The Broadband Penetration in Europe

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Abstract

In this article we estimate the determinants of broadband penetration in Europe. We use data from the European Innovation Scoreboard of the European Commission for 37 countries in the period 2010-2019. We apply Panel Data with Fixed Effects, Panel Data with Random Effects, WLS, OLS and Dynamic Panel. We found that the level of "*Broadband Penetration*" in Europe is positively associated to "*Enterprises Providing ICT Training*", "*Innovative Sales Share*", "*Intellectual Assets*", "*Knowledge-Intensive Service Exports*", "*Turnover Share SMEs*", "*Innovation Friendly Environment*" and negatively associated with "*Government procurement of advanced technology products*", "*Sales Impact*", "*Firm Investments*", "*Opportunity-Driven Entrepreneurship*", "*Most Cited Publications*", "*Rule of Law*". In adjunct we perform a clusterization with k-Means algorithm optimized with the Silhouette Coefficient and we find the presence of three different clusters. Finally, we apply eight machine learning algorithms to predict the level of "*Broadband Penetration*" in Europe and we find that the Polynomial Regression algorithm is the best predictor and that the level of the variable is expected to increase of 10,4%.

1. Introduction

In this article we investigate the determinants of broadband penetration in 37 European countries in the period 2010-2019. Broadband penetration is essential to promote the effective digitalization of the economy. In effect broadband penetration can sustain Internet of Things, telemedicine, smart cities and the promises of artificial intelligence and machine learning. The ability to promote innovation technology especially in ICT sector is deeply associated with the efficiency and capacity of broadband penetration. Innovation technology is a driving force of economic growth such as in the Solow's model [1] , in the theory of endogenous growth [2] and in the case of Schumpeterian economics [3]. Furthermore, innovation technology has positive effects on human resources [4] and on the ability of firms to improve their sales either at an international level [5]. The investment in innovation technology is also positively associated to deeper expenditures in Research and Development either at a country level [6] either in the corporate dimension [7]. Finally, innovation technology, in the sense of digitalization, also has positive effects on employment [8]. For all these motivations it is important to analyze the question of broadband penetration for its role in promoting digitalization and innovation technology.
Broadband penetration requires investments in fiber optics [9]. There is a positive relationship between broadband penetration and the economic growth in Asia either in high income countries

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either in medium income countries [10], [11]. The development of broadband penetration infrastructures improves total factor productivity and GDP growth [12]. The investments in internet penetration is positively associated to economic development and growth in Africa [13]. The creation of political economies that are specifically oriented to the creation of digital infrastructures in developing countries, such as in the case of Indonesia, shows that the effect on trade and e-commerce is structurally higher than the effect of human capital in terms of HDI [14]. The development of telecommunication infrastructure also has a positive role in promoting digitalization and economic growth especially in high performing EU-OECD economies [15]. The investment in broadband penetration in Asian countries is positively associated to GDP growth especially in the case of low inflation as a tool to promote job creation in the digital economy [16]. While on one side, families and individual customers could prefer mobile internet connection to broadband penetration, since these groups use internet for communication and entertainment, on the other side firms and business activities express a demand of broadband penetration to improve the profitability of their activities [17].

Broadband penetration has negative impact on social capital in terms of relationships and interactions since users tend to prefer virtual life to real life [18]. The diffusion of broadband penetration is positively associated to population density [19]. Broadband penetration can have a positive effect on productivity and regional convergence such as in the case of Brazil [20]. The investment in broadband penetration has positive effect on economic growth at regional level in Russia even in the theoretical and applicative framework of the Solow's model [21]. The mechanism of pricing can have a role in shaping the degree of broadband penetration among countries i.e. tariff diversity is positively associated to a widespread broadband penetration [22]. The diffusion of broadband penetration improves the ability of citizens to actively participate in political debate in Europe [23]. Since the diffusion of internet at a country level is positively associated to the number of customers and the quantity of digital contents then countries that are interested in promoting broadband penetration should also improve internet services [24].

The prediction of broadband penetration in developing countries such as India can also offer an outlook on the ability to promote economic growth and an improvement in Human Development Index-HDI [25]. There also controversial relationship among broadband penetration, income inequality and digital divide in the sense that either income inequality can reduce broadband penetration and either that digital divide can weaken the relation between digitalization and economic growth [26]. The impact of telecommunication infrastructure on economic growth is greater for developing countries in respect to developed ones [27]. Positive relationships between broadband penetration and economic growth are present also in Latin America [28]. Similar relationships also characterize the Nigerian economy [29] and Middle East countries [30]. Broadband penetration in South Korea has reached highest levels as a consequence of a co-opetition between public sector and the market and the presence of firms able to offer high qualitative services to customers that show a significative orientation towards product and service innovativeness [31]. Empirical studies have shown that an increase in 10% of mobile broadband penetration can rise Gdp per capita of an amount in the range 0,59-0,76% at a country level if the economy also have a developed industrial sector and the human capital necessary to create value added through digitalization [32].

The article continues as follows: the second paragraph presents the econometric model, the third paragraph contains the cluster analysis, the fourth paragraph shows the results of the machine learning algorithms used to predict the value of broadband penetration, the fifth paragraph concludes.

2. The Econometric Model

We use data from European Innovation Scoreboard in the period 2010-2019 for 37 countries to estimate the following equation:

$$
\begin{aligned}
BroadbandPenetration_{it} \\
= a_1 \\
+ b_1(Government\ procurement\ of\ advanced\ technology\ products)_{it} \\
+ b_2(Firm\ investments)_{it} + b_3(Enterprises\ providing\ ICT\ training)_{it} \\
+ b_4(Innovation-friendly\ environment)_{it} \\
+ b_5(Innovative\ sales\ share)_{it} + b_6(Intellectual\ assets)_{it} \\
+ b_7(Knowledge-intensive\ services\ exports)_{it} \\
+ b_8(Most-cited\ publications)_{it} \\
+ b_9(Opportunity-driven\ entrepreneurship)_{it} + b_{10}(Rule\ of\ law\ )_{it} \\
+ b_{11}(Sales\ impacts)_{it} + b_{12}(Turnover\ share\ SMEs\ )_{it}
\end{aligned}
$$

Where i=37 and t= [2010,2019].
The level of broadband penetration is defined as a relationship between a numerator that is the number of enterprises with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mb and a denominator that is based on the total number of enterprises. The level of broadband penetration is a measure that capture the ability of European countries to develop a digital economy based on e-commerce and internet of thing.
The level of broadband penetration is negatively associated to:

- *Government procurement of advanced technology products:* is a measure that consider the ability of a government to promote technological innovation through the public demand. There is a negative relationship between "*Broadband penetration*" and the level of "*Government Procurement of Advanced Technology Products*". This negative relationship can be interpreted in the sense that the public demand of technological innovation is not sufficient to promote a widespread diffusion of internet among European countries.
- *Sales impacts:* is an indicator that is created as the sum of three different measures that are "*Exports of medium and high-tech products*", "*Exports of knowledge intensive services*", "*Sales due to innovation activities*". There is a negative relationship between Broadband penetration and sales impacts. This negative relationship can be interpreted considering that European countries, even when export, do not use digitalization and e-commerce and prefer traditional and classical methodologies.
- *Firm investments:* is based on three different indicators that are R&D investments, non-R&D investments, and the investment of R&D to improve the skills of human resources. There is a negative relationship between firm investment and broadband penetration. The negative relationship means that the investment of the firms does not depend on the ability of a country to promote a widespread and efficient diffusion of internet network.
- *Opportunity-driven entrepreneurship:* is a ratio that measures the relationship between persons that create enterprises to improve their income and persons that creates enterprises since they have no other opportunity to work. The fact that there is a negative relationship between broadband penetration and opportunity driven entrepreneurship means that the level of digitalization in the European Countries is not sufficient to promote the creation of new firms that operate for profits maximizing technological improvements in the digital economy.
- *Most-cited publications:* is ratio in which at the denominator there is the number of scientific publication in the top 10 most cited publication worldwide and the denominator is the total number of publication. The fact that there is a negative relationship between broadband penetration and most-cited publication means that the impact of digitalization of

the efficiency of research system is not sufficient to promote an increase in the quality of publications at an international level.

- *Rule of law:* is a measure that capture the ability of economic agent to trust public institutions and their ability of governments to promote the quality of contract enforcement, property rights, police services, and courts and act in the reduction of crime and violence. The negative relationship between broadband penetration and rule of law means that public institutions are not able to apply the digital services to justice and public order. Probably an improvement in the ability of government to efficiently use digital services to promote the role of law could have a positive effect in strengthening the of rule of law.

Variables		Label	Dynamic Panel		Panel Data Fixed Effects		Panel Data Random Effects		Pooled OLS		WLS	
			Value	p-value	Value	p-value	Value	p-value	Value	p-value	Value	p-value
y_1	*Broadband Penetration*	A5										
	Costant		14,3267	***	0,829343		1,07776		2,11448		-2,144	
x_1	*Government procurement of advanced technology products (SD)*	A22	-1,69918	***	-1,75901	***	-1,78254	***	-1,87111	***	-1,95799	***
x_2	*Firm investments*	A18	-0,434044	***	-0,400542	***	-0,446602	***	-0,615974	***	-0,55982	***
x_3	*Enterprises providing ICT training*	A15	0,179466	**	0,418365	***	0,427743	***	0,440885	***	0,365166	***
x_4	*Innovation-friendly environment*	A25	1,11725	***	1,11032	***	1,09628	***	1,06707	***	1,2152	***
x_5	*Innovative sales share*	A26	0,306926	***	0,29238	***	0,338208	***	0,56413	***	0,439624	***
x_6	*Intellectual assets*	A29	0,432916	***	0,509248	***	0,532116	***	0,536519	***	0,468831	***
x_7	*Knowledge-intensive services exports*	A31	0,501403	***	0,845525	***	0,820915	***	0,698707	***	0,628133	***
x_8	*Most-cited publications*	A36	-0,320932	***	-0,323755	**	-0,356958	***	-0,531797	***	-0,40617	***
x_9	*Opportunity-driven entrepreneurship*	A39	-0,383583	***	-0,485218	***	-0,4408	***	-0,240413	***	-0,3453	***
x_{10}	*Rule of law (SD)*	A48	-0,262638	*	-0,423548	**	-0,449353	**	-0,51152	***	-0,34188	***
x_{11}	*Sales impacts*	A49	-0,59254	***	-0,884347	***	-0,884979	***	-0,820701	***	-0,68074	***
x_{12}	*Turnover share SMEs (SD)*	A58	0,671793	***	1,36469	***	1,3874		1,48295	***	1,03482	***
	Broadband Penetration	A5(-1)	-0,286854	**								

Figure 1. Synthesis of the main results of the econometric estimation realized with the usage of Panel Data with Fixed Effects, Panel Data with Random Effects, Pooled OLS, Dynamic Panel Data, and WLS.

The level of broadband penetration is positively associated with:

- *Enterprises providing ICT training:* is ratio between the number of firms that provide training in ICT sector for their personnel and the total number of enterprises. The idea is that the greater the number of firms that train their human resources in ICT skills the greater the ability of firms to perform in the digital economy with positive effects either in the sense of profits either in the sense of GDP. The presence of a positive relationship between the broadband penetration and the number of firms that among European countries promote ICT skills for their personnel shows that the digitalization through infrastructure improve the level of human capital. Furthermore, this positive relationship can also better understood considering the role of MOOCs platforms and remote learning that are used to professional training in the digital economy.

- *Innovative sales share:* is a ration between the total turnover of new products and total turnover for all enterprises. The indicator shows the level of turnover associated either with new products either with the diffusion of new technologies. The existence of a positive relationship between innovative sales share and the level of broadband penetration shows that the investment in broadband penetration has effective a positive role in promoting new products and services and in the diffusion of new technologies in the markets. Innovative sales share can also be considered as a tool that shows the presence of a higher degree of customer innovativeness that can effectively sustain the marketization of new products and services.

- *Intellectual assets:* is a measure that capture three different forms of intellectual propriety rights that are PCT patent applications, trademark application and design application. The fact that there is a positive relationship between broadband penetration and the value of intellectual assets means that the digitalization of the economies among European Countries

is positively associated to the promotion of a knowledge economy based on intangibles assets. The strengthening of the knowledge economy is either the condition either the output of the digitalization of the economy and can be efficiently realized in connection with an increase in the value of human resources at a country and international level.

- *Knowledge-intensive services export:* is ratio between the export of knowledge intensive services and the total export of services. The indicator can be considered as a measure of the ability of a country to export knowledge intensive services for example in the sector of transportation, finance, research and developments, ICT, media, and creative industries. The ability of a country to export knowledge intensive services is a consequence of the general degree of innovativeness of an economy. Furthermore, a higher degree of knowledge intensive services is also a signal of the ability of a country to actively participate in knowledge intensive global value chains. The positive relationship between broadband penetration and know-ledge intensive services exports means that effectively the production of high quality services in the knowledge economy requires a higher degree of digitalization.

- *Turnover share SMEs:* is a ratio between the turnover in SMEs and the total turnover of the business economy except financial activities. There is a positive relationship between broadband penetration and turnover share in SMEs. This means that the SMEs have greater benefits from broadband penetration in respect to big corporations. The economic opportunities for SMEs improve in the presence of higher level of broadband penetration. This result can be better understood considering the network effects and positive externalities offered by internet and the relative low cost of the ICT in respect to other innovations that are more costly such as in the case of the pharmaceutical and automotive sectors. The digital technologies are more sustainable for SMEs, either in the sense of financial resources either in the sense of know-how. Specifically broadband penetration can promote SMEs' competitiveness and productivity creating the conditions for better results in terms of turnover at a national level among European countries.

- *Innovation-friendly environment:* is measure that capture the ability of firms to operate in an environment that can sustain innovation and digital firms. There is a positive relationship between broadband innovation and innovation friendly environment. The positive relationship can be in part explained considering that the presence of a digital business culture, the development of human resources that can work in ICT sectors with STEM skills, and even the possibility to have access to digital markets are effectively related to the presence of high level of broadband penetration. Furthermore, there is a recursive effect between the innovation-friendly environment and the broadband penetration: at the first stage the broadband penetration promotes a more developed innovation friendly environment and in a second stage the innovation-friendly environment expresses a demand for improvements in broadband penetration.

3. Clusterization

The clusterization model is realized with the application of the k-Means algorithm optimized with the silhouette coefficient. We found three different clusters that are:
- Cluster 1: *Slovakia, United Kingdom, Norway, Bulgaria, France, Germany, Czechia, Bosnia and Herzegovina, Hungary, Austria, Poland, Estonia, Montenegro, Ukraine, North Macedonia, Romania, Ireland, Slovenia, Malta, Turkey*
- Cluster 2: *Lithuania, Finland, Netherlands, Belgium, Sweden, Portugal, Denmark, Luxembourg, Switzerland, Latvia, Iceland, Spain;*

- Cluster 3: *Greece, Serbia, Croatia, Cyprus, Italy.*

We can create an order of cluters based on the value of the median. Specifically, the value of the median of "*Broadband Penetration*" for the cluster 2 is equal to 197,48, the value of the median for the cluster 1 is equal to 132,08, and the value of the median for the cluster 3 is equal to 118,25. Based on the value of the median we can build the same order: C2>C1>C3.
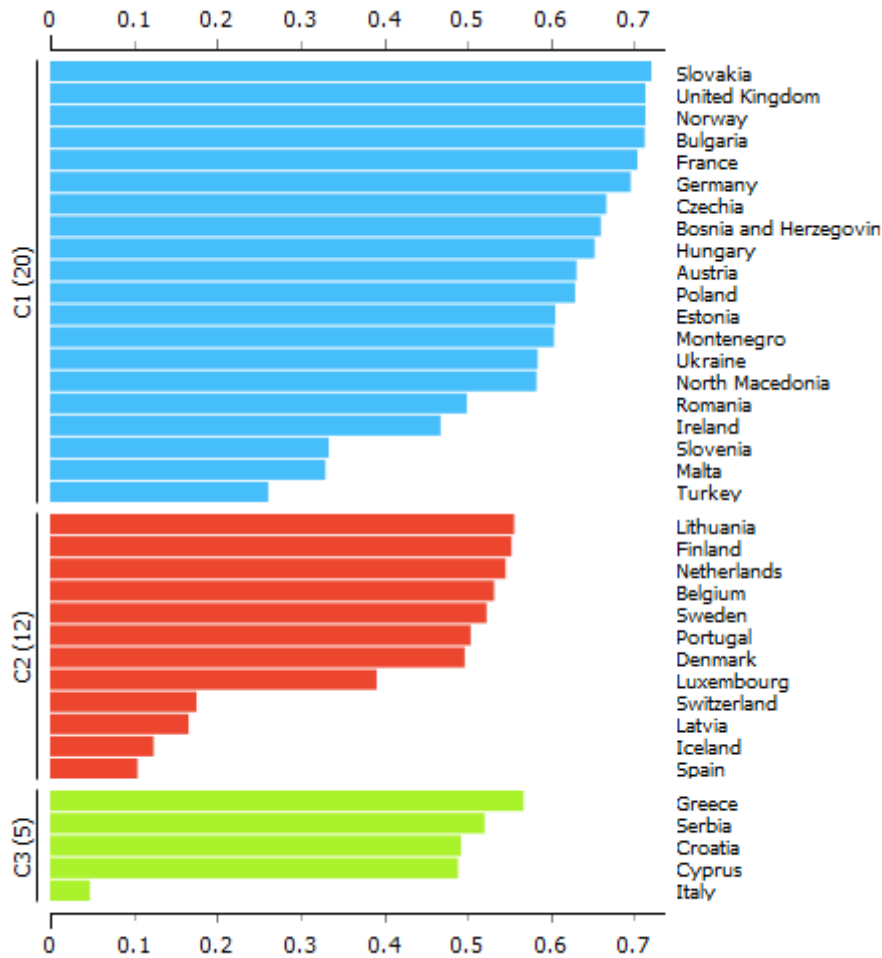

Figure 2. The Silhouette Coefficient of the Three Clusters Analyzed.

4. Machine Learning and Predictions

We use eight different typologies of machine learning algorithms to choose the best predictor of the level of "*Broadband Penetration*". We evaluate the algorithms based on their ability to maximize R-squared and to minimize "*Mean Absolute Error*", "*Mean Squared Error*", "*Root Mean Squared Error*", "*Mean Signed Difference*". To test the algorithms, we use data from the European Innovation Scoreboard for the period 2014-2021 for 37 countries. 70% of the dataset has been used for the learning rate and the remaining 30% has been used to effectively predict the degree of "Broadband Penetration" in Europe. We found obtain the following ranking of algorithms:
- *Polynomial Regression* with a payoff equal to 10;
- *Probabilistic Neural Network-PNN* with a payoff equal to 11;
- *Artificial Neural Network-ANN* with a payoff equal to 19;
- *Gradient Boosted Tree* with a payoff equal to 20;

- *Tree Ensemble* with a payoff equal to 24;
- *Linear Regression* with a payoff equal to 27;
- *Simple Regression Tree* with a payoff equal to 32;
- *Random Forest* with a payoff equal to 37.

	Ranking of Algorithms for Performance in Terms of Maximization of R^2 and Minimization of Errors					
Rank	Algorithms	R^2	Mean Absolute Error	Mean Squared Error	Root Mean Squared Error	Mean Signed Difference	Sum
1	Polynomial Regression	1	1	1	1	6	10
2	PNN	2	3	2	2	2	11
3	ANN	4	2	3	3	7	19
4	Gradient Boosted Tree	3	4	5	5	3	20
5	Tree Ensemble	5	6	6	6	1	24
6	Linear Regression	6	5	4	4	8	27
7	Simple Regression Tree	7	7	7	7	4	32
8	Random Forest	8	8	8	8	5	37

Figure 3. Ranking of algorithms in terms of performance for the maximization of R-squared and the minimization of errors.

The Polynomial Regression algorithm has predicted an increase of the level of "Broadband Penetration" in Europe equal to 10,4% on annual bases. Specifically, the algorithm has predicted the following values of "Broadband Penetration":

- A reduction for Austria from 130,38 to 117,38 equivalent to -9,97%;
- A reduction for Germany from 144,91 to 139,91 equivalent to -3,45%;
- An increase for Denmark from 202,48 to 208,96 equivalent to 3,20%;
- A reduction for Spain from 197,48 to 174,11 equivalent to -11,84%;
- A reduction for Croatia from 109,54 to 78,85 equivalent to -28,02%;
- A reduction for Iceland from 173,21 to 166,92 equivalent to -3,62%;
- An increase for Italy from 114,02 to 118,79 equivalent to 4,18%;
- A reduction for North Macedonia from 104,88 to 102,19 equivalent to -2,57%;
- An increase for Poland from 154,92 to 161,9 equivalent to 4,51%;
- An increase for Ukraine for 91,1 to 139,42 equivalent to +53,03%;
- An increase for United Kingdom from 134,16 to 140,86 equivalent to +4,99%.

Generally, the level of broadband penetration is expected to growth in Europe even if an heterogenous way among different countries.
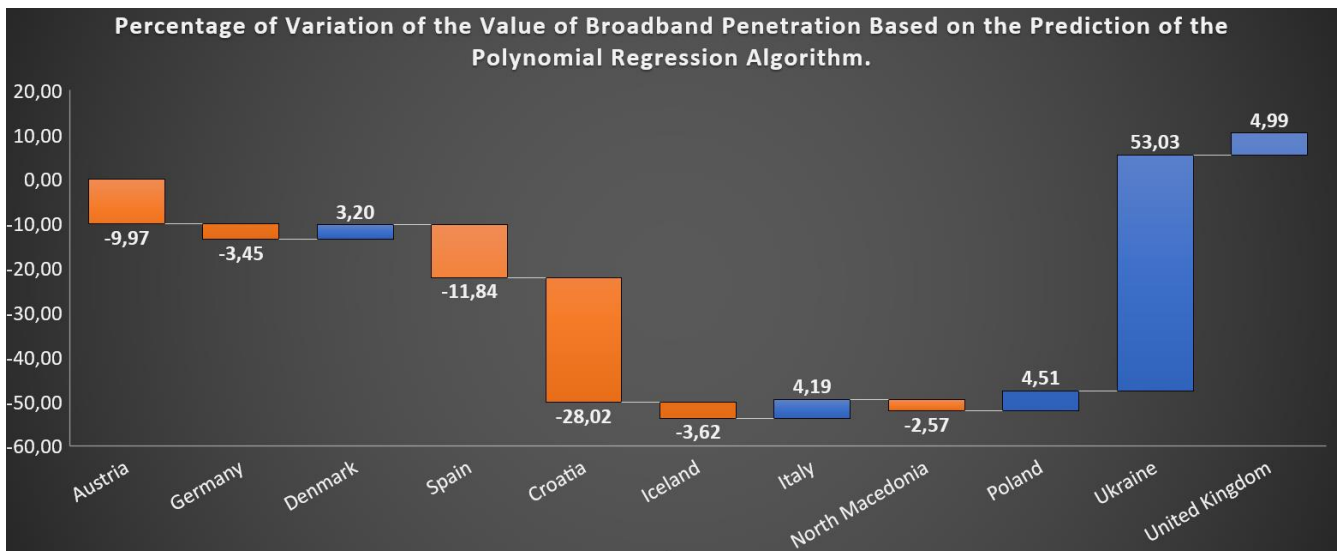
Figure 4. Percentage variation of the value of Broadband penetration among different countries in Europe as predicted using the machine learning algorithm of Polynomial Regression.

5. Conclusions

In this article we estimate the determinants of broadband penetration in Europe. We use data from the European Innovation Scoreboard of the European Commission for 37 countries in the period 2010-2019. In the first paragraph we present a theoretical introduction considering the role of broadband penetration as a tool to promote economic growth. Empirical studies have shown the presence of a positive relationship between broadband penetration and economic growth either in developed either in developing countries. In particular the effect of broadband penetration on economic growth is greater in countries with less income inequalities and a higher level of human capital and investments in intangible assets such as R&D.

In the second paragraph we estimate the level of broadband penetration in European countries using different econometric models i.e. We apply Panel Data with Fixed Effects, Panel Data with Random Effects, WLS, OLS and Dynamic Panel. The results obtained are consistent among different models and statistically significant. We found that the level of "*Broadband Penetration*" in Europe is positively associated to "*Enterprises Providing ICT Training*", "*Innovative Sales Share*", "*Intellectual Assets*", "*Knowledge-Intensive Service Exports*", "*Turnover Share SMEs*", "*Innovation Friendly Environment*" and negatively associated with "*Government procurement of advanced technology products*", "*Sales Impact*", "*Firm Investments*", "*Opportunity-Driven Entrepreneurship*", "*Most Cited Publications*", "*Rule of Law*". The cluster analysis with k-Means algorithm optimized with the Silhouette Coefficient shows the presence of three clusters that substantially coincide, with some exceptions, with Northern, Central and Southern Europe. Finally, we apply eight machine learning algorithms to predict the level of "*Broadband Penetration*" in Europe. We find that the Polynomial Regression algorithm is the best predictor and that the level of the broadband penetration is expected to increase of 10,4%. Our results shows that if policy makers are interested in promoting the economic growth then they should invest more in broadband penetration at a European level.

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7. Appendix

7.1 Econometric Estimation

Panel dinamico a un passo, usando 288 osservazioni					
Incluse 36 unità cross section					
Matrice H conforme ad Ox/DPD					
Variabile dipendente: A5					
	Coefficiente	*Errore Std.*	*z*	*p-value*	
A5(-1)	−0,286854	0,131576	−2,180	0,0292	**
const	14,3267	4,39060	3,263	0,0011	***
A22	−1,69918	0,167796	−10,13	<0,0001	***
A18	−0,434044	0,0939110	−4,622	<0,0001	***
A15	0,179466	0,0737442	2,434	0,0149	**
A25	1,11725	0,205615	5,434	<0,0001	***
A26	0,306926	0,0746325	4,112	<0,0001	***
A29	0,432916	0,112743	3,840	0,0001	***
A31	0,501403	0,177975	2,817	0,0048	***
A36	−0,320932	0,112613	−2,850	0,0044	***
A39	−0,383583	0,142815	−2,686	0,0072	***
A48	−0,262638	0,153474	−1,711	0,0870	*
A49	−0,592540	0,172724	−3,431	0,0006	***
A58	0,671793	0,191483	3,508	0,0005	***

Somma quadr. residui	156640,1	E.S. della regressione	23,90981

Numero di strumenti = 25
Test per errori AR(1): z = 1,57337 [0,1156]
Test per errori AR(2): z = 1,50915 [0,1313]
Test di sovra-identificazione di Sargan: Chi-quadro(11) = 63,5395 [0,0000]

Test (congiunto) di Wald: Chi-quadro(13) = 879,972 [0,0000]
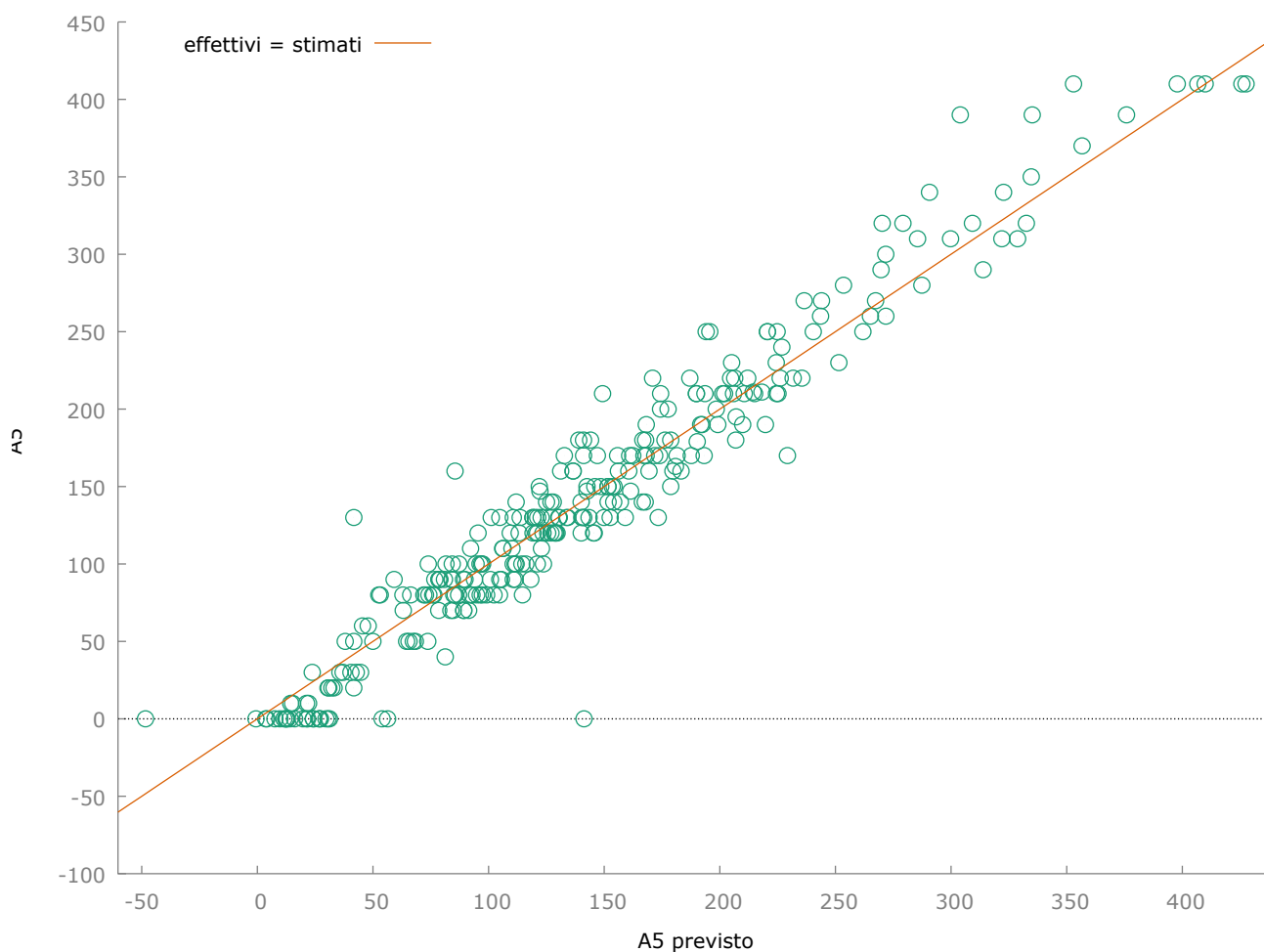
	Effetti fissi, usando 360 osservazioni				
	Incluse 36 unità cross section				
	Lunghezza serie storiche = 10				
	Variabile dipendente: A5				
	Coefficiente	*Errore Std.*	*rapporto t*	*p-value*	
const	0,829343	3,57650	0,2319	0,8168	
A22	−1,75901	0,172232	−10,21	<0,0001	***
A18	−0,400542	0,0950476	−4,214	<0,0001	***
A15	0,418365	0,0584097	7,163	<0,0001	***
A25	1,11032	0,0688436	16,13	<0,0001	***
A26	0,292380	0,0905978	3,227	0,0014	***
A29	0,509248	0,114761	4,437	<0,0001	***
A31	0,845525	0,140959	5,998	<0,0001	***

A36	−0,323755	0,147503	−2,195	0,0289	**
A39	−0,485218	0,0706066	−6,872	<0,0001	***
A48	−0,423548	0,208933	−2,027	0,0435	**
A49	−0,884347	0,181574	−4,870	<0,0001	***
A58	1,36469	0,126128	10,82	<0,0001	***

Media var. dipendente	112,0833	SQM var. dipendente	101,5265
Somma quadr. residui	314740,0	E.S. della regressione	31,76133
R-quadro LSDV	0,914945	R-quadro intra-gruppi	0,858641
LSDV F(47, 312)	71,40907	P-value(F)	3,1e-140
Log-verosimiglianza	−1730,030	Criterio di Akaike	3556,059
Criterio di Schwarz	3742,592	Hannan-Quinn	3630,228
rho	0,634619	Durbin-Watson	0,627291

Test congiunto sui regressori -

 Statistica test: F(12, 312) = 157,929

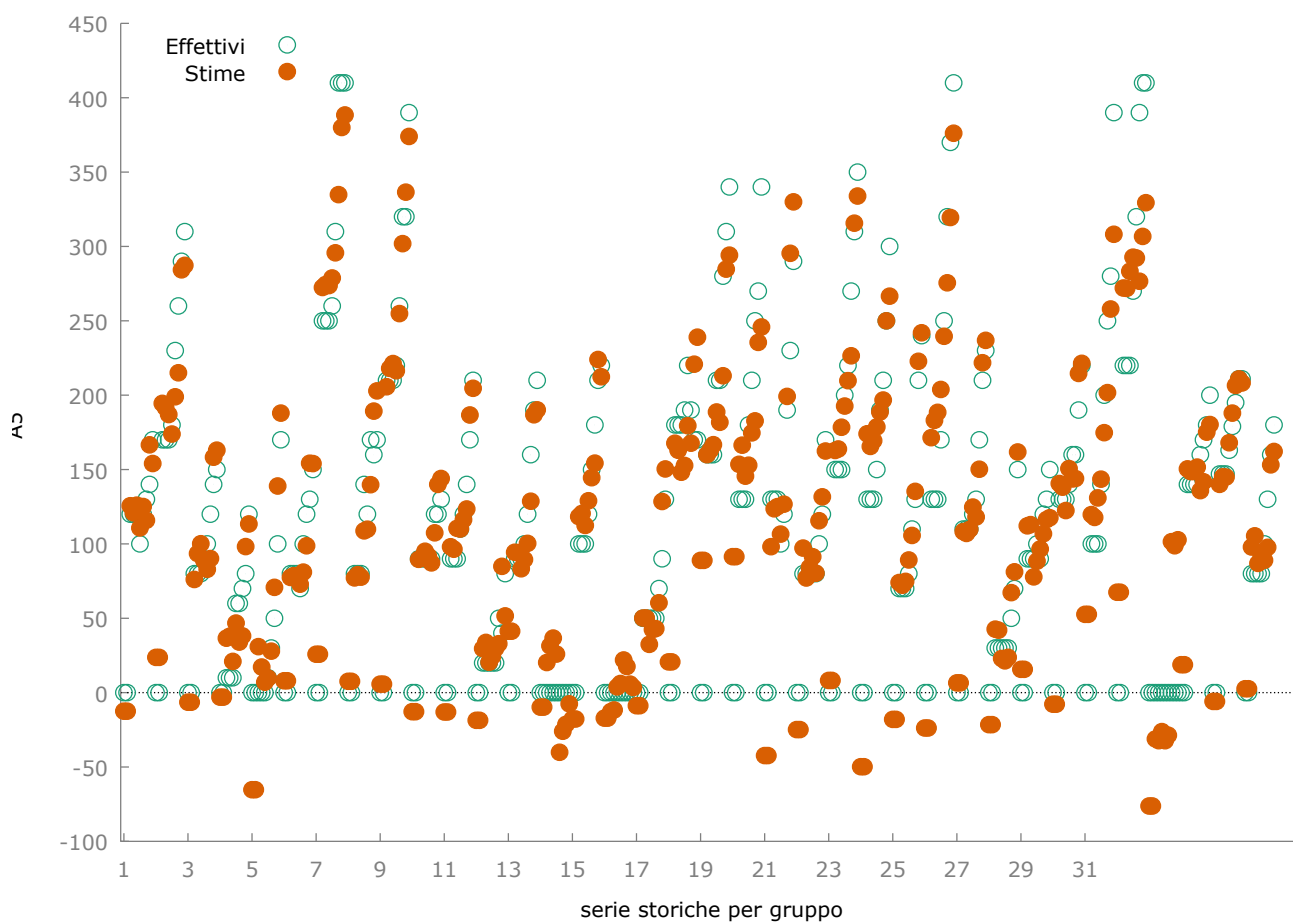 con p-value = P(F(12, 312) > 157,929) = 1,12046e-124

Test per la differenza delle intercette di gruppo -

 Ipotesi nulla: i gruppi hanno un'intercetta comune

 Statistica test: F(35, 312) = 10,4881

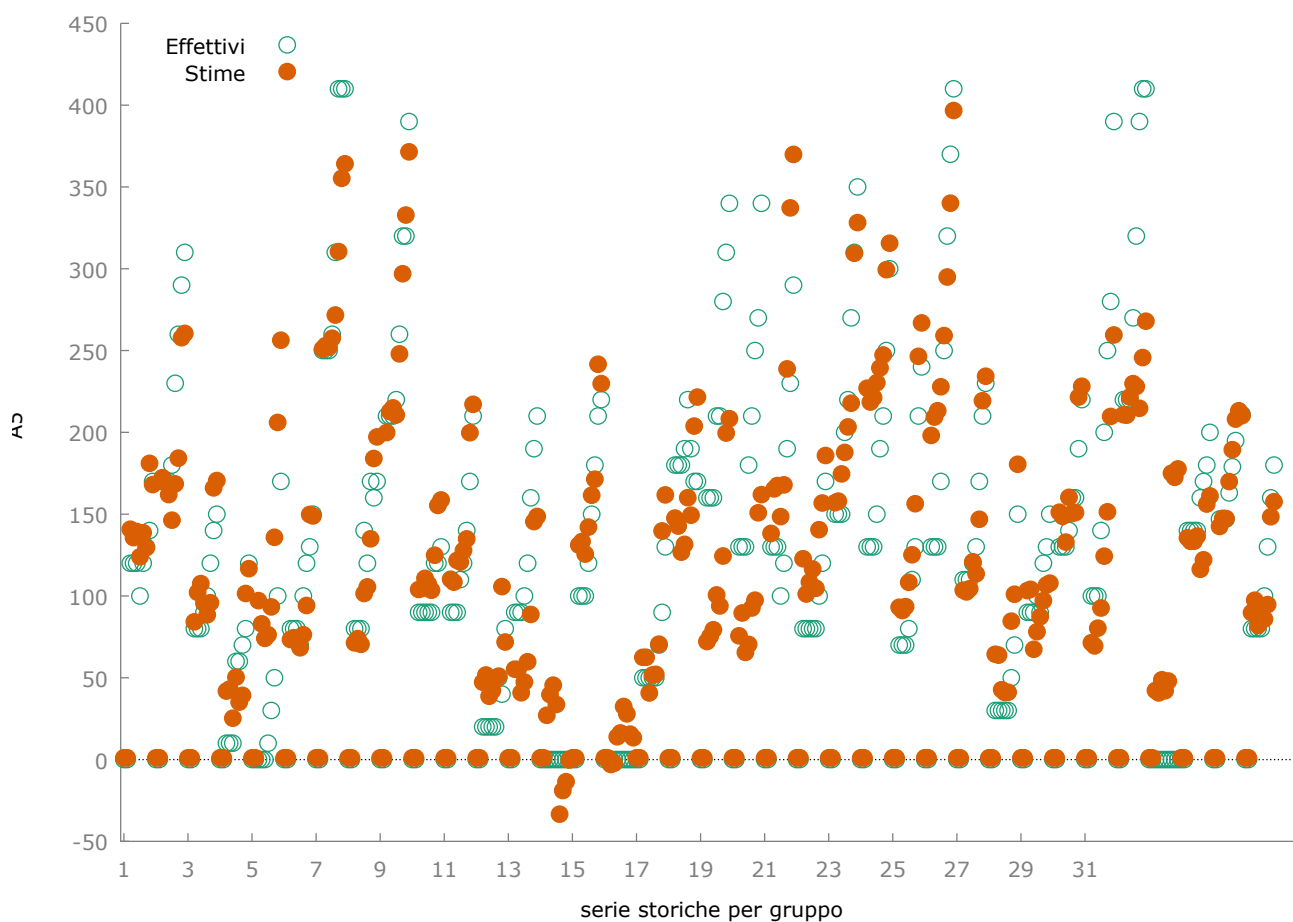 con p-value = P(F(35, 312) > 10,4881) = 3,82213e-035

A5: valori effettivi e stimati

	Coefficiente	Errore Std.	z	p-value	
	Effetti casuali (GLS), usando 360 osservazioni				
	Incluse 36 unità cross section				
	Lunghezza serie storiche = 10				
	Variabile dipendente: A5				
	Coefficiente	Errore Std.	z	p-value	
const	1,07776	6,67624	0,1614	0,8718	
A22	−1,78254	0,152514	−11,69	<0,0001	***
A18	−0,446602	0,0863458	−5,172	<0,0001	***
A15	0,427743	0,0525809	8,135	<0,0001	***
A25	1,09628	0,0639990	17,13	<0,0001	***
A26	0,338208	0,0848260	3,987	<0,0001	***
A29	0,532116	0,104139	5,110	<0,0001	***
A31	0,820915	0,127135	6,457	<0,0001	***
A36	−0,356958	0,136230	−2,620	0,0088	***
A39	−0,440800	0,0660597	−6,673	<0,0001	***
A48	−0,449353	0,186766	−2,406	0,0161	**
A49	−0,884979	0,162912	−5,432	<0,0001	***
A58	1,38740	0,124454	11,15	<0,0001	***

Media var. dipendente	112,0833	SQM var. dipendente	101,5265
Somma quadr. residui	744088,8	E.S. della regressione	46,24053
Log-verosimiglianza	−1884,904	Criterio di Akaike	3795,808
Criterio di Schwarz	3846,327	Hannan-Quinn	3815,895
rho	0,634619	Durbin-Watson	0,627291

Varianza 'between' = 1150,84

Varianza 'within' = 1008,78

Theta usato per la trasformazione = 0,716113

Test congiunto sui regressori -

Statistica test asintotica: Chi-quadro(12) = 1975,55

con p-value = 0

Test Breusch-Pagan -

Ipotesi nulla: varianza dell'errore specifico all'unità = 0

Statistica test asintotica: Chi-quadro(1) = 299,802

con p-value = 3,63909e-067

Test di Hausman -

Ipotesi nulla: le stime GLS sono consistenti

Statistica test asintotica: Chi-quadro(12) = 13,2734

con p-value = 0,349489

A5: valori effettivi e stimati

	Coefficiente	Errore Std.	rapporto t	p-value	
const	2,11448	4,59343	0,4603	0,6456	
A22	−1,87111	0,116558	−16,05	<0,0001	***
A18	−0,615974	0,0710567	−8,669	<0,0001	***
A15	0,440885	0,0418835	10,53	<0,0001	***
A25	1,06707	0,0573275	18,61	<0,0001	***
A26	0,564130	0,0799626	7,055	<0,0001	***
A29	0,536519	0,0853741	6,284	<0,0001	***
A31	0,698707	0,102075	6,845	<0,0001	***
A36	−0,531797	0,118725	−4,479	<0,0001	***
A39	−0,240413	0,0602629	−3,989	<0,0001	***
A48	−0,511520	0,145048	−3,527	0,0005	***
A49	−0,820701	0,128934	−6,365	<0,0001	***

Pooled OLS, usando 360 osservazioni
Incluse 36 unità cross section
Lunghezza serie storiche = 10
Variabile dipendente: A5

A58	1,48295	0,162968	9,100	<0,0001	***

Media var. dipendente	112,0833	SQM var. dipendente	101,5265
Somma quadr. residui	685047,7	E.S. della regressione	44,43198
R-quadro	0,814874	R-quadro corretto	0,808472
F(12, 347)	127,2833	P-value(F)	4,2e-119
Log-verosimiglianza	−1870,023	Criterio di Akaike	3766,046
Criterio di Schwarz	3816,565	Hannan-Quinn	3786,133
rho	0,912159	Durbin-Watson	0,339898
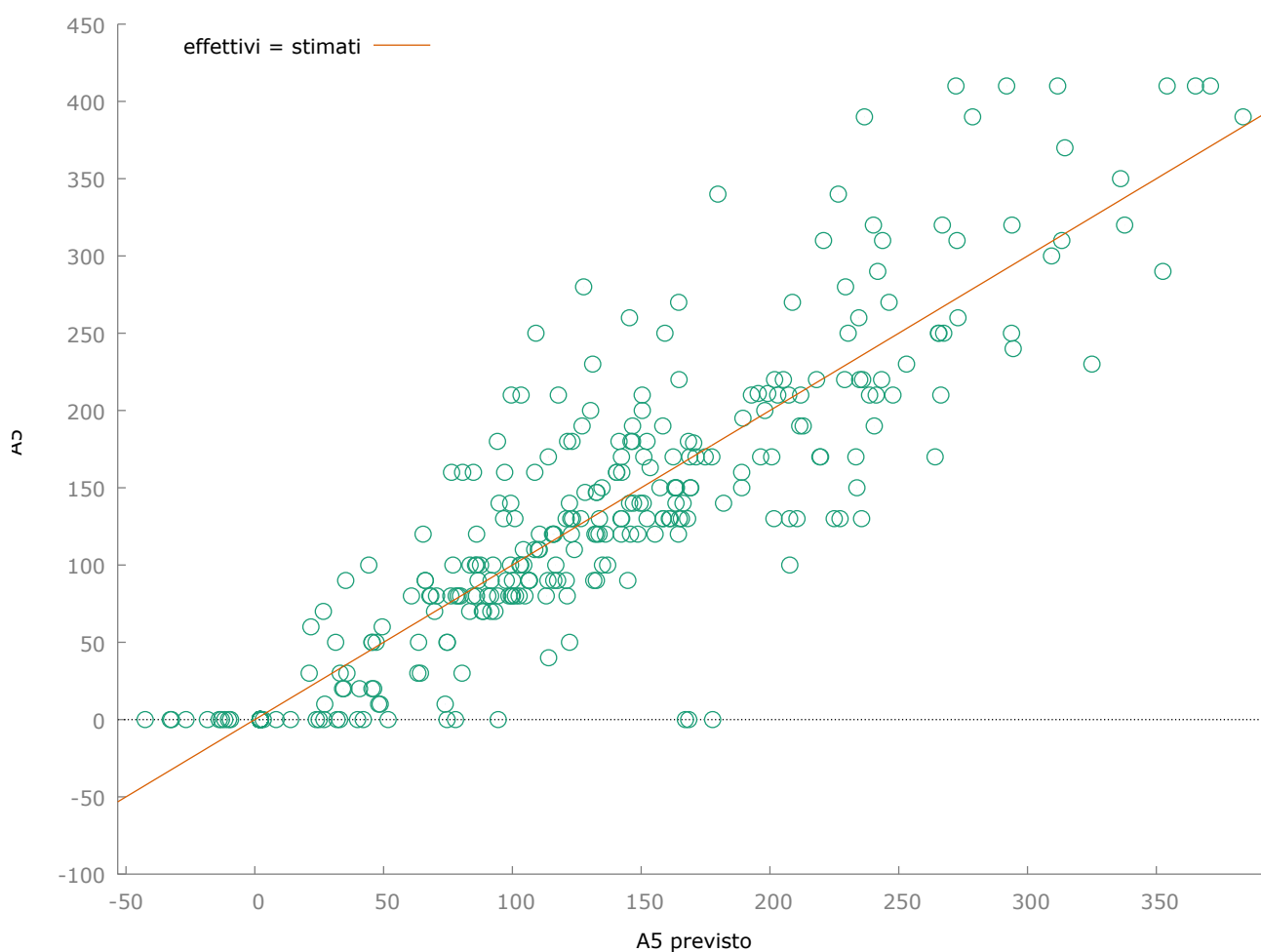
WLS, usando 360 osservazioni
Incluse 36 unità cross section
Variabile dipendente: A5
Pesi basati sulle varianze degli errori per unità

	Coefficiente	Errore Std.	rapporto t	p-value	
const	−2,14400	2,07945	−1,031	0,3032	
A22	−1,95799	0,0624419	−31,36	<0,0001	***
A18	−0,559823	0,0314576	−17,80	<0,0001	***
A15	0,365166	0,0204196	17,88	<0,0001	***
A25	1,21520	0,0329852	36,84	<0,0001	***
A26	0,439624	0,0357728	12,29	<0,0001	***
A29	0,468831	0,0461429	10,16	<0,0001	***
A31	0,628133	0,0590076	10,64	<0,0001	***
A36	−0,406173	0,0635971	−6,387	<0,0001	***
A39	−0,345296	0,0385359	−8,960	<0,0001	***
A48	−0,341875	0,0600756	−5,691	<0,0001	***
A49	−0,680742	0,0598350	−11,38	<0,0001	***
A58	1,03482	0,0770871	13,42	<0,0001	***

Statistiche basate sui dati ponderati:			
Somma quadr. residui	280,6645	E.S. della regressione	0,899351
R-quadro	0,948708	R-quadro corretto	0,946935
F(12, 347)	534,8533	P-value(F)	1,7e-215
Log-verosimiglianza	−466,0079	Criterio di Akaike	958,0159
Criterio di Schwarz	1008,535	Hannan-Quinn	978,1033

Statistiche basate sui dati originali:			
Media var. dipendente	112,0833	SQM var. dipendente	101,5265
Somma quadr. residui	734060,3	E.S. della regressione	45,99399

A5: valori effettivi e stimati

A5 A22 A18 A15

A25 A26 A29 A31

A36 A39 A48 A49

A58
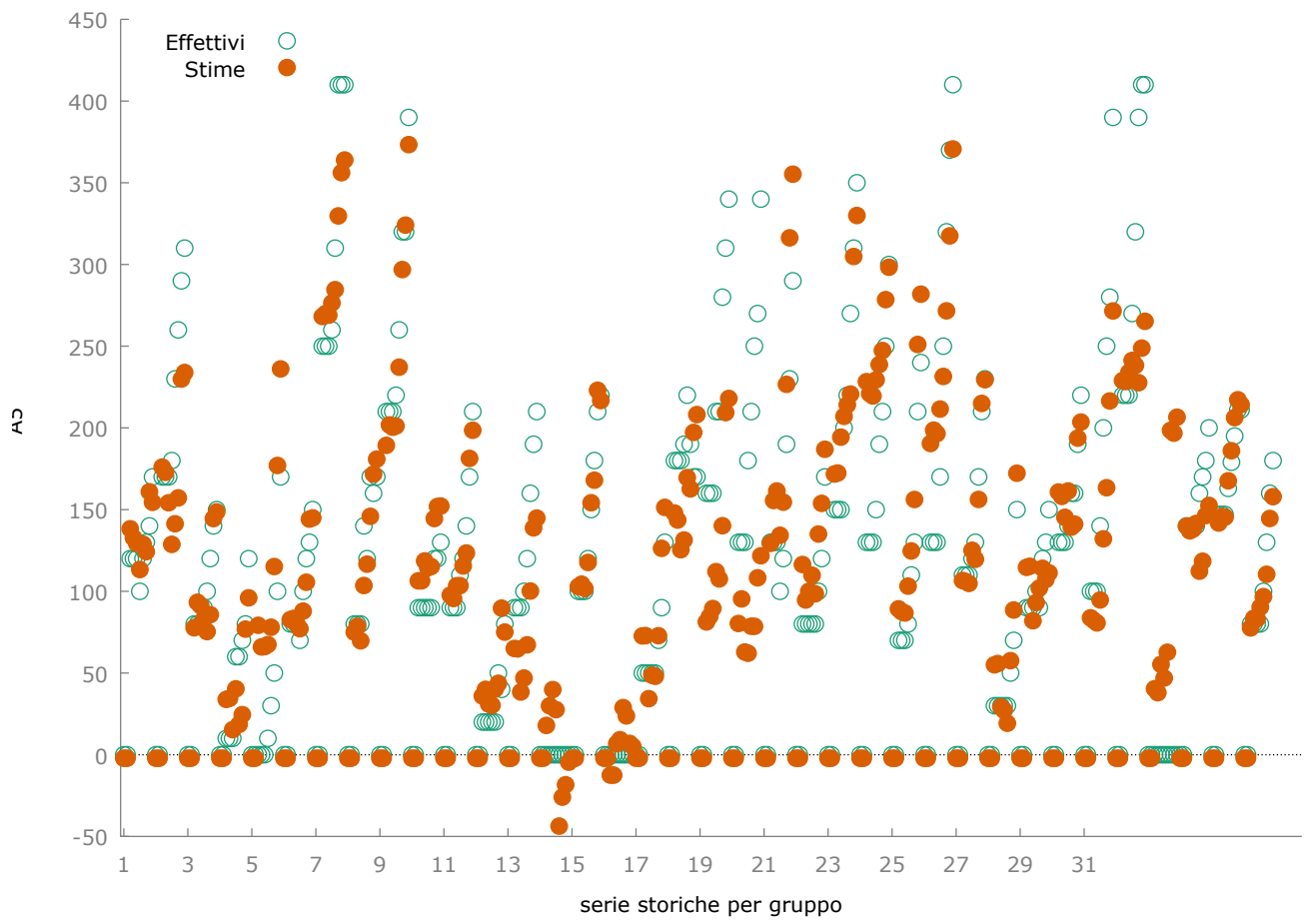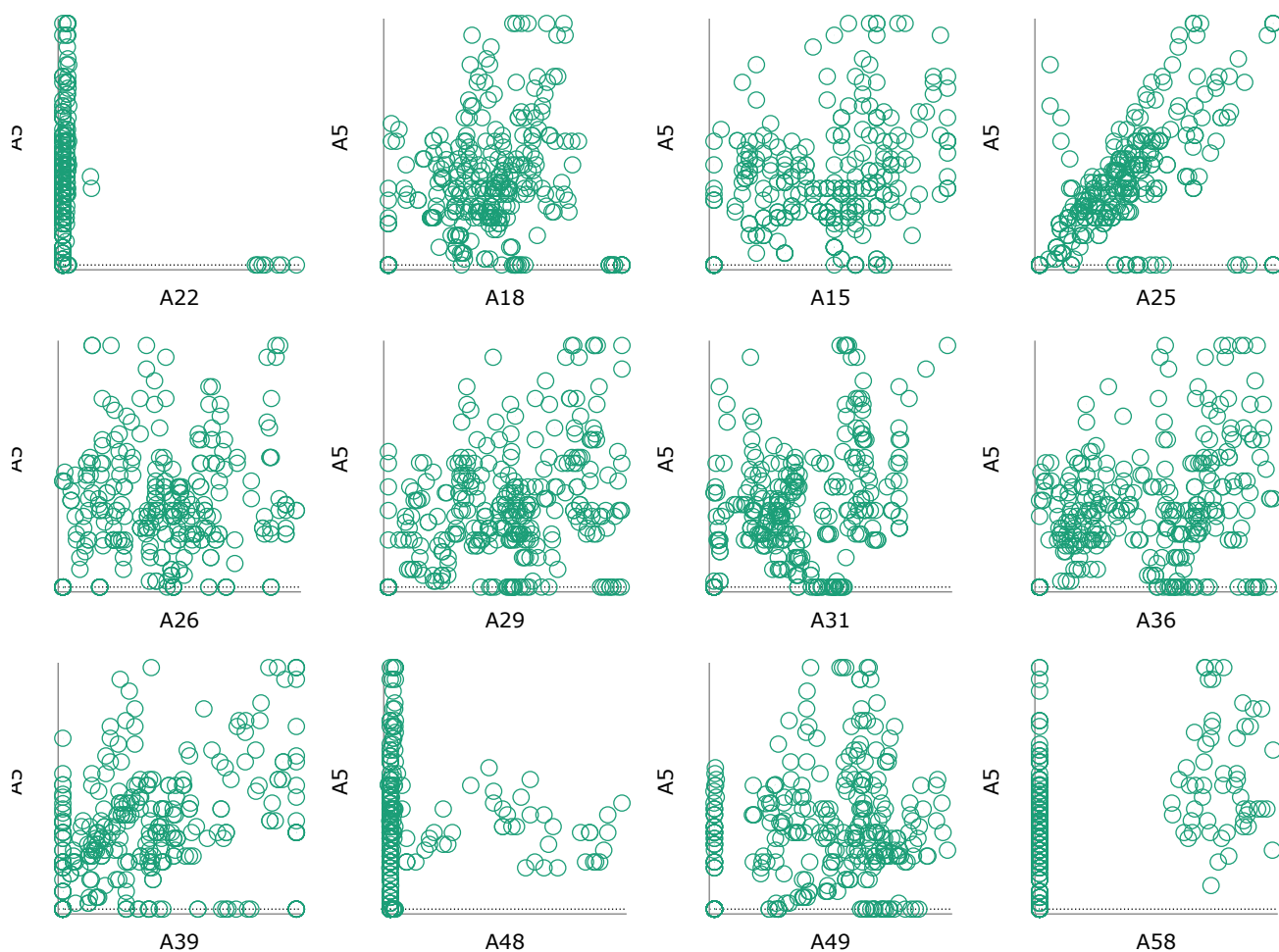
Analisi delle componenti principali
n = 360

Analisi degli autovalori della matrice di correlazione

Componente	Autovalore	Proporzione	Cumulata
1	6,5398	0,5031	0,5031
2	1,4193	0,1092	0,6122
3	1,2267	0,0944	0,7066
4	1,0484	0,0806	0,7872
5	0,6916	0,0532	0,8404
6	0,4933	0,0379	0,8784
7	0,4457	0,0343	0,9127
8	0,3546	0,0273	0,9399
9	0,2725	0,0210	0,9609
10	0,2296	0,0177	0,9786
11	0,1274	0,0098	0,9884
12	0,0984	0,0076	0,9959
13	0,0528	0,0041	1,0000

Autovettori (pesi della componente)

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A5	-0,252	-0,175	0,519	-0,083	-0,384	-0,080	-0,279
A22	-0,062	0,746	0,004	0,014	0,402	0,189	-0,026

A18	-0,325	-0,007	-0,188	0,022	0,178	0,025	-0,387
A15	-0,294	0,006	0,123	0,069	-0,195	0,850	-0,096
A25	-0,313	0,348	0,213	-0,008	-0,114	-0,233	-0,249
A26	-0,267	-0,330	-0,199	0,087	0,439	-0,097	-0,309
A29	-0,334	-0,069	-0,091	0,052	-0,030	-0,210	-0,178
A31	-0,334	-0,032	-0,119	-0,015	-0,197	0,010	0,568
A36	-0,360	0,029	-0,137	0,055	-0,056	-0,077	0,305
A39	-0,323	0,293	0,022	0,031	-0,129	-0,315	0,173
A48	-0,028	-0,101	0,208	0,925	0,140	-0,011	0,136
A49	-0,316	-0,227	-0,279	-0,203	0,191	0,147	0,173
A58	-0,115	-0,166	0,657	-0,276	0,548	-0,010	0,281
	PC8	PC9	PC10	PC11	PC12	PC13	
A5	0,321	0,041	-0,264	0,081	0,040	-0,464	
A22	0,264	0,219	-0,237	0,101	0,022	-0,239	
A18	-0,580	-0,345	-0,163	0,330	-0,155	-0,248	
A15	-0,008	0,035	0,299	-0,011	-0,039	0,177	
A25	-0,032	-0,296	-0,194	-0,342	0,164	0,579	
A26	0,589	-0,097	0,184	0,208	0,028	0,203	
A29	-0,240	0,840	0,007	-0,024	-0,088	0,157	
A31	0,137	-0,055	-0,415	0,415	-0,282	0,258	
A36	-0,090	-0,020	0,189	0,114	0,809	-0,185	
A39	0,072	-0,140	0,621	-0,096	-0,436	-0,229	
A48	-0,052	-0,033	-0,124	-0,156	-0,052	-0,075	
A49	0,052	-0,047	-0,262	-0,701	-0,099	-0,258	
A58	-0,221	0,025	0,099	0,056	-0,019	0,089	
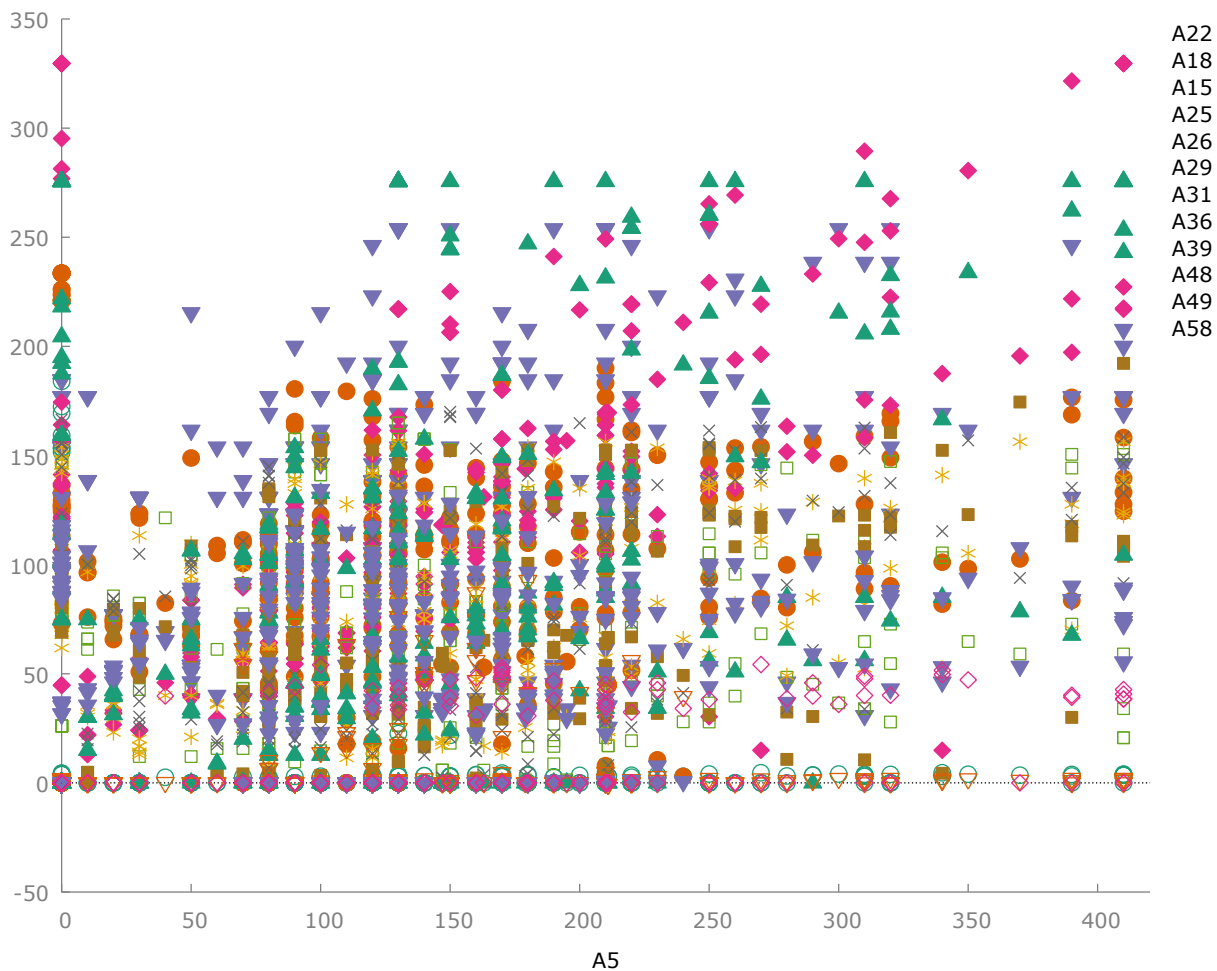
Statistiche descrittive, usando le osservazioni 1:01 - 36:10				
Variabile	Media	Mediana	Minimo	Massimo
A5	112,08	100,00	0,00000	410,00
A22	4,3792	0,00000	0,00000	183,97
A18	84,483	89,888	0,00000	233,51
A15	96,325	96,154	0,00000	253,85
A25	102,02	98,640	0,00000	329,62
A29	65,865	70,699	0,00000	156,33
A31	60,206	55,536	0,00000	192,21
A36	65,732	58,826	0,00000	170,01
A39	85,070	67,137	0,00000	275,59
A48	6,1413	0,00000	-0,76374	92,715
A49	52,107	54,227	-0,25937	134,39
A58	6,4516	0,00000	0,00000	54,230
Variabile	SQM	Coeff. di variazione	Asimmetria	Curtosi
A5	101,53	0,90581	0,79972	0,24640
A22	24,031	5,4875	6,4562	40,202
A18	61,263	0,72515	0,24491	-0,41895

A15	78,186	0,81169	0,19383	-1,1612
A25	84,060	0,82400	0,76051	0,18165
A29	48,645	0,73855	0,067354	-1,1580
A31	48,403	0,80395	0,29595	-1,0101
A36	53,789	0,81831	0,22152	-1,3515
A39	86,220	1,0135	0,88117	-0,28263
A48	18,346	2,9873	3,2151	9,3353
A49	41,619	0,79871	-0,029395	-1,4204
A58	15,399	2,3869	2,0294	2,2966
Variabile	5% Perc.	95% Perc.	Range interquartile	Osservazioni mancanti
A5	0,00000	310,00	170,00	0
A22	0,00000	4,0707	0,00000	0
A18	0,00000	184,03	85,907	0
A15	0,00000	238,08	161,54	0
A25	0,00000	269,24	113,18	0
A29	0,00000	145,41	82,152	0
A31	0,00000	146,72	96,837	0
A36	0,00000	155,39	98,825	0
A39	0,00000	275,59	130,58	0
A48	0,00000	56,015	0,85821	0
A49	0,00000	113,43	88,200	0
A58	0,00000	45,894	0,00000	0

serie storiche per gruppo
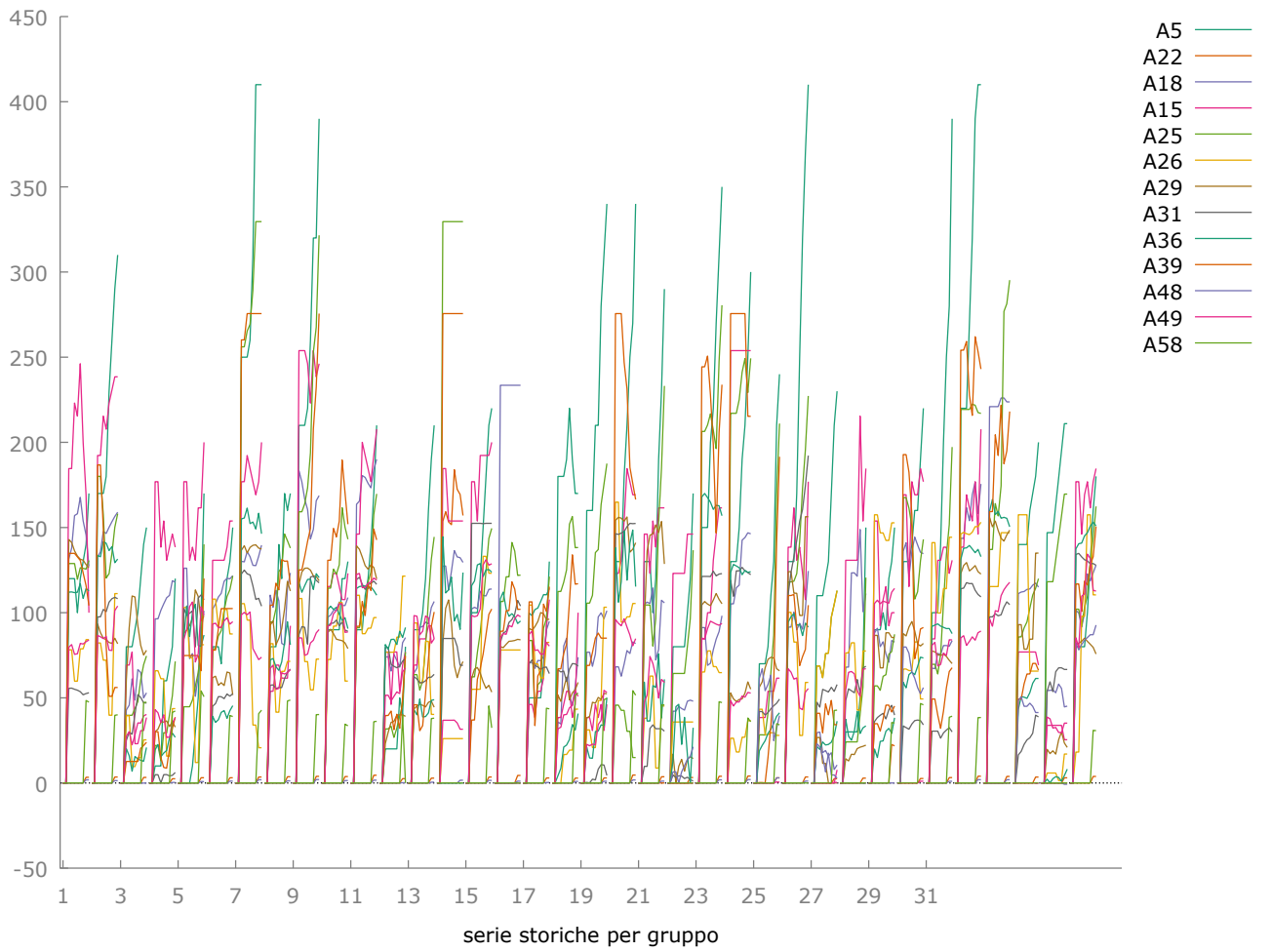
Matrice di correlazione
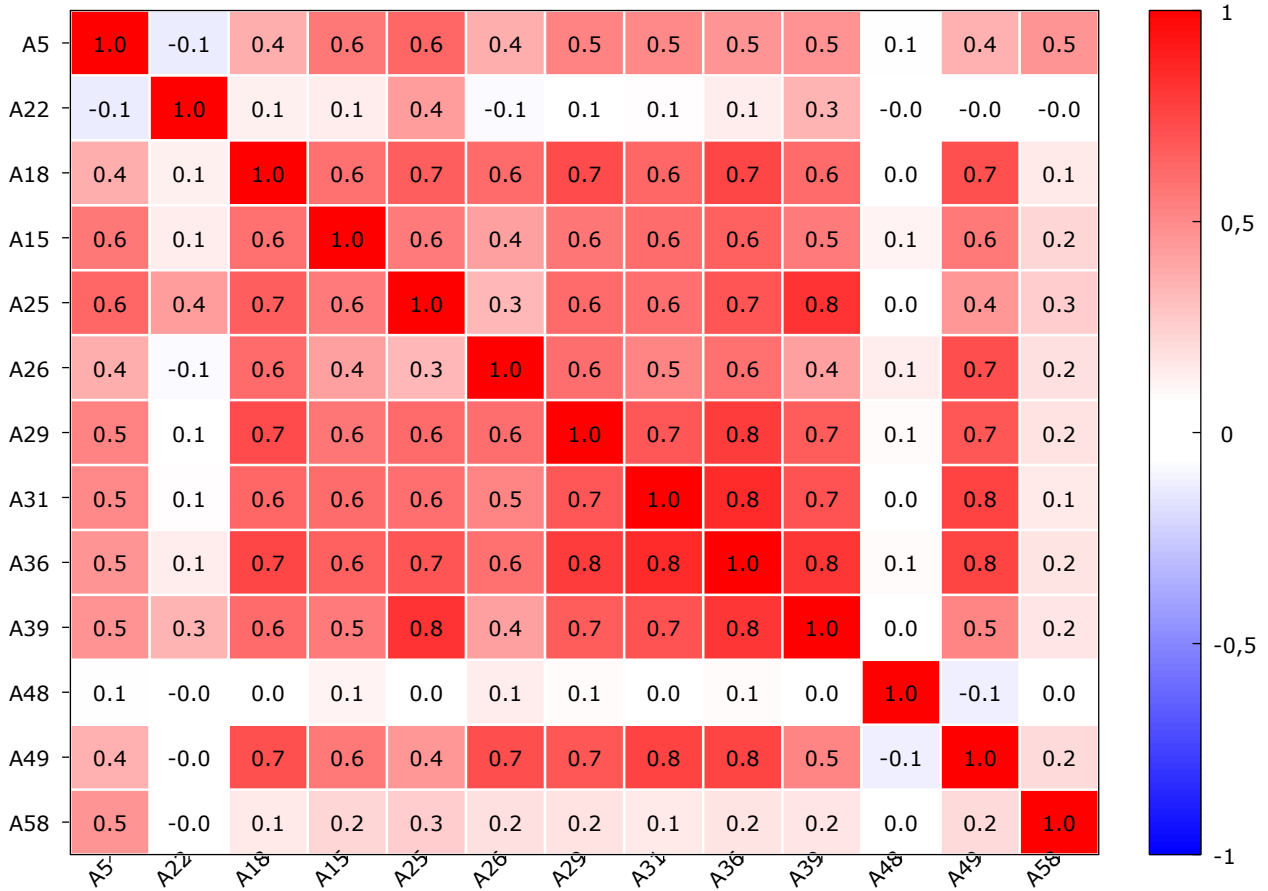
7.2 Clusterization
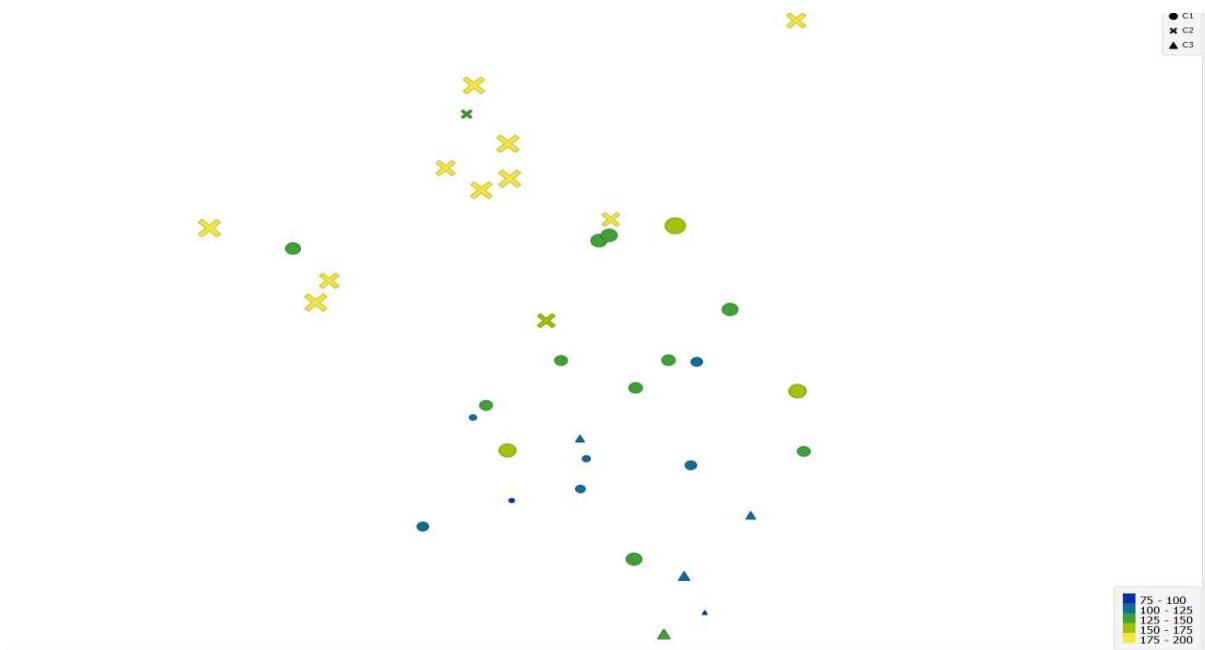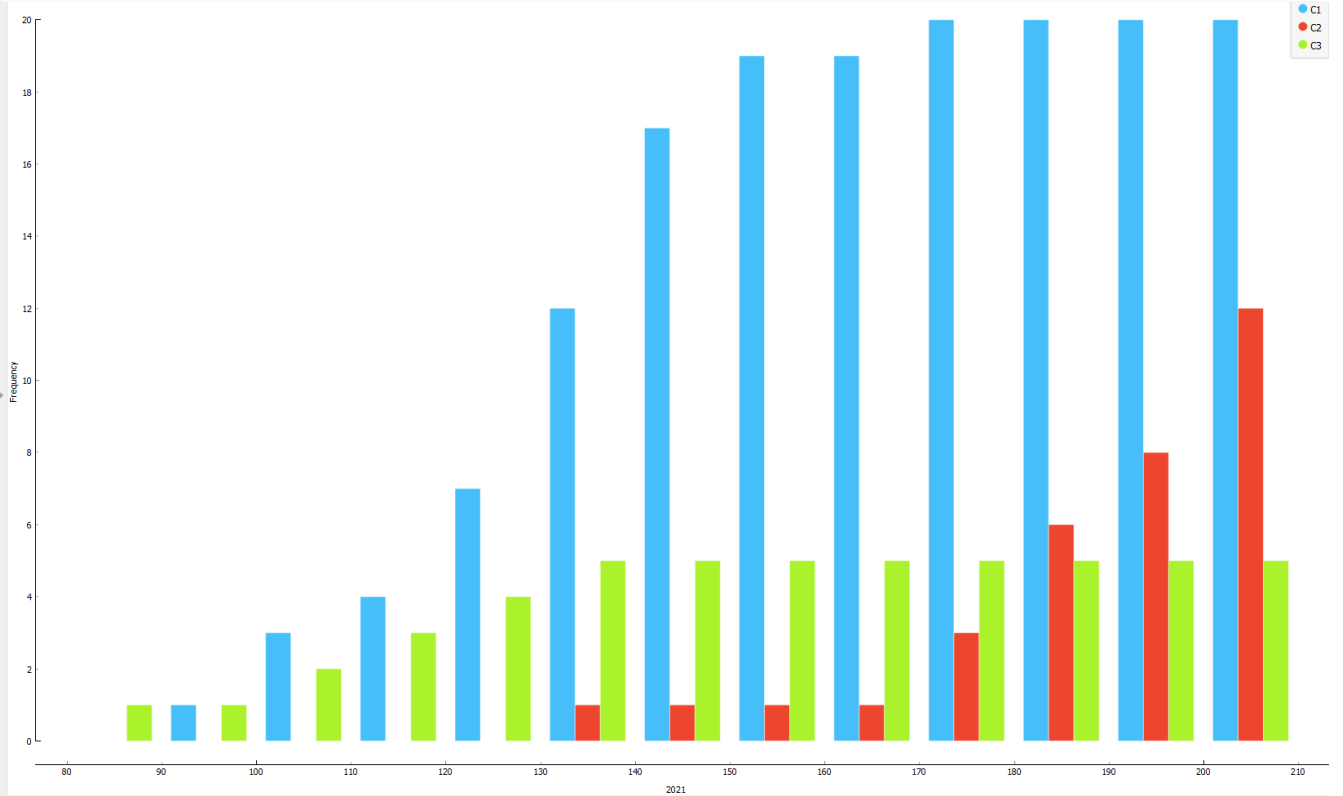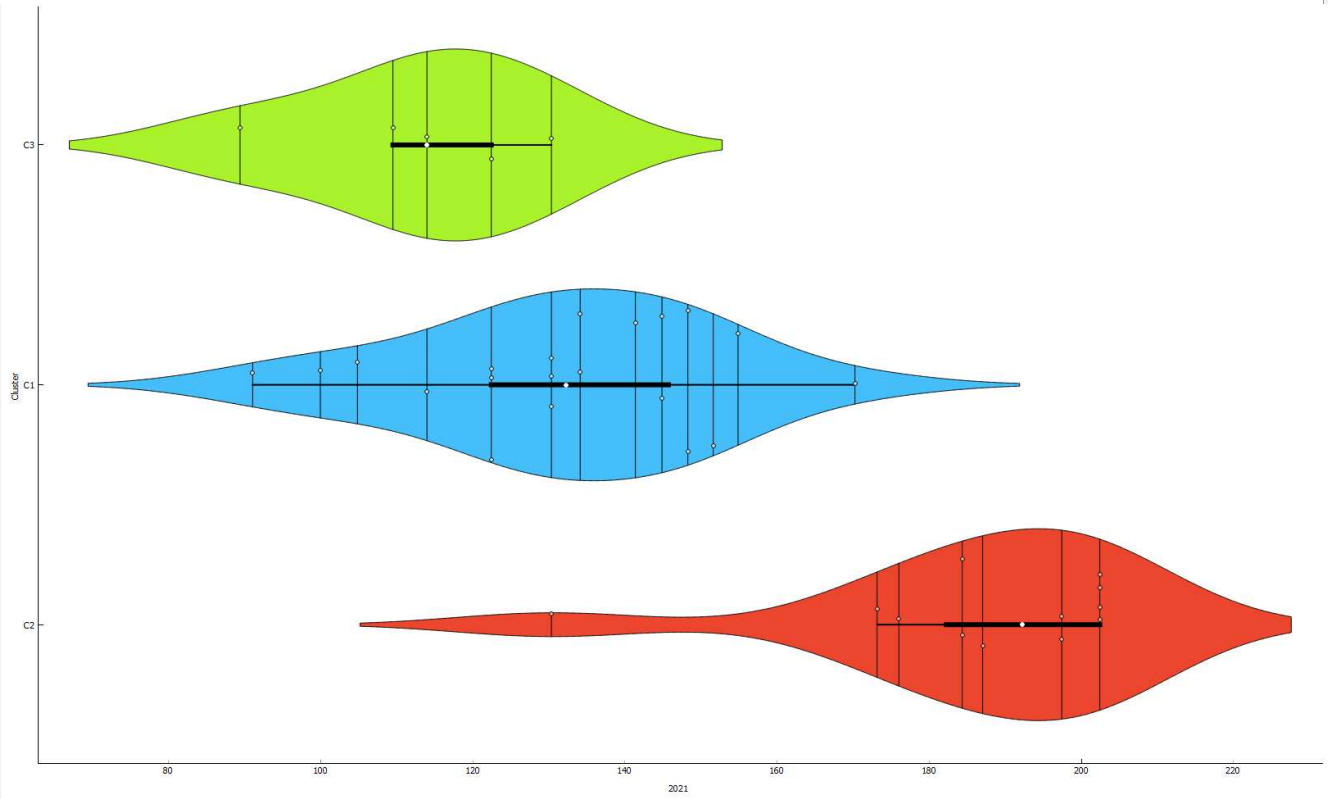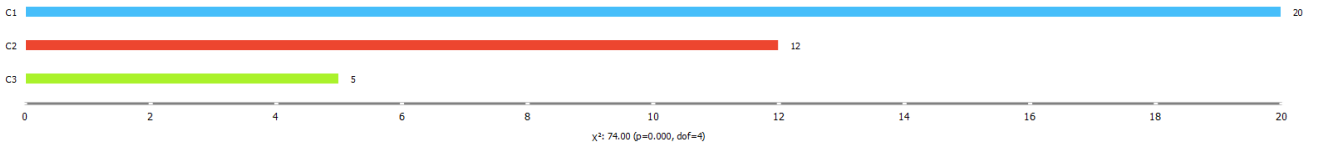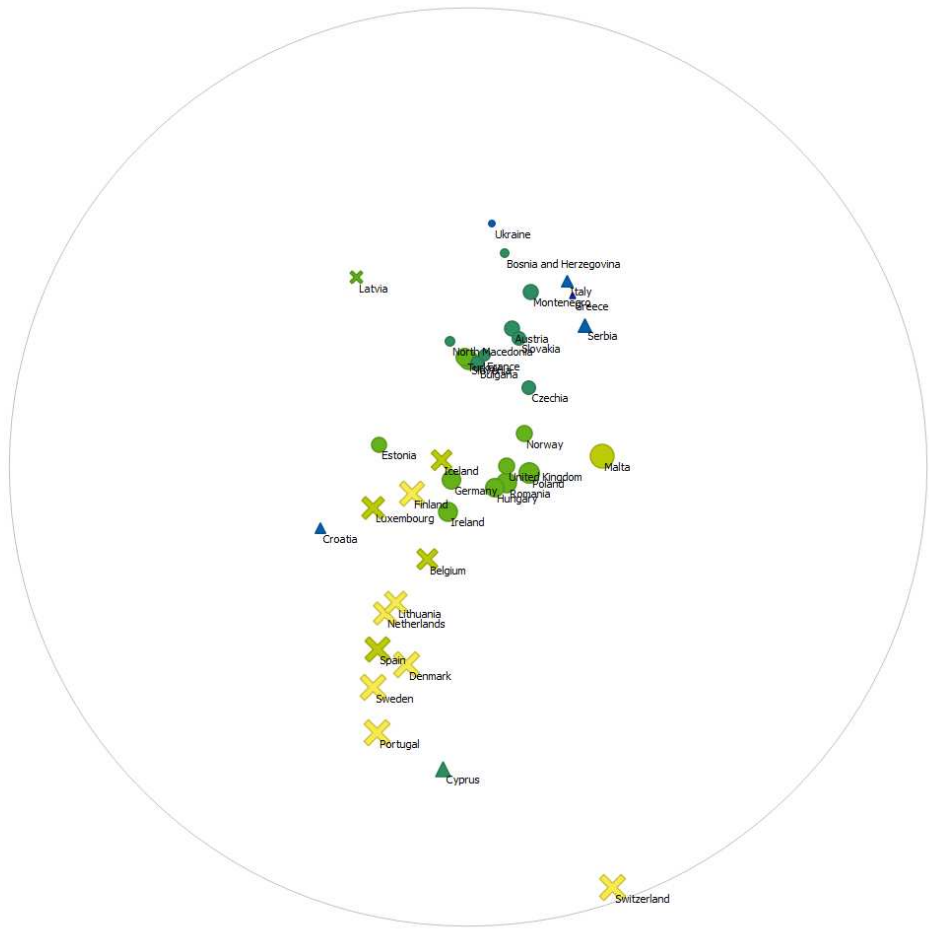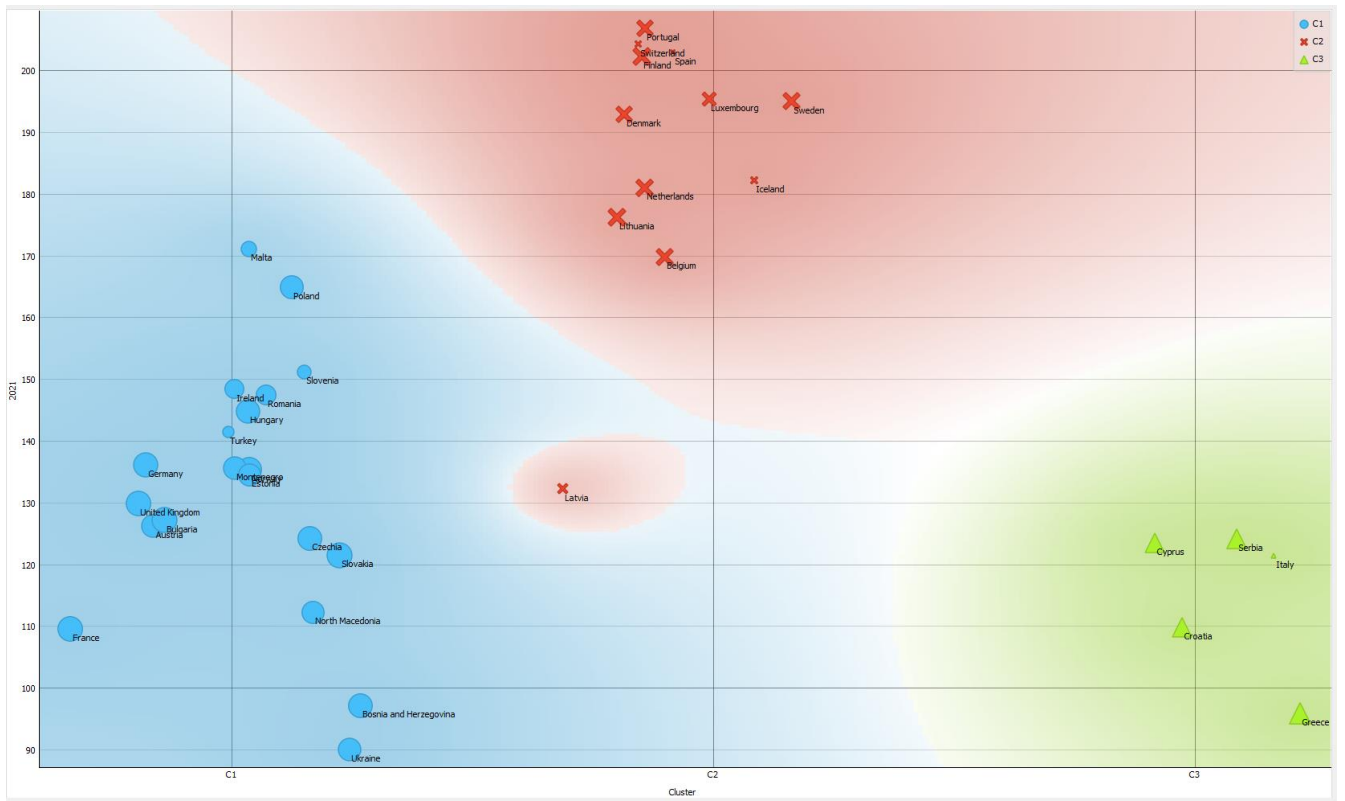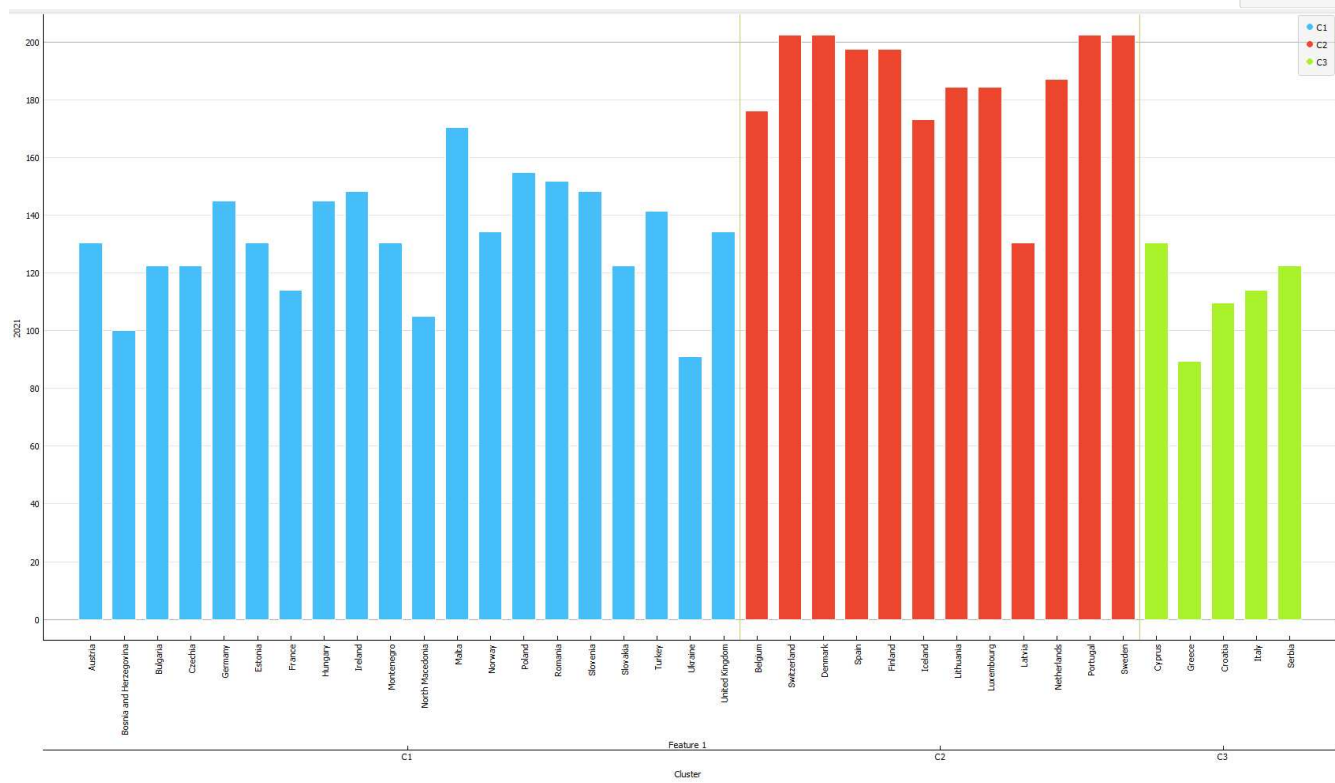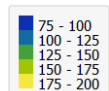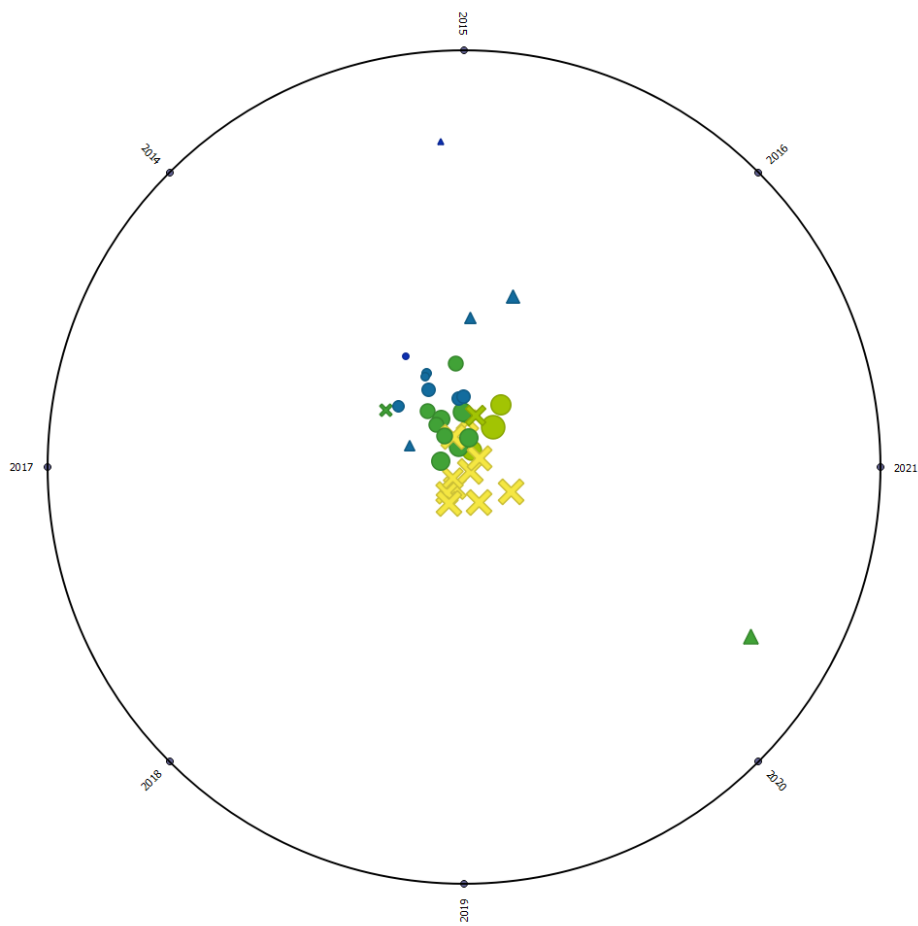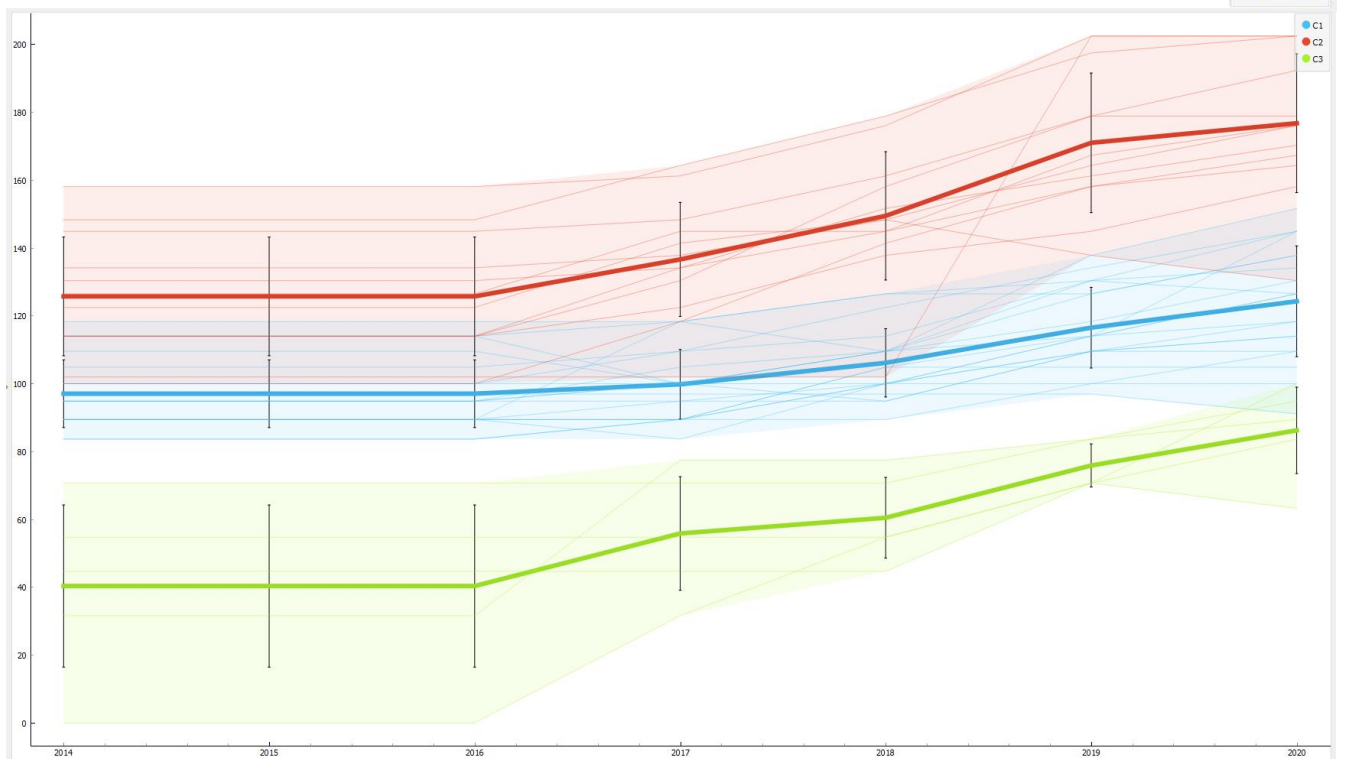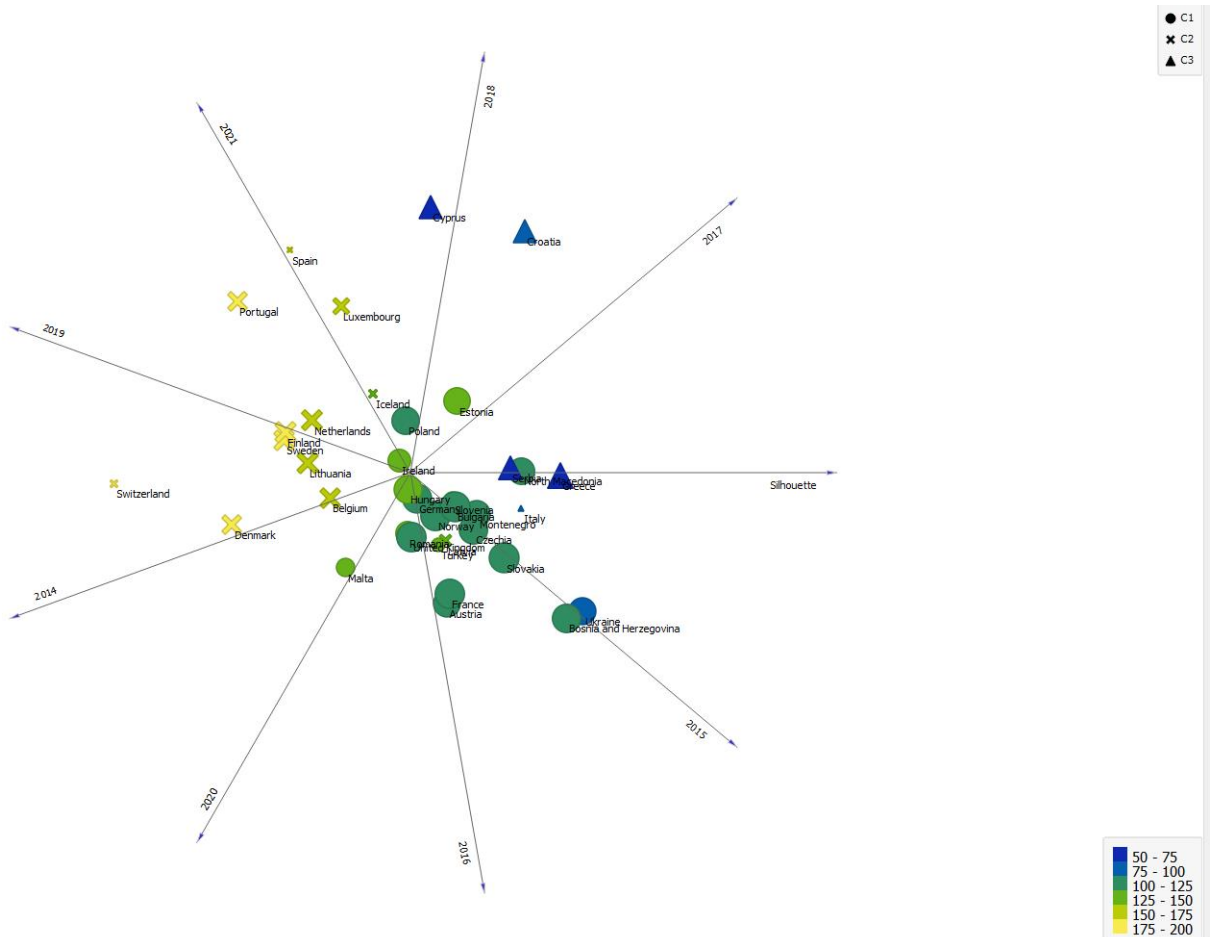
	2021	Feature 1	Cluster	Silhouette	2014	2015	2016	2017	2018	2019	2020
37	134.164	United Kingdom	C1	0.701575	89.4427	89.4427	89.4427	89.4427	100	114.018	126.491
36	91.1043	Ukraine	C1	0.680665	96.9536	96.9536	96.9536	96.9536	96.9536	96.9536	91.1043
35	141.421	Turkey	C1	0.568808	118.322	118.322	118.322	118.322	126.491	130.384	134.164
33	148.324	Slovenia	C1	0.59357	114.018	114.018	114.018	118.322	126.491	126.491	137.84
34	122.474	Slovakia	C1	0.704062	94.8683	94.8683	94.8683	100	94.8683	109.545	114.018
30	151.658	Romania	C1	0.651	104.881	104.881	104.881	109.545	114.018	130.384	144.914
28	154.919	Poland	C1	0.68278	83.666	83.666	83.666	89.4427	104.881	114.018	144.914
27	134.164	Norway	C1	0.701575	89.4427	89.4427	89.4427	89.4427	100	114.018	126.491
24	104.881	North Macedonia	C1	0.67468	83.666	83.666	83.666	89.4427	104.881	104.881	104.881
23	130.384	Montenegro	C1	0.680726	89.4427	89.4427	89.4427	89.4427	89.4427	100	109.545
25	170.294	Malta	C1	0.607852	114.018	114.018	114.018	100	109.545	137.84	151.658
17	148.324	Ireland	C1	0.644739	100	100	100	109.545	122.474	134.164	144.914
16	144.914	Hungary	C1	0.688867	94.8683	94.8683	94.8683	100	109.545	126.491	137.84
8	144.914	Germany	C1	0.696346	94.8683	94.8683	94.8683	104.881	109.545	118.322	130.384
14	114.018	France	C1	0.70175	94.8683	94.8683	94.8683	94.8683	94.8683	109.545	109.545
10	130.384	Estonia	C1	0.674277	89.4427	89.4427	89.4427	118.322	109.545	130.384	126.491
7	122.474	Czechia	C1	0.691607	89.4427	89.4427	89.4427	83.666	100	109.545	114.018
4	122.474	Bulgaria	C1	0.702373	89.4427	89.4427	89.4427	94.8683	100	109.545	118.322
2	100	Bosnia and Her...	C1	0.693818	100	100	100	100	100	100	100
1	130.384	Austria	C1	0.679029	109.545	109.545	109.545	100	109.545	114.018	118.322
5	202.485	Switzerland	C2	0.530825	101.98	101.98	101.98	101.98	101.98	202.485	202.485
32	202.485	Sweden	C2	0.654816	148.324	148.324	148.324	164.317	178.885	197.484	202.485
12	197.484	Spain	C2	0.512998	100	100	100	118.322	141.421	158.114	167.332
29	202.485	Portugal	C2	0.646199	114.018	114.018	114.018	130.384	158.114	178.885	192.354
26	187.083	Netherlands	C2	0.660178	122.474	122.474	122.474	141.421	148.324	164.317	176.068
21	184.391	Luxembourg	C2	0.618379	114.018	114.018	114.018	134.164	144.914	158.114	164.317
20	184.391	Lithuania	C2	0.662973	126.491	126.491	126.491	144.914	144.914	167.332	176.068
22	130.384	Latvia	C2	0.574488	134.164	134.164	134.164	137.84	148.324	137.84	130.384
18	173.205	Iceland	C2	0.539233	114.018	114.018	114.018	122.474	137.84	144.914	158.114
13	197.484	Finland	C2	0.662329	144.914	144.914	144.914	148.324	161.245	178.885	178.885
9	202.485	Denmark	C2	0.647816	158.114	158.114	158.114	161.245	176.068	202.485	202.485
3	176.068	Belgium	C2	0.657884	130.384	130.384	130.384	134.164	151.658	161.245	170.294
31	122.474	Serbia	C3	0.652859	54.7723	54.7723	54.7723	54.7723	54.7723	70.7107	83.666
19	114.018	Italy	C3	0.503911	70.7107	70.7107	70.7107	70.7107	70.7107	83.666	94.8683
11	89.4427	Greece	C3	0.666662	44.7214	44.7214	44.7214	44.7214	44.7214	70.7107	63.2456
6	130.384	Cyprus	C3	0.646983	0	0	0	31.6228	54.7723	70.7107	100
15	109.545	Croatia	C3	0.646792	31.6228	31.6228	31.6228	77.4597	77.4597	83.666	89.4427

Value of Median for the Clusters

197,48

132,08

118,25

	MEDIAN
C2	197,48
C1	132,08
C3	118,25

7.3 Machine Learning and Predictions