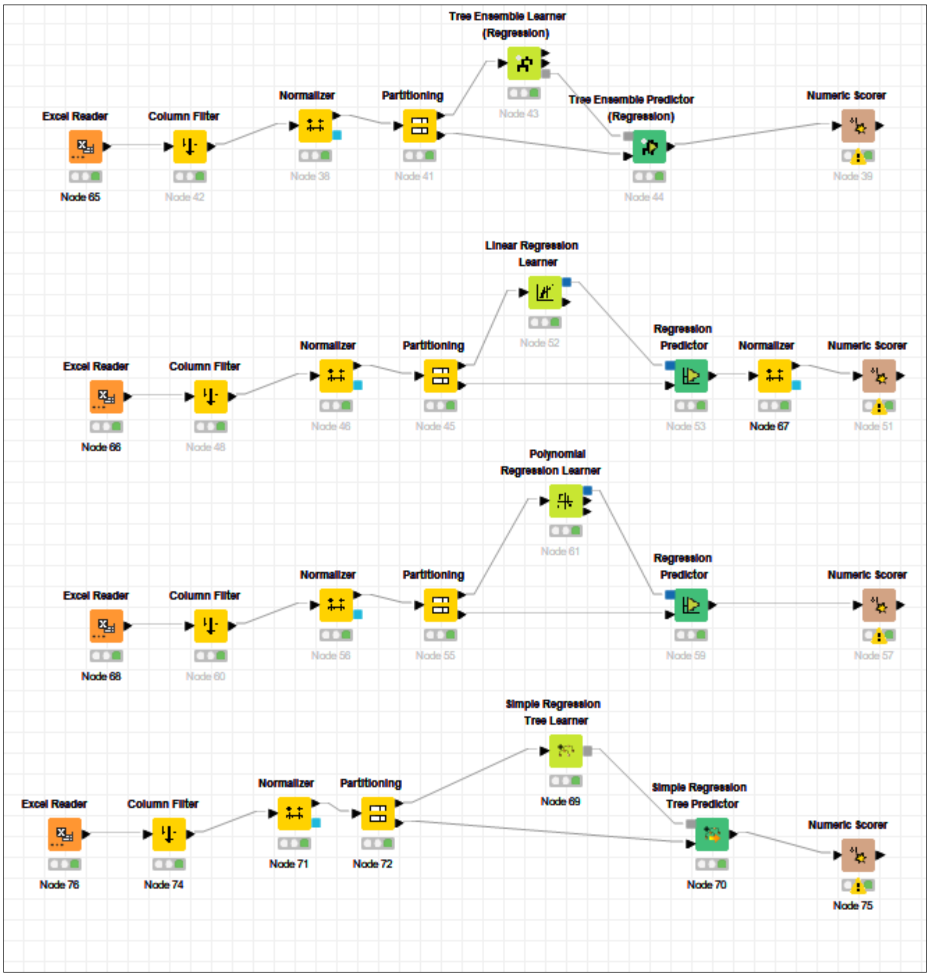


Machine Learning and Prediction

Ranking of algorithms by predictive ability							
Rank	***Algorithm***	**R^2**	**Mean absolute erro**	**Mean squared erro**	**Root mean squared erro**	**Mean signed difference**	**Total**
1	*ANN*	3	1	1	1	4	10
2	*Gradient Boosted Trees*	5	2	2	2	2	13
3	*Random Forest Regression*	1	3	3	3	6	16
4	*Simple Regression Tree*	2	5	5	5	1	18
5	*PNN*	6	4	4	4	3	21
6	*Tree Ensemble Regression*	4	6	6	6	5	27
7	*Polynomial Regression*	7	7	7	7	7	35
8	*Linear Regression*	8	8	8	8	8	40

Results of the prediction with the Artificial Neural Network-ANN algorithm.					
Rank	**Country**	**2021**	**Normalization**	**Absolute Variation**	**%**
2	**Bulgaria**	7,082	6,467	-0,615	-8,687
11	**Germany**	6,705	6,526	-0,179	-2,666
12	**Greece**	3,763	5,989	2,226	59,175
13	**Hungary**	5,234	6,288	1,054	20,136
14	**Ireland**	5,089	5,926	0,837	16,437
18	**Luxembourg**	6,221	6,450	0,229	3,688
19	**Malta**	4,320	6,271	1,951	45,147
24	**Slovakia**	7,036	6,217	-0,819	-11,642
25	**Slovenia**	6,213	6,288	0,075	1,211
	Mean	5,740	6,269	0,529	9,212


RProp MLP Learner
Node 5
MultiLayerPerceptron Predictor
Excel Reader
Column Filter
Normalizer
Partitioning
Numeric Scorer
Node 62
Node 2
Node 3
Node 6
Node 4
Node 9
PNN Learner (DDA)
Node 16
PNN Predictor
Node 63
Node 14
Node 13
Node 12
Node 17
Node 15
Gradient Boosted Trees Learner (Regression)
Node 25
Gradient Boosted Trees Predictor (Regression)
Node 64
Node 22
Node 19
Node 24
Node 26
Node 21
Random Forest Learner (Regression)
Node 34
Random Forest Predictor (Regression)
Node 33
Node 29
Node 28
Node 32
Node 35
Node 27


Tree Ensemble Learner (Regression)
Node 43
Tree Ensemble Predictor (Regression)
Excel Reader
Column Filter
Normalizer
Partitioning
Numeric Scorer
Node 65
Node 42
Node 38
Node 41
Node 44
Node 39
Linear Regression Learner
Node 52
Regression Predictor
Node 66
Node 48
Node 46
Node 45
Node 53
Node 67
Node 51
Polynomial Regression Learner
Node 61
Node 68
Node 60
Node 56
Node 55
Node 59
Node 57
Simple Regression Tree Learner
Node 69
Simple Regression Tree Predictor
Node 76
Node 74
Node 71
Node 72
Node 70
Node 75