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The Determinants of Human Resources in European Countries During the Period 2010-2019

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ABSTRACT: We analyze the determinants of the "*Human Resources*" in European countries during the period 2010-2019. The variable "*Human resources*" is considered as a proxy for human capital. We use a dataset from European Innovation Scoreboard that analyze 36 countries. Data are processed using panel with fixed and random effects, pooled OLS, WLS and dynamic panel.Theliterature relative to human capital and human resources is analyzed considering that the usage of Artificial Intelligence and automation can transform the workforce into a "useless class". Results show that the variable "*Human Resources*" is positively associated with the sequent macro-variables "*Attractive Research Systems",* "*Education*", "*Innovation Index*", "*Linkages*", "*Performance and Structure of the Economy*" and negatively associated with "*Finance and Support*", "*Governance and Policy Framework*", "*Innovators*", "*Intellectual Assets*" and "*Sales Impact*".

I. INTRODUCTION

In this article we consider the role of human resources. Human resources are considered as a proxy for human capital. The relationship between human capital an economic growth is essential to understand the question of innovation(Leogrande, et al., 2020). Human capital is relevant either for the purpose of the economic growth theory either for the definition and analysis of innovations. The two elements finally coincide since the accumulation of capital seems not able to explain therelationship between the development of economic system and the development of technology. Especially in the western economies, the large accumulation of capital is not able anymore to sustain large Gdp growth either in the short and in the long run. This has created the premise for the adfirmation of the secular stagnation hypothesis i.e. the idea of a prolonged period of low economic growth and low inflation rates. To escape from the trap of low Gdp growth it is necessary to increase the production and investment in innovations and technologies. Innovations and technologies can improve the degree of potential output creating the conditions for a sustained Gdp growth. Human capital is essential to create innovation, technology, knowledge and research and development in the traditional framework of economic growth especially in the theories of endogenous economic growth. Economic growth models and the economics of innovation are both centered in human capital and human resources. But the centrality of human capital and human resources for the economic growth is questioned by the rising role of artificial intelligence. In effect in the future artificial intelligence either in its application in the industrial sector, either in its implementation in the service sector, can reduce the role of human capital and human resources. Artificial intelligence, especially in the version of "*super-intelligence*" (Tegmark, 2017)will be able to produce knowledge, innovations and technologies that can replace the role of humans either in the sense of human resources either in the sense of human capital. The role of humans as workforce and in their ability to contribute to the benefit of firms and society is at risk with the adfirmation of artificial intelligence. Humans risk to become redundant, meaningless, useless. The useless of humans for the economic systems reduce the incentives to invest in human capital and human resources as a tool to boost economic growth.

In effect if the productive system has no convenience in the employment of humans to generate technology, innovations, knowledge then and also private and public investments in human resources and human capital, that are essentially investments in education and training, can be reduced. Artificial intelligence can actively participate in the process of generating innovation, technology and knowledge, either professionally and scientifically, and can create the premise for the redundancy of humans in the economic and productive system.

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But, our analysis, is based on data that are geographically determined i.e. 36 European countries[4] in a specific period i.e. 2010-2019. Data are collected from the European Research and Development Scoreboard (Scoreboard, 2019).

In Solow growth model (Solow, 1956) the role of human capital is essential either for the labour either for knowledge and technology. But the development of artificial intelligence, especially in the form of super-intelligence can make the labour irrelevant and the variable knowledge more associated to financial and technological capital than to human capital. Artificial intelligence can reduce the role of labour either in the industrial and in the service sector.

The role of human capital is associated to a more productive economic system that is more devoted to boost innovation and technology through the Research and Development(Leogrande, et al., 2020), and also through learning by doing and tacit knowledge. But the role of human capital is also crucial to generate social capital that is associated to an increasing level of trust of citizens in institutions and in the economic system as a whole. Social capital is essential to generate some conditions that are essential for the development of resilient institutions that are able to sustain efficient economic growth. Human capital has a twofold function:

- **An innovational impact:**it enforces the role of innovations and technology increasing the possibility for economic growth and development. Human capital also in the Solow Model has the ability to impact on two of the three elements of the economic growth that are knowledge and labour. Human capital has the ability to improve the level of potential output, to increase the productivity of the firms and to improve the technological change with also positive impacts in boosting the competition among entrepreneurs in investing in new products and goods, even if too competitive markets are associated to lower levels of innovation. The contribution of human capital in the sense of innovation, with its ability to increase the knowledge and labour variables in the Solow's model equation, can be measured either formally either informally. On a formal point of view the impact of human capital can be metrically estimated analyzing the presence of patents and intellectual propriety rights that are generated either by corporations either by public institutions focused on research and development. But not all the innovations are effectively technological innovations. There are non-technological innovations that are able to improve the productivity of the firms through changing in organizational forms, through marketing and in the management of resources either material either immaterial. The complex set of technological and non-technological innovation, that create knowledge feasible to the ends of productivity, is generated by human capital, in its creative, professional and scientific contribution to the economic productivity process of the firm. But human capital can only partially be analyzed based on the valuable outputs that are realized in the sense of propriety rights and patents or modification that are improved in the organizational, managerial or marketing framework. Human capital has also immaterial values that are difficult to consider metrically and among these characteristics there are two that have been recognized as essential to promote the economic growth through innovations: learning by doing and tacit knowledge(Polanyi, 2009). The two definitions can be in a certain sense considered as convergent for the fact that learning by doing is based on tacit knowledge. But there is difference among learning by doing and tacit knowledge in the sense of distribution: while on one side learning by doing can be distributed and communicated at least empirically with educational tools based on the model of training and errors, on the other side tacit knowledge is defined as untransferable knowledge. But, even with these differences, either learning by doing either tacit knowledge can effectively be produced only with the empowerment of human capital. The complex process that creates innovation in firms and corporations is based on human capital. Firms, corporations, public and not for profits organizations have the possibility to improve the degree of innovation applied in their productive processes empowering human capital. The process of servitization and informatization of the economy has created the conditions to evaluate the contributions of human capital especially in the sense of the immaterial outputs that humans are able to implement and produce with creativity, scientific and professional knowledge. The question of knowledge, in its connections with innovations, has acquired a prominent role in the context of economic growth and economic development.
- **An institutional impact:**human capital has the ability to boost the social capital and the creation of institutions more oriented to innovation. As in the Schumpeterian theory, the possibility to create more innovative economic system is not only based on technology, but it is also connected with the idea of institutional change (Schumpeter, 2013). The role of institutions in promoting innovation, research and development, technological change and entrepreneurial activism, has been recognized in the Schumpeterian theory. A more developed human capital has the ability to boost social capital, and social capital can actively operate as a force for the institutional and political change. Western liberal democracies have developed

[4]The countries are Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finlandia, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Spain, Sweden, Switzerland, Turkey, Ukraine, UK.

institutions that are more open to innovation, technological improvements and scientific discoveries. In this sense there is a positive and recursive relation between institutions that are able to enrich the human capital and the ability of human capital to enforce social capital able to sustain pro-innovation institutions and economic growth (Acemoglu, et al., 2014). Social capital has the ability to improve the degree of trust in a certain legal and political order, and can operate as a force to introduce legislation more oriented to innovation. The degree of innovation at a country level can be affected by the presence of institutions that have the ability to create fiscal incentives to promote the development of human capital and social capital. Institutions promote innovation. Social capital has the ability to improve the efficacy of institutions. Human capital is the main driver to improve a pro-innovation attitude in social capital. This relationship among human capital, social capital and institution can be virtuous, indifferent, or vicious in the sense of innovation. The relation is virtuous in the case in which well skilled and professionalized human capital promote an increasing awareness in social capital about the necessity of innovation for economic growth and development, and as a consequence social capital makes political and cultural pressures to implement more pro-innovations policies and financial programs. But in certain circumstances this tripartite relation is not able to promote any significative impact on institutional change in the sense of innovation: this is the case of economic systems that are not devoted to innovation as a tool for economic growth and is the case of countries of new industrialization. In other cases, the tripartite relationship has a negative impact in the sense of innovation: this is the case of countries in which there is a negative scientific and professional environment and in which a low empowered human capital generate a society with low sensibility for innovation with an scarce impact on the creation of pro-innovation institutions.
But human capital is also a driver for the creation of a class of entrepreneurs that are either able to innovate in their productive processes, either are able to apply new technologies and to perform partnerships with research centers and research institutions. Entrepreneurs have a particular role in the process of creation of the human capital. In fact, on one side entrepreneurs have the necessity to compete in the market and hire qualified human capital with innovative orientation while on the other side entrepreneurs participate actively in the creation of that social capital that is crucial to promote pro-innovation policies and institutions.

Human capital is able to sustain either the process of innovation in technology and organizations, either the process of institutional change. Either the private and public response to the question of innovation is based on the quality of human capital. But while the relationship between human capital and innovation is more direct, since innovation can be considered effectively as the output of the human capital, on the other side the relationship between human capital and the process of institutional change is indirect and mediated by the role of social capital.

The development of information science has had a huge impact in the creation of the "*knowledge economy*" that is an economy in which the entire process of production is based on science, technology and professional skills. The question of skills is of increasing relevance for the fact that skills are changing and differentiated among different degrees from hard to soft skills. Human capital, and human resources considered as workforce, determine a process of production that is oriented to various forms of lifelong learning, that is based on the continuosly process of acquiring new information and knowledge that can be used in the productive system. But, the process of lifelong learning is not a force that can be realized only with the usage of human capital, it requires also political institutions that have the ability to invest in the sustaining process of lifelong learning and also a social capital. The complex set of hard and soft skills that human capital has to acquire to participate in the productive process, requires a deeper awareness about the possibility to use knowledge as a tool to innovate in private corporation and public institutions either in technological and in non-technological sense.

But as we argued before, either theoretically and either empirically, the role of human capital and human resources in the future will be marginal, especially in the process of creation of knowledge and innovation. Generally, the labour share on wages is decreasing in many developed countries due to the combination of automation and artificial intelligence. But especially in the future artificial intelligence will produce knowledge in more efficient way in respect to humans. Artificial intelligence will reduce also the employment in creative, professional and scientific tasks creating the premise for the transformation of workforce in "*useless class*" (Harari, 2014). The despotic vision of a future in which humans are marginal in the sense of production of economic product and services can be considered as an exaggeration by tech-enthusiasts. But, in the end, artificial intelligence and automation, and in general the complex set of technologies of the fourth industrial revolution seems to make an interesting promise to entrepreneurs and managers: the possibility to expand productivity without employing humans. The dream of corporations completely devoted to the generation of economic value and at the same time free from any kind of conflict among workers, managers and shareholders, seem to be realized with artificial intelligence and automation. But, if the hypothesis of the creation of a "*useless class*" (Harari, 2017) turns true at least partially, the consequences for political institutions and managerial choices will be that of reducing the financial efforts to enrich human capital.

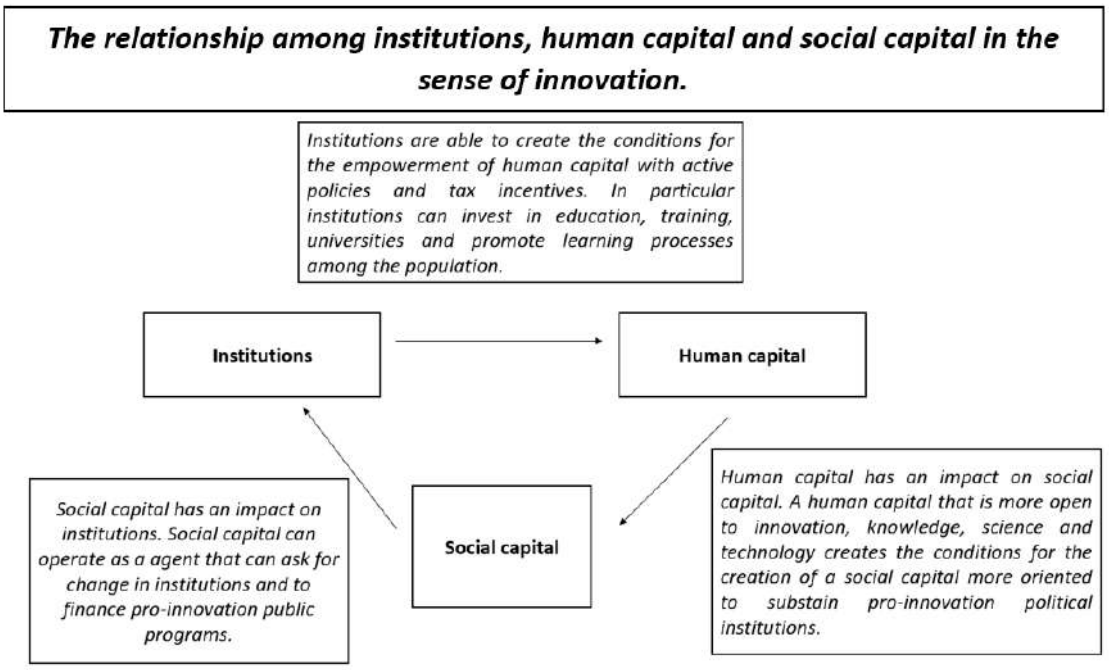


Figure 1. Relationship between Institutions, Human Capital and Social Capital in the sense of innovation. The case of the virtuous cycle.

The theory of economic growth, either in their neoclassical framework i.e. based on the model of Solow, either in its schumpterian approach, has recognized the relevant role of human capital in creating knowledge and in boosting innovation through technological change, institutions and entrepreneurs. But, the same development of innovations, especially in the sense of information science and in the context of artificial intelligence and automation, has reduced the actual and future value of human capital and human resources in the productive system. The development of artificial intelligence and automation can create a capitalism and market economy free from workforce with an increase in productivity and social inequality. But artificial intelligence can also create a sort of "*artificial knowledge*" i.e. a knowledge that is not produced by humans but that is produced with the usage of algorithms. The passage from "*human knowledge*" to "*artificial knowledge*" can create a depreciation of human capital and can offer incentives to reduce the investments in education, training, universities and research. This depreciation of human capital can have also negative impact on social capital, reducing the level of trust in liberal-democracies and can create deeper inequalities in the sense of knowledge. The adfirmation of liberal-democracies has created the conditions to the democratization of knowledge, innovation, research and development. But the adfirmation of "*artificial knowledge*" i.e. the knowledge generated through artificial intelligence creates the conditions for a more hierarchic society, with high concentration of knowledge in small elitist centers, and the increasing widespread inequalities. While, on one side the role of knowledge, innovation and technology still remains relevant for the purpose of economic growth, on the other side the role of humans, either in sense of capital either in sense of resources, will be depreciated, in the best hypothesis, and annihilated, in the form of the "*useless class*", in the worst case.

The development of technological innovations challenges the question of human capital and human resources in a paradoxical way. In effect human capital and human resources are essential to generate technological innovations. But once that technological innovations are created, especially in the form of artificial intelligence and automation, humans become redundant and their contribution to the productive system become marginal. Human capital and human resources are actually employed, especially in the high-tech sector, to produce innovations that will create large and massive unemployment in the future. Governments and corporations, are operating toghether in financing the transition to artificial intelligence and automation, and to create new kind of knowledge i.e. "*artificial knowledge*" while human capital and human resources experience increasing inequality and a decline in the labor share of the economy.

The article proceeds as follow: the second paragraph presents the literature review; the third paragraph introduces the estimated model; the fourth paragraph contains the conclusion; the appendix presents the results of the metric analysis, the definition of the model in extended and implicit form, graphs and correlation matrix.

II. LITERATURE REVIEW

Innovation and human capital. In the future artificial intelligence could change the role of human capital and human resources but in the short period the role of humans remains important especially in the sense of creation of new discoveries and application in science and technology. (Mahroum, 2007)argues that the ability of countries to develop systems of human resources able to gain competitive advantages at an international level is based on national components that characterize the inner market such as for example the offer and demand of qualified human capital and the presence of public policies and legislation that are able to increase the presence of human capital. The ability of firms to be competitive in international market exporting goods that are characterized by a high degree of innovation and technology and the possibility to strengthen the relationships also with scientific institute and programs is positively associated with a national market characterized by the presence of qualified human capital and by a legislation favorable to the empowerment of human capital.

(Crook, 2011) argues that the investment in human capital is positively associated with the presence of high corporate performance. Corporations that have more qualified human capital have also the ability to perform better in the market. But corporations and institutions have to invest in human capital in order to obtain the benefits associated with the presence of high skilled employees. The authors analyze 66 studies to investigate if the presence of more qualified human capital is effectively associated to more efficient performance in firms and corporations. Authors found that effectively the presence of qualified human capital is associated to better performance of corporations and productive organizations especially for that skills and competencies that are not feasible in the market and controlling the efficiency in a non-strictly profitable dimension.

(McGuirk, et al., 2015) develop a model to evaluate human capital at a metrical level in order to consider the impact of Innovative Human Capital in innovation and growth expressed in terms of jobs, sales and productivity. This new definition of Innovative Human Capital is based on four elements that are: education, training, willingness to change in the workplace and job satisfaction. The main objective of the author is the fact to test that Innovative Human Capital is associated to more innovative firms. But there are limitations in the usage of this particular index. Innovative Human Capital seems to be more valuable for small firms that have less than 50 employees than for larger firms with more than 50 employees. Authors with the usage of Innovative Human Capital have the possibility to analyze better the conditions that generate deep innovation in the context of small firms. Authors try to solve the question of how to evaluate metrically the development of innovation. In the literature are present many indexes that can be used to evaluate innovation such as for example the European Human Capital Index and the Index of Innovation. But in both these indexes there is no evidence of an explicit role of the human capital. Authors have tried to fill this gap introducing the Innovative Human Capital. Generally, in the context of innovation, the human capital is evaluated in the sense of formal education. But formal education is insufficient to evaluate the human capital.

The evaluation of human capital in the sense of innovation is a relevant tool, since innovation is in general associated to an improvement in human capital and technology. But also, technology needs human capital to change the productive system and to generate new products and services. Innovation needs human capital but the development of artificial intelligence can change the role of human capital in the innovation process, since in the future artificial intelligence could use technology to innovate and generate knowledge. The usage of artificial intelligence can reduce the usage of human capital in innovation processes.

(Baldwin & Johnson, 1995) analyze the ability of small and medium sized firm to improve the human capital condition through training. The authors use data from Statistics Canada that can be used to control for the ability of firms to train employment. There is a positive relationship among human capital, training and innovation and technological change. Corporations that gives importance to research and development, technologies and innovations have greater probability to invest in training and by this way to develop a more capable human capital. Corporations that are more sensible to human-resources have also greater probability to invest more in human resources. Technology, innovations and human resources are generally associated in corporation that apply the tools of knowledge management and that operate in the knowledge economy. But training is not the only tools in the knowledge management. Generally, when firms and corporations have a deep knowledge orientation develop also tools and strategies to improve the role of innovation, technology and human capital. Other general signal of the diffusion of training program is the orientation of the corporation towards quality. Corporations that are more devoted to pursue the end of quality have also greater probability to develop training programs for their employee. Authors find that all the four typologies of innovative compensation prototypes i.e. The General Innovator, the Passive Adapter, the R&D-Driven Innovator and the Outward Oriented Innovator tend to implement training programs for their employees. The enrichment of human capital is a strategy that characterize firms and corporations in their attempt to increase innovation, technology, research and development and quality goals. It is not possible to separate the choice to train

employee from the choice to pursue strategic objectives i.e. research and development, innovation, technology and quality.

Human capital and immigration.(Singer, 2014) analyzes the relationship between investing in human capital and improving the conditions of immigrants. The author considers the economic condition of many U.S. communities in the aftermath of the Great Financial Crisis of 2007 and finds a solution to the question of economic growth in increasing the level of human capital especially for immigrants.Metropolitan areas have more opportunities to build the capacity to invest in human capital. Firms and economic organizations can realize partnership with educational institutions to increase the level of human capital and specially to improve the knowledge and professional skills of immigrants. A particular role in the process of improving the condition of immigrant is constituted by the presence of partnerships between corporations and non-profit educational institutions. The non-profit sector can create the conditions to solve the question of the training and education of immigrant workers. In the development of strategies to improve the condition of workers a relevant role has to be recognized to community colleges. In effect community colleges are able to offer new possibilities for training and education especially for immigrants. The author suggests to improve on a regional scale the diffusion of community colleges especially in areas that are characterized by the presence of large immigration.

University and human capital.(Abel & Deitz, 2012)analyze the relationship between the presence of colleges that perform research and development activities and the impact on the human capital on a geographical basis. The authors find that academic R&D activities are associated to increases in human capital levels. There is a positive effect between the development of Research and Development activities and the qualification of human capital. Authors find also a positive relationship between the presence of higher education institutions and the employment of human capital in high skilled occupations. Authors conclude that colleges and universities can increase the level of human capital. The existence of a nexus between colleges and universities and human capital can shed light on the presence of policies that are able to increase the productivity of a certain area. The servitization, informatization and intangibilization of the economy create the conditions to remunerate better high skilled human capital. The possibility to reinforce human capital with the creation of universities and educational institutions offer a solution to the problem of developing strategies to reinforce human capital. The main point of the authors is the fact that while degrees are not associated to increasing level of human capital, research and development activities realized in colleges and universities have effectively the ability to increase the level of human capital. The greater the activism of colleges and universities in the research and development the higher the presence of human capital occupations. The presence of colleges and universities that are able to produce higher human capital is associated to more innovative economies characterized by the presence of technologies, star-ups, tech businesses and organizational application of mathematical and scientific knowledge. The presence of these connections among universities and colleges, business, technology and human capital can have a relevant effect in promoting local economic development. The final suggestion of the author for policy makers is to improve the research and development activities realized in colleges and universities since these are associated to a higher level of human capital formation and occupation. The spillover between R&D activities in colleges and universities is associated to an increase in local demand for skilled labor.

Human capital, cognitive abilities, economic growth and development.(Rindermann, 2008) analyzes the relationship between Gdp growth and the level of cognitive abilities as a proxy for human capital. The author considers two essential relations: the positive relationship between the presence of positive cognitive abilities and the educational system and the presence of a positive relationship between cognitive abilities and Gdp growth. The author controls also the relationship among intelligence, education and economic freedom and founds that the effects on economic freedom are lower than the effects of Gdp growth. The relationships among intelligence, education and economic growth are two way in the sense that not only intelligence and educational degrees have a positive effect on Gdp growth but also Gdp growth has a positive effect on cognitive abilities and educational degree. These relationships are effectively able to represent and describe the modifications of the economic system that is more oriented to productive systems that are more associated to knowledge, innovations, technologies and intangible assets and in which the cognitive abilities and the educational levels are effectively relevant to generate value added in the sense of Gdp growth.

(Hanushek & Woessmann, 2008) question the relevance of human capital and education in the process of economic growth and economic development. The presence of investments in the schooling has not created an adequate and expected impact in terms of gpd growth and economic development. The authors analyze the role schooling in boosting economic well-being. Schooling is considered either in a quantitative either in a qualitative dimension. It is proposed a distinction between the presence and diffusion of effective skills among the population and the presence of schooling. While it is clear the existence of a positive association between the presence of skills and the presence of Gdp growth, the positive relationship between Gdp growth and schooling remains obscure. The presence of cognitive skills among the population is associated to individual earnings, distribution of income, and economic growth. What authors criticize is the existence of an identity between the

acquisition of skills among the population and schooling. While skills are clearly associated with Gdp growth and development the positive relationship between schooling and Gdp growth and development remains ambiguous. Authors estimate the value of skills either minimal either high-level skills. Skills, at any degree, are associated to efficient economic institution. The relationship between skills and economic growth is robust. International data shows that the gap in terms of skills between richer and poorer countries is higher that the gap in terms of schooling between the same set of countries. To fill the gap among richer and poorer countries it is necessary to reform schooling institutions and create the conditions for more skill based educational system. The author affords the question of the relationship between education and human capital in economic growth and development. One of the main point of the analyses of the role of education in economic development is the fact that the quality of schooling institutions can effectively be dependent from the quality of other institutions in developing countries such as for example in the case of the presence of democracies, cultural and scientific institutions and the presence of free media. The analysis of the authors has conducted to two main conclusions:

- *Cognitive skills have powerful effects on individual earnings, on the distribution of income and on economic growth:* cognitive skills have the ability to improve the economic condition of individuals and nations. The problem is that international institutions and policies are concentrated on measuring the quantity and quality of schooling without controlling for the presence of mechanism able to empower human capital with the improvement of skills. The focus on schooling rather than on skills has reduced the ability to design and perform efficient policies that are able to generate the professional knowledge and capability necessary to produce economic growth and development. The diffusion of cognitive skills is also able to be increased with the presence of economic institutions that are able to defend property rights, sustain labor and product markets, and to participate in international markets. But the presence of cognitive skills is able to boost economic growth even in the absence of economic institutions. The acquisition of cognitive skills is obscure. In some cases, cognitive skills can be acquired with learning by doing or with tacit knowledge. Even if generally top performers have both cognitive skills and good educational results, it is not sufficient to have good schooling institutions to promote the diffusion of cognitive skills among the population.
- *The skills-gap in developing countries is larger than the schooling gap:* the policies associated to the improvement of human capital in developing countries has been associated to the empowerment of schooling. The question of cognitive skills has been minimized as a marginal topic. But the investment in schooling has produced low effect. Literacy rates are low in many developing countries. To develop a more qualified human capital in developing countries it is necessary to improve the quality of schools. But the impact of schooling on economic growth is mediated by the development of skills among population. Only if schooling is a way to increase cognitive skills than the impact of schooling on economic growth is positive. Creating mechanism of assessment for students is necessary to improve the ability of schools to be more generative in terms of skills for the population. Authors critique the ability of PISA test to be efficient in the production of evaluation in developing countries.

The authors have relevant policies suggestions to improve the attention to skills rather than to focus on years of schooling. In effect years of schooling are not able to assure the improvement and diffusion of cognitive skills among the population. Policies able to develop cognitive skills among the populations are different from policies that are devoted to improve years of schooling. Schooling institutions are not the only tool to apply for the production of cognitive skills since also families, peers and informal groups and organizations have a relevant role in creating the conditions for boosting abilities. The investment in schooling in developing countries has not created the level of skills that was predicted in the aims of policy makers. Authors suggest to improve policies that are able to increase students' outputs and performances. Authors suggest three policies that are able to improve students' skills: strong accountability system to measure student performance; local autonomy of schools; competition among schools. To improve the impact of schooling on economic performance it is necessary to create incentives that are able to improve students' performance. But the model analyzed by the authors should be augmented with technology. The possibility to have access to online courses in which students can effectively test their ability and skills improve the probability that the investment in schools with the implementation of technology can provide tools and incentive to transform schooling institutions in organizations able to empower students with skills appropriate to promote economic growth and development.

(Liepè & Sakalas, 2014) analyzes the role of human capital. The relevance of human capital increases due to the competition in the market. Corporations and institutions try to win the competition through an increase in the level of human capital. The authors consider the role of human capital in the promotion of Gdp in Lithuania. But human capital needs some particular conditions to be effectively implied in the productive process i.e. investment in appropriate material economic development such as for example fixed assets and materials. Authors evaluate the impact of Human Capital in the contribution to GDP growth in 26 European countries. The authors realize a multivariate linear regression that shed lights on the relationship between human capital and GDP growth. Based on their analysis authors suggest that human capital is relevant in the

determination of GDP growth, even if it is not the only parameter that should be considered. Other elements in the production function are relevant as tools to explain economic growth either after having controlled for country size and population. The article introduces some interesting arguments. In effect, in the future development of artificial intelligence in the production system, the relevance of human capital in determining economic growth and economic development is expected to decline, while the relevance of technical, scientific and professional non-human equipment is expected to growth. The percentage of labour in wages should be reduced while on the other side the role of technology and of information technology is expected to growth.

(Máté, 2015)considers the role of human capital accumulation on the productivity growth. Authors analyze the relationships among physical and human capital, employment, productivity growth in various sectors. The authors found the presence of an increasing role of Human Capital in the period between 1985 and 2007. The author considers the role of employment growth and labour productivity in the period 1980-2007 in OECD countries. The higher the level of skills among the workforce the higher the productivity and growth rate. High skilled sectors are also characterized by the presence of greater employment growth rates. Sectors characterized by lower skills have low productivity and low employment growth rates. The economic performance increases with the level of skills among the workforce. The demand for low skilled workers is decreasing, while the offer of high skilled employees is insufficient in high productive sectors. The author finds also a positive association between physical and human accumulation and output growth per capita. The author suggests to create public incentives for corporations and sectors that request high skilled workers, while lower skilled workers should receive subsidies to improve their professional knowledge.

(Antonelli, et al., 2010) consider the role of labour demand as a determinant for human capital formation. Authors try to analyze the relationship that exists between human capital and programs that are applied in the firm to offer work-based training (WBT). The analysis is based on three database that consider the work-based training intensity in italian manufacturing in the period 2001-2005. Authors take in consideration the capacity of the firm to organization knowledge and to remunerate and promote some skills such as for example: innovation, internationalization, out-sourcing and hirings. The final result is that the more the corporation is oriented to support organizational innovation the greater the effect of work-based training within the corporation. Authors divide the effect of work-based training in two parts: in-house and outside training. Firms, in their necessity for jobs and tasks, create a correspondent workforce. Workers are forced to acquire certain typologies of skills that are transmitted with learning by doing, tacit knowledge and also training. The particular training that workers perform is able to improve competition among workers in the market. Authors find that corporations that are able to invest in organizational and technological change are also more oriented to realize some form of WBT, while a lower level is associated to internationalization processes. Corporations that purchase business services are more oriented to realize in-house training, while techno-organizational change are more oriented to produce outside training. The main point of the authors is the analysis of the impact of labour demand on the development of human capital. Schooling, formal education, ability and age can measure the degree of human capital on the supply side, while the propensity of firms to invest in technology, innovation, high skilled personnel and international trade can measure human capital on the demand side.

(Fulghieri & Sevilir, 2009) afford the question of the relationship between the value of the firm and the presence of human and physical capital. The development of capitalism and market economy toward the knowledge economy has increased the value of human capital in respect to physical assets. The ability of a firm to generate value is based not only on the presence of physical assets but is based essentially on the evaluation of human capital. Since human capital is devoted to use technologies, to produce innovation and to generate knowledge, the presence of human capital that is skilled and with good ability to produce is an essential component of the productivity of the firm and contribute significantly in the process of corporate evaluation. Human capital is an essential asset in the context of the metric evaluation of the firm and for this reason firms invest more in human resource management. The investment in human resource management is an essential tool to improve human capital value creating the condition to generate more profitable firms and more favorable market value. The size and scope of the firm have an impact on the employee incentives. The recognition of the role of human capital in the evaluation of the firm has changed the methodologies of production and the incentives that firms realize to invest and immobilize capital. In effect, the greater the impact of human capital for the determination of the corporate value the lower the investment of the firm in physical and tangible assets. The orientation of the market toward the intangible economics has changed also the incentives of firms to invest, even if, in the reduction of physical capital and in the emphasize of human capital there are also critical elements that can increase the risks of the firm in case of crisis. And it is also necessary to consider the depreciation rate of human capital in respect to physical capital. In effect in a dynamic knowledge economy that is based on innovation and technology the level of knowledge, either educational either acquired with training, can be depreciated and can generate the necessity of larger turnovers. The solution for employees is to become "*superstars professionals*", even if this opportunity lasts only for the few and not for the many. The solution for corporations is to have relationships with universities and high educational institutes that have the ability to

generate human capital with the required skills to enter and guide successfully the market. But the strategy, either for employee and for corporations can change structurally with the introduction of artificial intelligence that has the ability to create continuously innovation, knowledge and technology with dynamism and increasing value added.

(Awan, 2012) defines human capital as the stock of competencies, knowledge and personality that is essential in creating economic value. Human capital is built with education, training and experience. Modern growth theory considers the accumulation of human capital as an essential driver to economic growth and development. The authors consider the ability of human capital to participate in fast-economic growth of BRIC countries like Brazil, Russia, India and China in the period 2000-2011. The author sustains that human capital has had an essential role in the economic growth of China, India, Brazil and Russia. But in his analysis Russia has underperformed in respect to other BRICS countries in implementing policies devoted to promote human capital as a driver for economic growth, while India, China and Brazil have overperformed empowering human capital not only either as a tool to promote economic growth either as a solution against poverty.

Human capital and education. (Mincer, 1958) considers the tradeoff between studying and income. The author considers the choice of studying in the present as a postponement of the income in the future. Workers that train more in the present expect to have a higher income in the future. The presence of incentive to acquire more training generate differences in earning among population. Training can be considered also in the sense of experience. Workers that have greater experience earn more. But the general model of (Mincer, 1958) seems to be no more effectively valid in the contemporary labour market and it could be completely obsolete in the future. Even if there are sectors that requires more high skilled workers such as for example technology and in general sectors that are related to STEM professions, there are others that seems effectively to be characterized by the presence of over-skilled workers especially in that labour marked that are disconnected in respect to educational systems. And the development of artificial intelligence could shorten the obsolescence period for knowledge acquired by humans in universities and training institutions.

(Gibbons & Waldman, 2006) afford the question of the impact job assignment, human capital acquisition and learning as variables to gain higher wages and promotion inside firms. The authors consider the role of schooling in creating the conditions to being promoted in firms. The authors try to analyze the differences between general purpose and firm specific human capital. The authors consider the depreciation of human capital either in the case of firms-specific human capital either in the case of task specific human capital in the case of turnover of change of tasks. Tasks specific human capital can also be considered in the light of new particular methodologies of education and training such as for example in the case of the presence of incentives and asymmetric learning. When workers change firms, or change task inside the same firm, there are a loss of human capital that reduce the ability of the firm to operate efficiently. Even if it is necessary to consider that these particular changes can be imposed to workers and firms in the context of innovation and creative-destruction. The authors consider promotions and turnovers as alternative exit strategies for the current job of the worker. The main idea of the authors is the introduction of "*task-specific human capital*". But this particular definition of human capital should be considered in the dynamic of changes in the organizational structure of the firm. Any innovation, either technological or organizations, generate a change in tasks for workers, and this change destroys knowledge and human capital. But in the technological and organizational change the firm acquire also new knowledge, and new tasks for workers are generated. It is necessary to balance between the loss of task-specific human capital, and the acquisition of new knowledge and competencies that can change the tasks. In this balance, especially in the case of technological change in the context of artificial intelligence and machine learning there are losses of human capital that are compensated with technological and innovative productive systems. In the long run, especially in the service sector, the substitution of humans with algorithms will create redundancy in human capital, either in the case of task specific human capital.

(Diebolt, et al., 2014) define human capital as the stock of skills that workforce possesses. Workforce acquires those skills if the return to investment is higher in respect to costs. The particular relevance of skills consists in the fact that skills are able to improve and promote individual productivity. But the effects of skills are not only individual since the usage of skills generate also positive externalities and increase the value of human capital. In productive economic organizations the development and execution of skills, not only increases the level of productivity, but also increment the value of know-how, that is valuable in the balance sheet in the part of the intangible assets. (Diebolt, et al., 2014)find that the diffusion of human capital is based on the presence two elements i.e. education and training and health. Authors consider the complex set of institutions that are able to boost human capital. The role of human capital in respect to economic growth is analyzed. In the idea of the authors human capital is not only professional and scientific knowledge that characterize the workforce, but more specifically, human capital is the set of productive skills, talents, health and expertise that characterize the labor force. The authors consider that the main cost of human capital investment is the opportunity cost of individual's time. In the production function of the authors there are essentially five elements that are: the level of technology, the level of capital, the level of resources, labour and

human capital. Human capital is an economic variable that is multiplied for the level of the variable labour. Human capital can be produced in schools, families, firms, and in other organizations. Health, training and education are essential components of the human capital evaluation that require a certain public intervention at least in development countries. The author tries to delineate a new sub-field that is the historical analysis of the schooling institutions in their ability to have an impact in terms of human capital. The idea of the author is completely relegated in a sociological and historically view. Human capital is determined on historical basis and the ability to create the conditions to boost education, training and health care change historically.

Human capital and globalization. (Ng, et al., 2011)consider the role of "*cosmopolitan human capital*" i.e. the ability of workers to operate in corporate environment that are characterized by the presence of cultural, linguistic, and ethnical diversity. The ability of workers to operate in an international context characterized by the presence of diversity is a necessity in cities and great urban aggregates. The authors investigate the determinants of the creation of a "cosmopolitan human capital" considered as a tool to improve competition and to gain efficiency in the production process and in the ability of the firm to promote social and communitarian stakes. To solve the question of the formation of "*cosmopolitan human capital*" authors refer to the idea of cultural capital and analyze the way in which cultural capital is determined at a firm-based level. There is a connection between human capital and cosmopolitan human capital: the learning process.

A metric evaluation of human capital.(Folloni & Vittadini, 2010)analyze the role of human capital in economic though. Authors consider either the retrospective either the prospective method for estimate the value of Human Capital. The retrospective and prospective method to estimate Human Capital is associated with the methodology of Human Capital as a rational choice, either with the analysis of Human capital ad a tool for economic growth and finally with the idea of Human capital as an educational attainment. The idea of a multidimensional analysis of Human Capital is associated with different variables that are considered either in the sense of formal education and training but also in the sense of culture, family background, social context and innate and non-cognitive abilities and skills. The evaluation of the costs of acquiring Human Capital is difficult. Evaluate the quality of education, and the link between investment in Human Capital and their returns can depend from assumption and quantitative linkages between earnings and productivity. One of the main problems in evaluating Human capital consists in the question of endogeneity and causality in respect to economic growth. It is in fact difficult to affirm that human capital is generated through Gdp growth or if Gdp growth is effectively generated with a casual effect with human capital accumulation. The impossibility to clearly nullify the endogeneity condition and the difficulty to stabilize the causal effect between human capital and Gdp, is a limitation that reduce the ability of the Human Capital as an explicative variable in the context of economic growth predictions.

(Le, et al., 2003) afford the question of human capital evaluation. Human capital is difficult to evaluate. The authors analyze three different methodologies to evaluate human capital that are: cost-bases, income-based and educational stock-based. But authors afford the case of cost-based and income-based evaluation of human capital. The various methodologies used to evaluate human capital are essentially interlinked, for example a common base to different indexes is the computation of the cost of rearing and education. In income-based approach the evaluation of human capital is based on the earnings, in this case the main hypothesis is that if an individual earns more than its human capital has a higher value. But this definition does not consider many distortions and idiosyncrasies that are present in the market such as for example the fact that firms and corporations in traditional sectors of in area with low income could not have the sufficient amount of money necessary to remunerate the skills of human capital. For example, in rigid labour market in developing low income economies the mechanism of remuneration of skills is largely inefficient and income are not representative of the real capability of human capital in the market. Another methodology to evaluate metrically human capital is to consider the literacy rates, school enrolment rates, and mean years of schooling; but also, these elements can be distorted in inefficient labour markets. The evaluation of human capital is considered an essential determinant to obtain social economic valuable objectives such as for example the development of individual capabilities, the reduction of poverty and delinquency, and the participation in democratic processes. Human capital not only increase the private sector, through an increase in productivity and in value added, but also generate positive outcomes for the public sector, augmenting the social conscience, and the partecipation to public and political events and procedures. In the western definition of the civilization, human capital increases the social, cultural, economic and political outcomes of a certain country and in greater terms of the globalization and international affairs.

Human capital and displaced workers. (Neal, 1995)afford the question of the displaced workers, their human capital and the costs of the displacement. The authors find that workers are generally compensated for skills that are neither completely general neither firm-specific to a single industry or a single work. In the process of displacement, the firm-specific abilities of workers are not relevant in the process of preserving income. Data shows that the wage cost of switching industries depends essentially either for pre-displacement measures and for work experience tenure. Workers receive compensation either for skills that are neither generic neither

specific to a single firm but are rather specific to a set of firms that operate in similar markets. But there are also costs in the process of displacement. Experienced workers that experiment a displacement in a declining industry suffer greater losses in respect to other typologies of workers. Displaced workers generally lose their job since their corporations have failed. The failure of a corporation is generally not due to technology but in general is associated to mismanagement in resources, or misunderstanding of the market and consumers. In this circumstance the skills or workers are not able to save the workers for unemployment, since, a firm that fails for mis-management generally has no ability to improve the level of skills among employee. The result is that if workers want to be saved in case of displacement, they should try to be employed only in well managed corporations that have the ability to apply high technology. In this case displaced workers have more probability to be re-employed in similar industries with equal or higher wages. But, if workers are employed in well managed and tech-oriented corporations, they have low incentives to change. In the end displaced workers are employed in corporation that have a bad management and operate with obsolete technology and in this case, if the corporation fails, it is sure that workers will be penalized in terms of income: they have a higher probability to found a job with a lower income.

III. THE ESTIMATED MODEL

We have estimated the sequent model:

$$\begin{aligned}\boldsymbol{HumanResources}_{it} &= \boldsymbol{a}_{it} + \boldsymbol{b}_1(\boldsymbol{AttractiveResearchSystems})_{it} + \boldsymbol{b}_2(\boldsymbol{AverageAnnualGdpGrowth})_{it} \\ &+ \boldsymbol{b}_3(\boldsymbol{BasicSchoolEntrepreneurialEducationAndTraining})_{it} \\ &+ \boldsymbol{b}_4(\boldsymbol{DesignApplications})_{it} + \boldsymbol{b}_5(\boldsymbol{FinanceAndSupport})_{it} \\ &+ \boldsymbol{b}_6(\boldsymbol{ForeignDoctorateStudents})_{it} \\ &+ \boldsymbol{b}_7(\boldsymbol{GovernmentProcurementeOfAdvancedTechnologyProducts})_{it} \\ &+ \boldsymbol{b}_8(\boldsymbol{InnovationIndex})_{it} + \boldsymbol{b}_9(\boldsymbol{InternationalCoPublications})_{it} \\ &+ \boldsymbol{b}_{10}(\boldsymbol{LifelongLearning})_{it} + \boldsymbol{b}_{11}(\boldsymbol{MediumaAndHighTechProductExports})_{it} \\ &+ \boldsymbol{b}_{12}(\boldsymbol{PrivateCoFoundingOfPublicR\&D}Expenditures)_{it} \\ &+ \boldsymbol{b}_{13}(\boldsymbol{R\&D}ExpendituresPublicSector)_{it} \\ &+ \boldsymbol{b}_{14}(\boldsymbol{ShareHighAndMediumHighTechManufacturing})_{it} \\ &+ \boldsymbol{b}_{15}(\boldsymbol{SMEsInovationInHouse})_{it} + \boldsymbol{b}_{16}(\boldsymbol{VentureCapital})_{it}\end{aligned}$$

Data are collected from the European Innovation Scoreboard during the period 2010-2019. Data are analyzed with Pooled OLS, Dynamic Panel Data, Panel Data with random effects, panel data with fixed effects, WLS.

Sum of Coefficient of the independent variables for macro-category. Dependent Variable: Human Resources

Variables	Macro-Categories	Pooled OLS	Dynamic Panel Data	Fixed Effects	Random Effects	WLS	Mean
Attractive research systems	**Attractive research systems**	2,0101769	0,517648	1,160212	1,260305	0,817587	1,15318578
Foreign doctorate students							
International co-publications							
Lifelong learning	**Education**	0,299348	0,348397	0,310971	0,308908	0,308306	0,315186
Finance and support	**Finance and support**	-0,076954	-0,001512	-0,050395	-0,055207	-0,121614	-0,0611364
R&D expenditure public sector							
Venture capital							
Basic-school entrepreneurial education and training (SD)	**Governance and policy Framework**	-1,651566	-1,027507	-1,373774	-1,419269	-1,838885	-1,4622002
Government procurement of advanced technology products (SD)							
Innovation index	**Innovation index**	1,15471	0,832732	1,01073	1,03496	1,27247	1,0611204

SMEs innovating in-house	**Innovators**	-0,206472	-0,145724	-0,180035	-0,183038	-0,248832	-0,1928202
Design applications	**Intellectual assets**	-0,0696566	-0,0559445	-0,0547646	-0,0565783	-0,0688263	-0,0611541
Private co-funding of public R&D expenditures	**Linkages**	0,210329	0,221489	0,230139	0,228324	0,211704	0,220397
Average annual GDP growth (SD)	**Performance and structure of the economy**	2,231696	0,9661993	2,2534025	2,2709127	2,6351644	2,07147498
Share High and Medium high-tech manufacturing (SD)							
Medium and high-tech product exports	**Sales impacts**	-0,209327	-0,110379	-0,157369	-0,167549	-0,206108	-0,1701464

IV. CONCLUSION

We analyze the determinants of the "*Human Resources*" in European countries during the period 2010-2019. The variable "*Human resources*" is considered as a proxy for human capital. We use a dataset from European Innovation Scoreboard that analyze 36 countries. Data are processed using panel with fixed and random effects, pooled OLS, WLS and dynamic panel. The literature relative to human capital and human resources is analyzed considering that the usage of Artificial Intelligence and automation can transform the workforce into a "*useless class*". Results show that the variable "*Human Resources*" is positively associated with the sequent macro-variables "*Attractive Research Systems",* "*Education*", "*Innovation Index*", "*Linkages*", "*Performance and Structure of the Economy*" and negatively associated with "*Finance and Support*", "*Governance and Policy Framework*", "*Innovators*", "*Intellectual Assets*" and "*Sales Impact*".

BIBLIOGRAPHY

[1] Abel, J. R. &Deitz, R., 2012. Do colleges and universities increase their region's human capital?.*Journal of Economic Geography*, 12(3), pp. 667-691.

[2] Acemoglu, D., Gallego, F. A. & Robinson, J. A., 2014. Institutions, human capital, and development. *Annu. Rev. Econ.*, 6(1), pp. 875-912.

[3] Antonelli, G., Antonietti, R. & Guidetti, G., 2010. Organizational change, skill formation, human capital measurement: evidence from Italian manufacturing firms. *Journal of Economic Surveys*, 24(2), pp. 206-247.

[4] Awan, A. G., 2012. Human Capital: Driving Force of Economic Growth in Selected Emerging Economies. *Global disclosure of economics and business*, 1(1), pp. 9-30.

[5] Baldwin, J. R. & Johnson, J., 1995. Human capital development and innovation: the case of training in small and medium-sized firms. *Statistics Canada Working Paper*, Volume 74.

[6] Ciccone, A. & Peri, G., 2006. Identifying human-capital externalities: Theory with applications. *The Review of Economic Studies*, 73(2), pp. 381-412.

[7] Cohen, D. & Soto, M., 2007. Growth and human capital: good data, good results. *Journal of economic growth*, 12(1), pp. 51-76.

[8] Crook, T. R. et al., 2011. Does human capital matter? A meta-analysis of the relationship between human capital and firm performance. *Journal of applied psychology*, 93(3), p. 443.

[9] Dagum, C., Vittadini, G. & Lovaglio, P. G., 2007. Formative indicators and effects of a causal model for household human capital with application..*Econometric Reviews*, 26(5), pp. 579-596.

[10] Diebolt, C., Haupert, M. & Goldin, C., 2014. Human Capital. *Handb. Cliometrics*, pp. 1-40.

[11] Földvári, P. && Leeuwen, B. V., 2005. An estimation of the human capital stock in Eastern and Central Europe. *Eastern European Economics*, 43(6), pp. 53-65.

[12] Folloni, G. &Vittadini, G., 2010. Human capital measurement: a survey. *Journal of economic survey*, 24(2), pp. 248-279.

[13] Fulghieri, P. &Sevilir, M., 2009. Size and scope of human capital intensive firms.

[14] Gibbons, R. & Waldman, M., 2004. Task-specific human capital. *American Economic Review*, 94(2), pp. 203-207.

[15] Gibbons, R. & Waldman, M., 2006. Enriching a theory of wage and promotion dynamics inside firms. *Journal of Labor Economics*, 24(1), pp. 59-107.

[16] Hanushek, E. A. &Woessmann, L., 2008. The role of cognitive skills in economic development. *Journal of economic literature*, 46(3), pp. 607-68.

[17] Harari, Y. N. (., 2014. *Sapiens: A Brief History of Humankind.* s.l.:Random House.

[18] Harari, Y. N., 2017. *Reboot for the AI revolution.* [Online] Available at: https://www.nature.com/news/reboot-for-the-ai-revolution-1.22826 [Consultato il giorno 01 09 2020].

[19] Kaufman, B. E., 2001. Human resources and industrial relations: Commonalities and differences. *Human Resource Management Review* ,11(4), pp. 339-374.

[20] Leogrande, A., Massaro, A. & Galiano, A. M., 2020. The Determinants of Innovation in European Countries in the period 2010-2019. *American Journal of Humanities and Social Sciences Research (AJHSSR)*, 4(8), pp. 91-126.
[21] Leogrande, A., Massaro, A. & Galiano, A. M., 2020. The Impact of R&D Investments on Corporate Performance in. *American Journal of Humanities and Social Sciences Research (AJHSSR)*, 4(7), pp. 186-201.
[22] Le, T., Gibson, J. &Oxley, L., 2003. Cost-and income-based measures of human capital. *Journal of economic surveys*, 17(3), pp. 271-307.
[23] Liepè, Z. &Sakalas, A., 2014. Evaluation of human capital role in the value creation process. *Procedia-Social and Behavioral Sciences*, Volume 156, pp. 78-82.
[24] Lovaglio, P. G., 2008. Process of accumulation of Italian human capital. *Structural Change and Economic Dynamics*, 19(4), pp. 342-356.
[25] Mahroum, S., 2007. Assessing human resources for science and technology: the 3Ds framework. *Science and Public Policy*, 34(7), pp. 489-499.
[26] Máté, D., 2015. Impact of human capital on productivity growth in different labour-skilled branches. *Acta Oeconomica*, 65(1), pp. 51-67.
[27] McGuirk, H., Lenihan, H. & Hart, M., 2015. Measuring the impact of innovative human capital on small firms' propensity to innovate. *Research Policy*, 44(4), pp. 965-976.
[28] Millimet, D. L., Nieswiadomy, M. &Slottje, D., 2010. Detailed estimation of worklife expectancy for the measurement of human capital: accounting for marriage and children. *Journal of Economic Surveys*, 24(2), pp. 339-361.
[29] Mincer, J., 1958. Investment in human capital and personal income distribution. *Journal of political economy*, 66(4), pp. 281-302.
[30] Neal, D., 1995. Industry-specific human capital: Evidence from displaced workers. *Journal of labor Economics*, 13(4), pp. 653-677.
[31] Ng, K. Y. et al., 2011. Culture capital and cosmopolitan human capital: The impact of global mindset and organizational routines on developing cultural intelligence and international experiences in organizations. *The Oxford handbook of human capital*, pp. 96-119.
[32] Polanyi, M., 2009. *The tacit dimension.* Chicago: University of Chicago press.
[33] Rindermann, H., 2008. Relevance of education and intelligence at the national level for the economic welfare of people. *Intelligence*, 36(2), pp. 127-142.
[34] Schumpeter, J. A., 2013. *Capitalism, socialism and democracy.* s.l.:Routledge.
[35] Scoreboard, E. I. R. I., 2019 .*Economics of Industrial Research and Innovation.* [Online] Available at: https://iri.jrc.ec.europa.eu/data [Consultato il giorno 23 7 20202].
[36] Singer, A., 2014. Investing in the Human Capital of Immigrants, Strengthening Regional Economies. *Washington, DC: Brookings Institution*, October(20), p. 2012.
[37] Solow, R. M., 1956. A contribution to the theory of economic growth. *The quarterly journal of economics*, 70(1), pp. 65-94.
[38] Tegmark, M., 2017. Life 3.0: Being human in the age of artificial intelligence. In: *Knopf*. s.l.:s.n.
[39] Toya, H., Skidmore, M. & Robertson, R., 2010. A reevaluation of the effect of human capital accumulation on economic growth using natural disasters as an instrument. *Eastern Economic Journal*, 36(1), pp. 120-137.
[40] Weisbrod, B. A., 1961. The valuation of human capita. *Journal of political economy*, 69(5), pp. 425-436.

6. Appendix

Legend of variables			
Attractive research systems	A	1	x_1
Average annual GDP growth (SD)	A	2	x_2
Basic-school entrepreneurial education and training (SD)	A	4	x_3
Design applications	A	7	x_4
Finance and support	A	17	x_5
Foreign doctorate students	A	19	x_6
Government procurement of advanced technology products (SD)	A	22	x_7
Human resources	A	23	y
Innovation index	A	24	x_8
International co-publications	A	30	x_9
Lifelong learning	A	32	x_{10}
Medium and high-tech product exports	A	35	x_{11}
Private co-funding of public R&D expenditures	A	43	x_{12}
R&D expenditure public sector	A	47	x_{13}
Share High and Medium high-tech manufacturing (SD)	A	50	x_{14}

SMEs innovating in-house	A	52	x_{15}
Venture capital	A	59	x_{16}

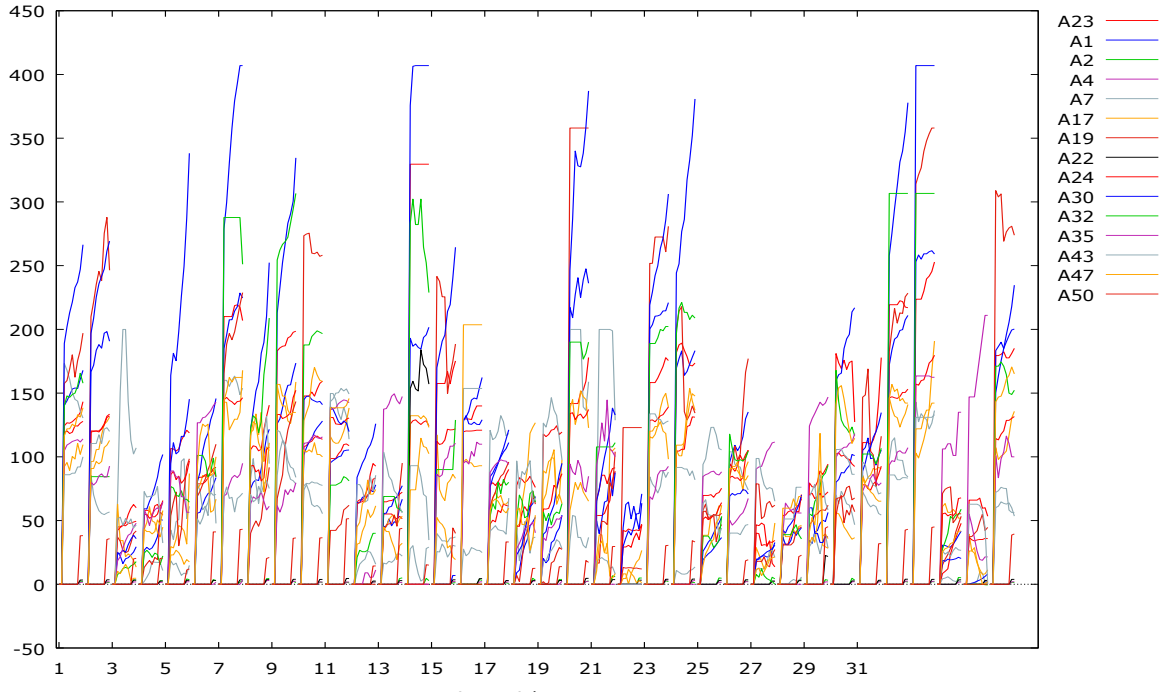


Figure 2. Group Time Series.

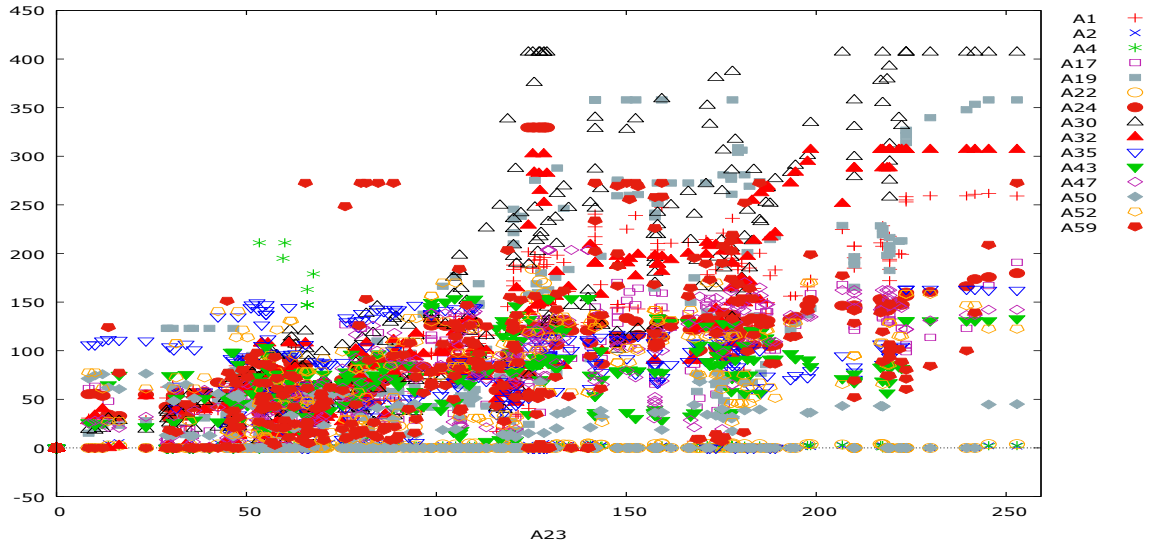


Figure 3. Scatter chart.

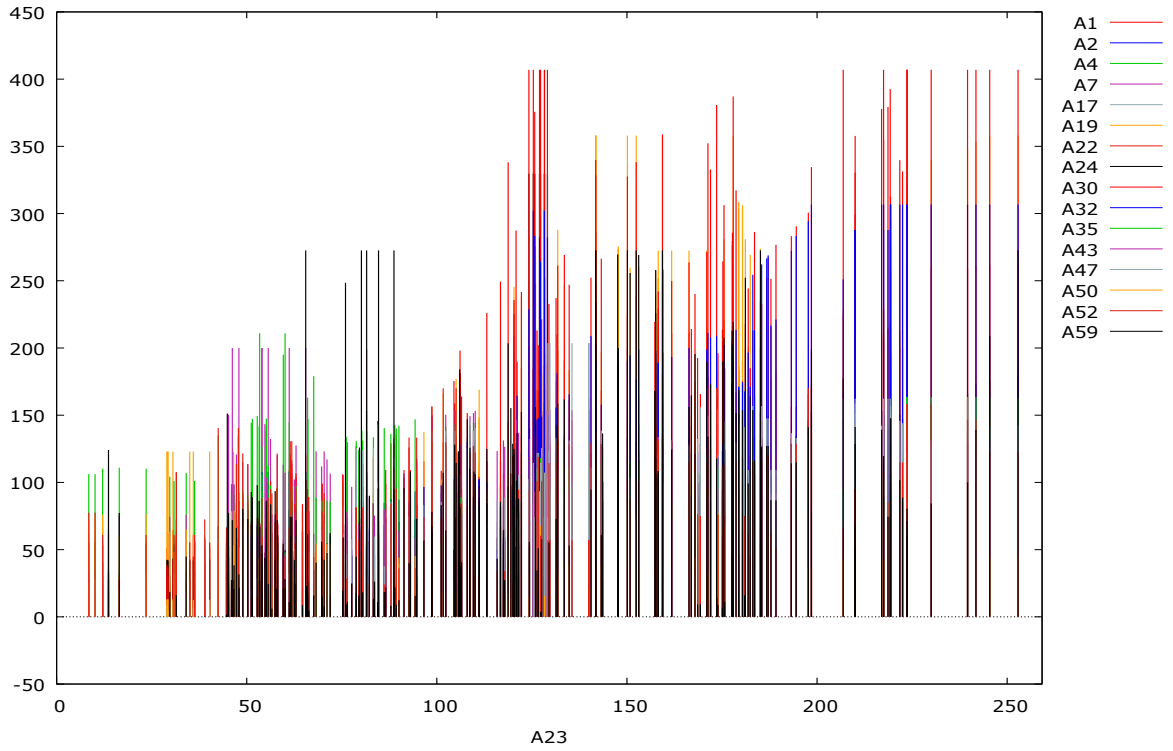
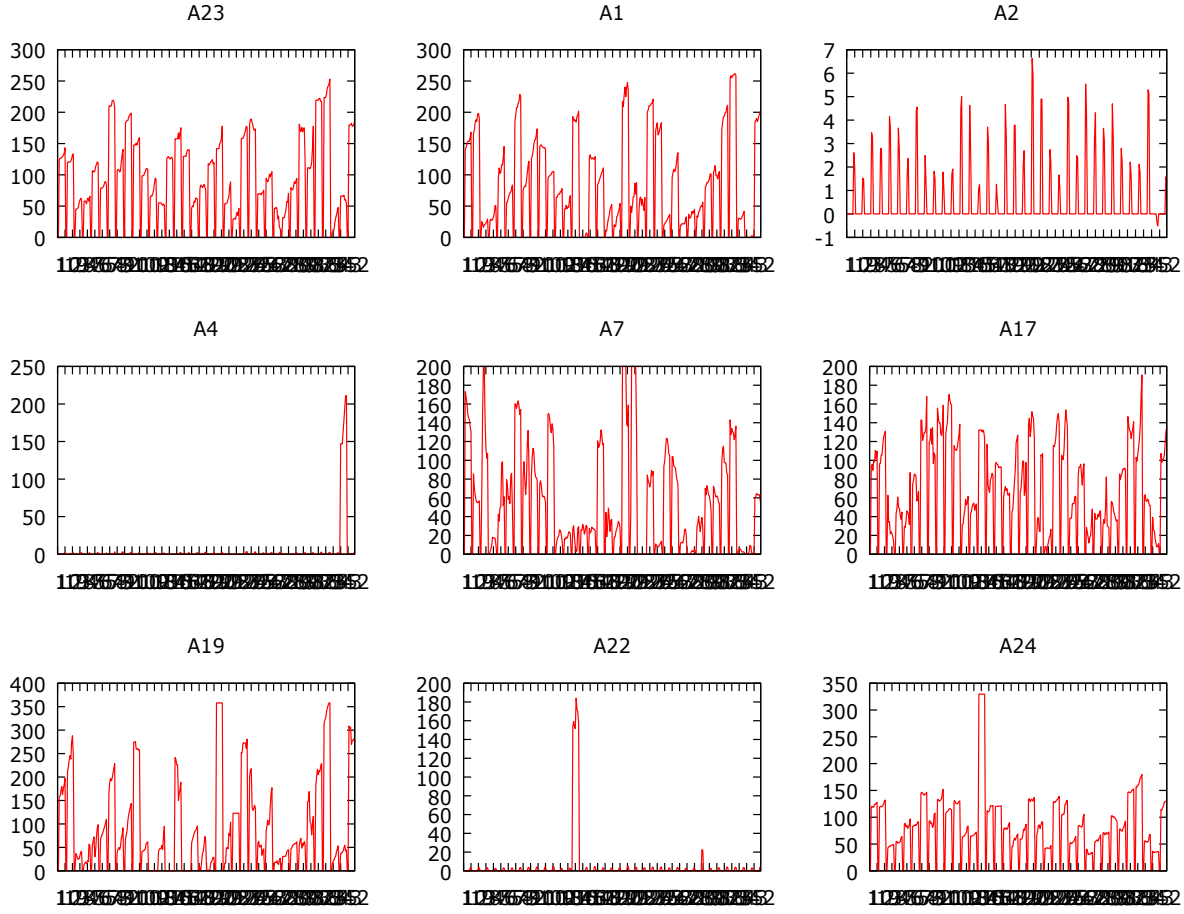


Figure 4. Pulse graph.



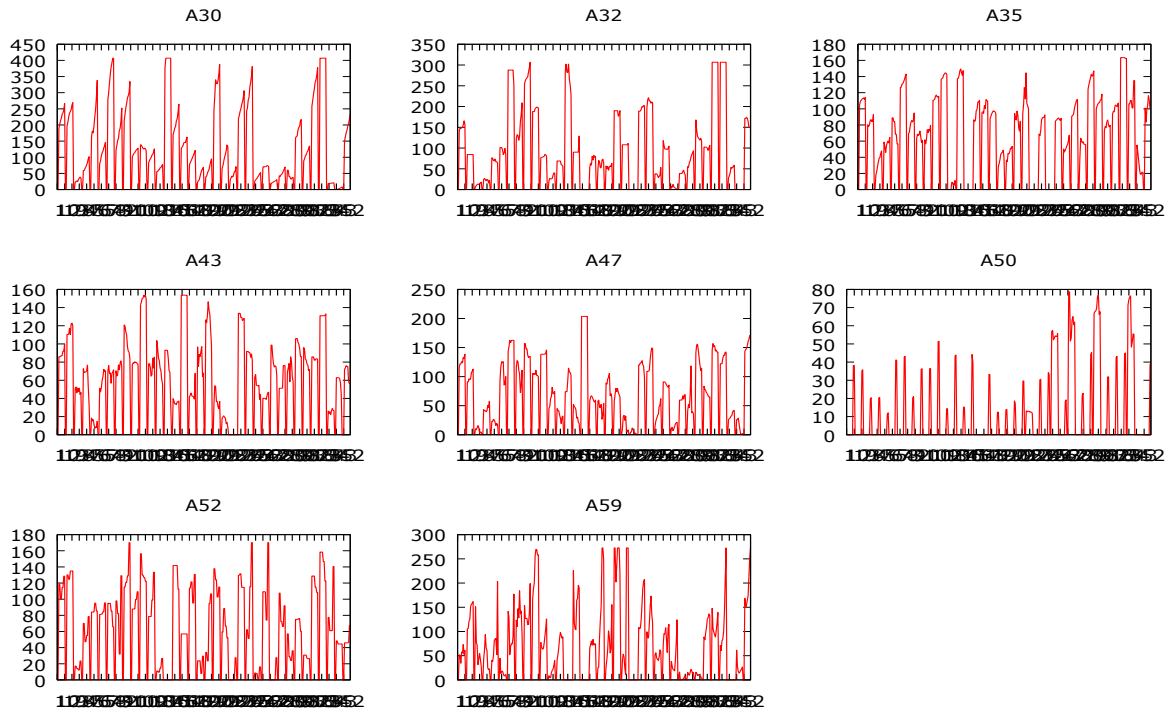


Figura 5. Time series.

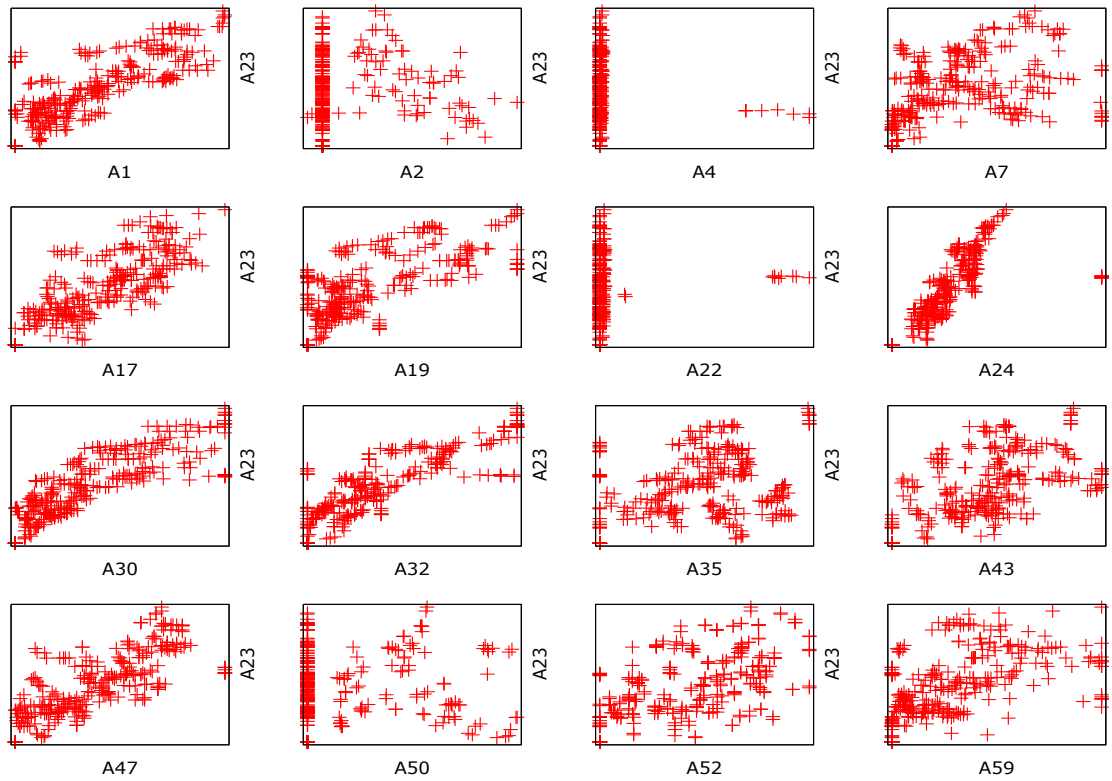


Figure 6. Scatter chart.

Descriptive statistics, using observations 1:01 - 36:10					
Variable	*Mean*	*Median*	*Standard Deviation*	*Min*	*Max*
A23	90,9	84,0	68,1	0,00	253,
A1	83,0	63,8	76,5	0,00	262,
A2	0,585	0,00	1,35	-0,510	6,62
A4	4,23	0,00	26,1	0,00	211,
A7	54,3	31,5	56,1	0,00	200,
A17	66,7	61,5	50,8	0,00	191,
A19	89,8	50,2	101,	0,00	358,
A22	4,38	0,00	24,0	0,00	184,
A30	124,	87,7	122,	0,00	407,
A32	90,8	68,9	93,6	0,00	307,
A35	64,6	72,4	49,8	0,00	163,
A43	59,2	64,1	44,5	0,00	154,
A47	66,1	59,7	56,8	0,00	204,
A50	10,8	0,00	20,5	0,00	78,9
A52	61,2	58,2	51,7	0,00	170,
A59	68,4	47,2	75,6	0,00	273,

Principal component analysis

n = 360

Analysis of the eigenvalues of the correlation matrix

Component	Eigenvalue	Cumulative Proportion	
1	8,0081	0,5005	0,5005
2	1,6236	0,1015	0,6020
3	1,4492	0,0906	0,6926
4	1,0838	0,0677	0,7603
5	0,9898	0,0619	0,8222
6	0,6204	0,0388	0,8609
7	0,5395	0,0337	0,8946
8	0,4833	0,0302	0,9249
9	0,3228	0,0202	0,9450
10	0,3068	0,0192	0,9642
11	0,1983	0,0124	0,9766
12	0,1531	0,0096	0,9862
13	0,0952	0,0060	0,9921
14	0,0774	0,0048	0,9969
15	0,0312	0,0019	0,9989
16	0,0177	0,0011	1,0000

Eigenvectors (component weights)

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
A23	0,333	0,053	0,013	0,086	0,067	-0,083	0,152
A1	0,325	0,155	0,050	-0,084	0,006	0,025	0,073
A2	0,053	-0,399	0,498	-0,252	0,239	-0,306	-0,491
A4	-0,051	0,032	-0,141	0,364	0,888	0,183	-0,028
A7	0,237	-0,139	-0,184	-0,165	-0,101	0,640	-0,444
A17	0,331	0,071	0,037	-0,016	0,023	-0,174	-0,081
A19	0,283	-0,040	-0,218	-0,290	0,158	-0,027	0,334

A22	0,036	0,470	0,579	-0,008	0,078	0,257	-0,137
A30	0,311	0,216	0,159	-0,102	0,048	0,080	0,091
A32	0,311	0,206	0,097	-0,108	0,023	0,157	0,147
A35	0,224	-0,405	-0,050	0,233	-0,139	0,333	-0,050
A43	0,247	-0,036	0,056	0,559	-0,118	-0,241	-0,122
A47	0,297	0,059	0,036	0,356	-0,166	-0,190	-0,039
A50	0,039	-0,522	0,453	0,062	0,034	0,203	0,559
A52	0,274	-0,147	-0,176	0,075	0,048	-0,086	-0,187
A59	0,247	-0,121	-0,182	-0,391	0,201	-0,273	0,004

	PC8	PC9	PC10	PC11	PC12	PC13	PC14
A23	-0,079	0,147	-0,094	0,339	-0,315	-0,153	0,506
A1	-0,140	0,076	-0,255	-0,400	0,206	-0,097	-0,510
A2	-0,193	0,038	-0,285	0,059	-0,030	0,090	0,010
A4	0,011	0,072	-0,034	0,025	0,085	-0,025	-0,072
A7	0,064	0,433	0,066	-0,149	-0,050	0,044	0,153
A17	0,283	0,020	0,244	0,063	0,306	0,093	-0,114
A19	-0,066	-0,208	-0,356	-0,394	0,047	0,302	0,386
A22	0,251	-0,336	0,142	-0,175	0,087	0,040	0,296
A30	-0,250	0,002	-0,007	0,012	-0,320	-0,603	-0,166
A32	-0,099	0,047	0,005	0,521	-0,110	0,587	-0,311
A35	0,209	-0,591	-0,308	0,248	0,076	-0,166	-0,112
A43	0,268	0,085	-0,042	-0,351	-0,499	0,233	-0,093
A47	-0,091	0,269	-0,107	0,122	0,608	-0,124	0,234
A50	0,027	0,222	0,302	-0,131	0,060	0,007	-0,006
A52	-0,505	-0,375	0,615	-0,126	0,010	0,077	0,054
A59	0,578	0,001	0,236	0,068	-0,033	-0,208	-0,052

	PC15	PC16
A23	-0,374	-0,418
A1	-0,492	-0,225
A2	0,034	0,008
A4	0,029	0,015
A7	0,031	0,011
A17	0,476	-0,600
A19	0,260	0,094
A22	-0,146	0,084
A30	0,457	0,195
A32	-0,010	0,238
A35	-0,016	-0,027
A43	0,059	0,124
A47	0,013	0,410
A50	-0,007	0,010
A52	-0,147	0,049
A59	-0,255	0,342

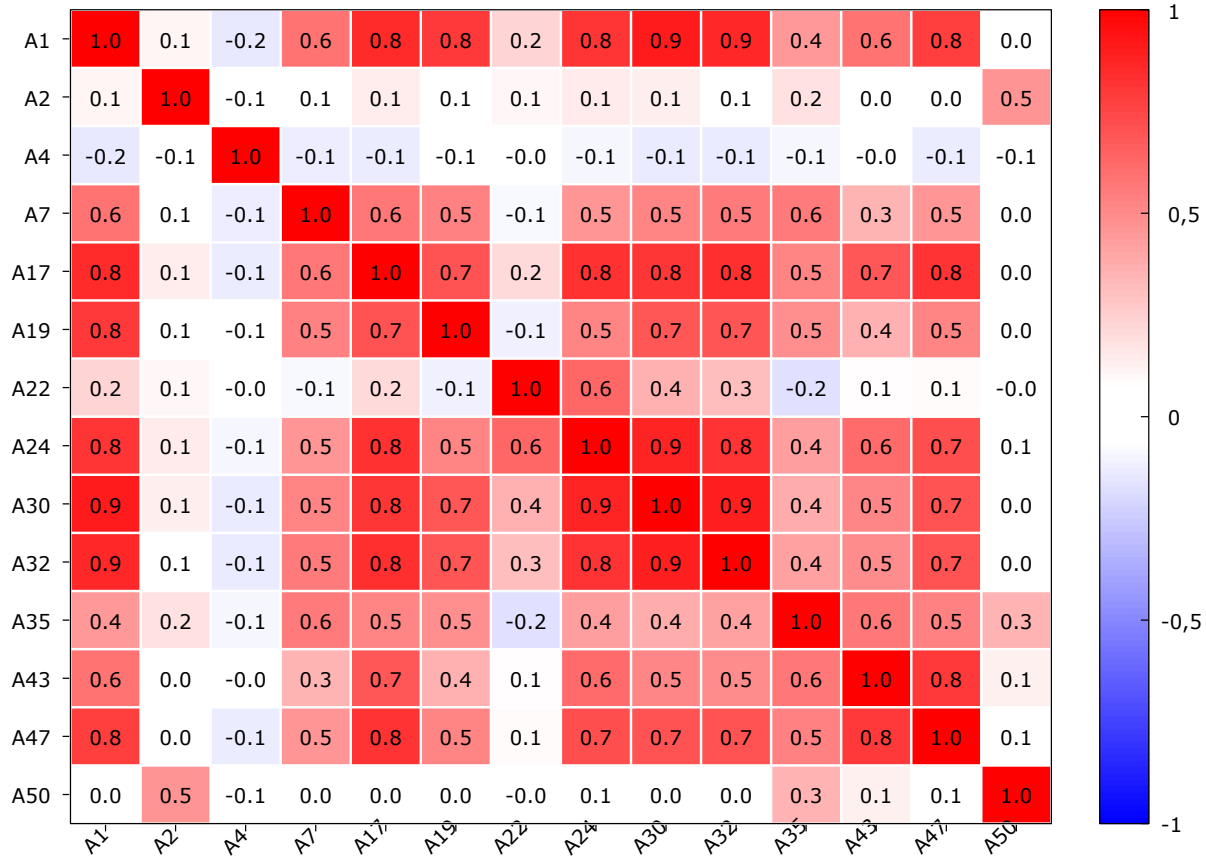


Figura 7. Correlation matrix.

Summary of regression results															
Pooled OLS				**Dynamic panel data**			**Fixed effects**			**Causal Effects**			**WLS**		
	Coefficient	**p-value**		**Coefficient**	**p-value**		**Coefficient**	**p-value**		**Coefficient**	**p-value**		**Coefficient**	**p-value**	
const	1,80732	0,1842		0,317462	0,6217		0,9507	0,3353		1,05009	0,5979		0,604424	0,4454	
A1	−0,296048	<0,0001	***	−0,251789	0,0002	***	−0,281140	<0,0001	***	-0,2865	<0,0001	***	−0,341398	<0,0001	***
A2	2,11939	0,0004	***	0,88725	0,071	*	2,16125	<0,0001	***	2,17639	<0,0001	***	2,57839	<0,0001	***
A4	0,135184	<0,0001	***	0,195813	<0,0001	***	0,12848	0,0009	***	0,13004	0,0001	***	0,131435	<0,0001	***
A7	−0,0696566	0,0001	***	−0,0559445	0,0129	**	−0,0547646	0,0123	**	-0,0566	0,0051	***	−0,0688263	<0,0001	***
A17	−0,657864	<0,0001	***	−0,693481	<0,0001	***	−0,645702	<0,0001	***	-0,6508	<0,0001	***	−0,647442	<0,0001	***
A19	0,0905119	<0,0001	***	0,103411	0,0004	***	0,10659	<0,0001	***	0,10516	<0,0001	***	0,106082	<0,0001	***
A22	−1,78675	<0,0001	***	−1,22332	<0,0001	***	−1,50225	<0,0001	***	-1,5493	<0,0001	***	−1,97032	<0,0001	***
A24	1,15471	<0,0001	**	0,832732	<0,0001	**	1,01073	<0,000	**	1,03496	<0,0001	**	1,27247	<0,0001	**

			*			*		1	*			*			*
A30	0,112345	<0,0001	***	0,096775	0,0031	***	0,10293	<0,0001	***	0,10506	<0,0001	***	0,107081	<0,0001	***
A32	0,299348	<0,0001	***	0,348397	<0,0001	***	0,31097	<0,0001	***	0,30891	<0,0001	***	0,308306	<0,0001	***
A35	−0,209327	<0,0001	***	−0,110379	0,0694	*	−0,157369	<0,0001	***	-0,1675	<0,0001	***	−0,206108	<0,0001	***
A43	0,210329	<0,0001	***	0,222489	0,0003	***	0,23014	<0,0001	***	0,22832	<0,0001	***	0,211704	<0,0001	***
A47	0,367585	<0,0001	***	0,445112	<0,0001	***	0,39062	<0,0001	***	0,3892	<0,0001	***	0,348971	<0,0001	***
A50	0,112306	0,005	***	0,078949	0,0185	**	0,09215	0,0269	**	0,09452	0,0162	**	0,056774	0,0487	**
A52	−0,206472	<0,0001	***	−0,145724	0,0003	***	−0,180035	<0,0001	***	-0,183	<0,0001	***	−0,248832	<0,0001	***
A59	0,213325	<0,0001	***	0,246857	<0,0001	***	0,20469	<0,0001	***	0,20639	<0,0001	***	0,176857	<0,0001	***
A23 (-1)				0,015837	0,3764										

Sum of Coefficient of the independent variables for macro-category. Dependent Variable: Human Resources							
Variables	**Macro-Categories**	**Pooled OLS**	**Dynamic Panel Data**	**Fixed Effects**	**Random Effects**	**WLS**	**Mean**
Attractive research systems	**Attractive research systems**	2,0101769	0,517648	1,160212	1,260305	0,817587	1,15318578
Foreign doctorate students							
International co-publications							
Lifelong learning	**Education**	0,299348	0,348397	0,310971	0,308908	0,308306	0,315186
Finance and support	**Finance and support**	-0,076954	-0,001512	-0,050395	-0,055207	-0,121614	-0,0611364
R&D expenditure public sector							
Venture capital							
Basic-school entrepreneurial education and training (SD)	**Governance and policy Framework**	-1,651566	-1,027507	-1,373774	-1,419269	-1,838885	-1,4622002
Government procurement of advanced technology products (SD)							
Innovation index	**Innovation index**	1,15471	0,832732	1,01073	1,03496	1,27247	1,0611204
SMEs innovating in-house	**Innovators**	-0,206472	-0,145724	-0,180035	-0,183038	-0,248832	-0,1928202
Design applications	**Intellectual assets**	-0,0696566	-0,0559445	-0,0547646	-0,0565783	-0,0688263	-0,0611541
Private co-funding of public R&D expenditures	**Linkages**	0,210329	0,221489	0,230139	0,228324	0,211704	0,220397
Average annual GDP growth (SD)	**Performance and structure of the economy**	2,231696	0,9661993	2,2534025	2,2709127	2,6351644	2,07147498

Share High and Medium high-tech manufacturing (SD)							
Medium and high-tech product exports	**Sales impacts**	-0,209327	-0,110379	-0,157369	-0,167549	-0,206108	-0,1701464

Pooled OLS, using 360 observations					
36 cross section units included					
Time series length = 10					
Dependent variable:A23					
	Coefficient	*Std. Error*	*t*	*p-value*	
const	1,80732	1,35823	1,331	0,1842	
A1	−0,296048	0,0310894	−9,522	<0,0001	***
A2	2,11939	0,597900	3,545	0,0004	***
A4	0,135184	0,0266323	5,076	<0,0001	***
A7	−0,0696566	0,0180072	−3,868	0,0001	***
A17	−0,657864	0,0680332	−9,670	<0,0001	***
A19	0,0905119	0,0169115	5,352	<0,0001	***
A22	−1,78675	0,126386	−14,14	<0,0001	***
A24	1,15471	0,0803936	14,36	<0,0001	***
A30	0,112345	0,0200239	5,611	<0,0001	***
A32	0,299348	0,0186597	16,04	<0,0001	***
A35	−0,209327	0,0252012	−8,306	<0,0001	***
A43	0,210329	0,0294281	7,147	<0,0001	***
A47	0,367585	0,0376247	9,770	<0,0001	***
A50	0,112306	0,0397770	2,823	0,0050	***
A52	−0,206472	0,0267010	−7,733	<0,0001	***
A59	0,213325	0,0264652	8,061	<0,0001	***

Mean Dependent Variable	90,89693	Standard deviation dependent variable	68,08024
Residual Sum of Squares	53769,21	Standard error of the regression	12,52044
R-squares	0,967686	Adjusted R-Squared	0,966178
F(16, 343)	641,9650	P-value(F)	1,9e-244
Log-likelihood	−1411,961	Akaikecriterion	2857,923
Schwarz criterion	2923,986	Hannan-Quinn	2884,191
rho	0,917094	Durbin-Watson	0,335504

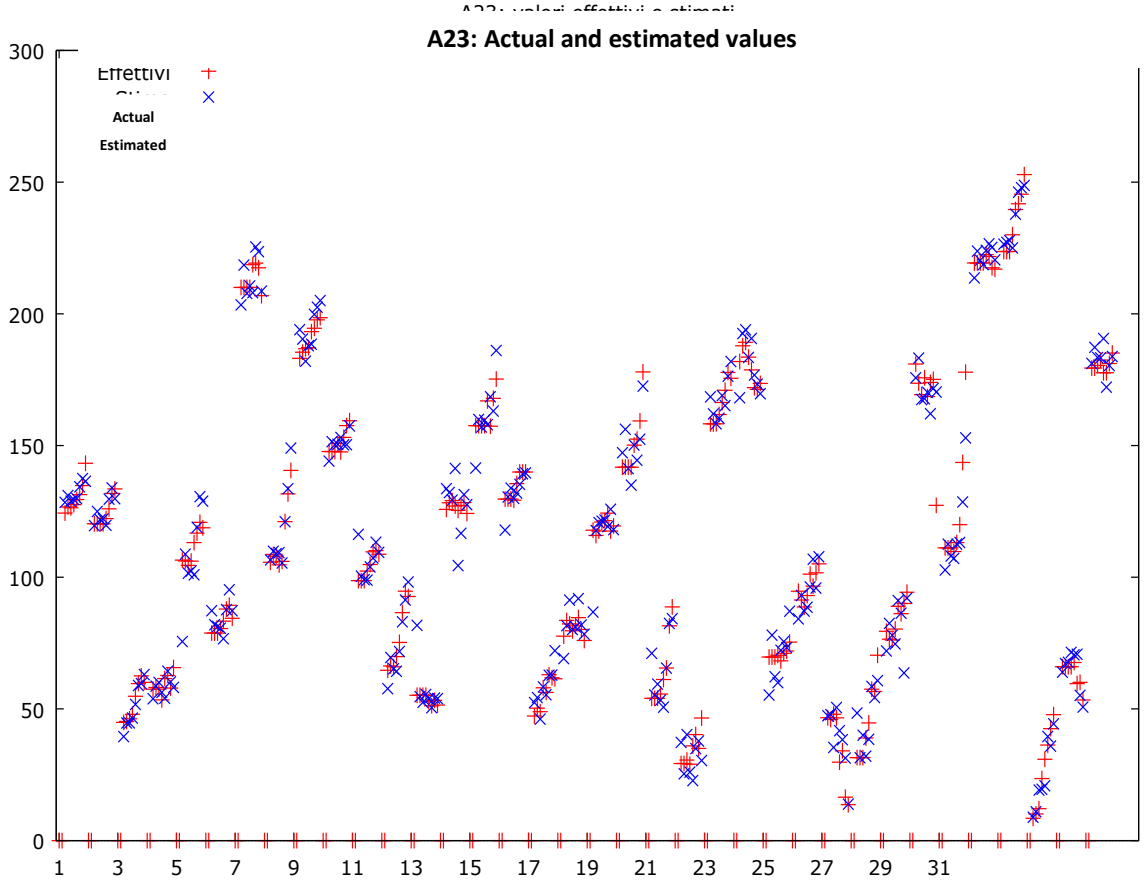


Figura 8. Time series for the group.

One step dynamic panel, using 288 observations					
36 cross section units included					
Ox / DPD compliant H matrix					
Dependent variable: A23					
	Coefficient	*Std. Error*	*z*	*p-value*	
A23(-1)	0,0158365	0,0179039	0,8845	0,3764	
const	0,317462	0,643421	0,4934	0,6217	
A1	−0,251789	0,0671236	−3,751	0,0002	***
A2	0,887250	0,491374	1,806	0,0710	*
A4	0,195813	0,0239899	8,162	<0,0001	***
A7	−0,0559445	0,0225029	−2,486	0,0129	**
A17	−0,693481	0,110928	−6,252	<0,0001	***
A19	0,103411	0,0291866	3,543	0,0004	***
A22	−1,22332	0,202290	−6,047	<0,0001	***
A24	0,832732	0,131127	6,351	<0,0001	***
A30	0,0967750	0,0326955	2,960	0,0031	***
A32	0,348397	0,0353615	9,852	<0,0001	***
A35	−0,110379	0,0607800	−1,816	0,0694	*
A43	0,221489	0,0607333	3,647	0,0003	***
A47	0,445112	0,0617176	7,212	<0,0001	***
A50	0,0789493	0,0335238	2,355	0,0185	**
A52	−0,145724	0,0400887	−3,635	0,0003	***

A59	0,246857	0,0421727	5,853	<0,0001	***
Quadratic sum of residuals	16227,10	Standard error of the regression		7,752443	
Number of instrument= 38					
Test for errorsAR(1): z = 0,117675 [0,9063]					
Test for errorsAR(2): z = -0,872767 [0,3828]					
Sargan over-identificationtestChi-quadro(20) = 62,335 [0,0000]					
Wald (joint) test: Chi-quadro(17) = 15068,5 [0,0000]					

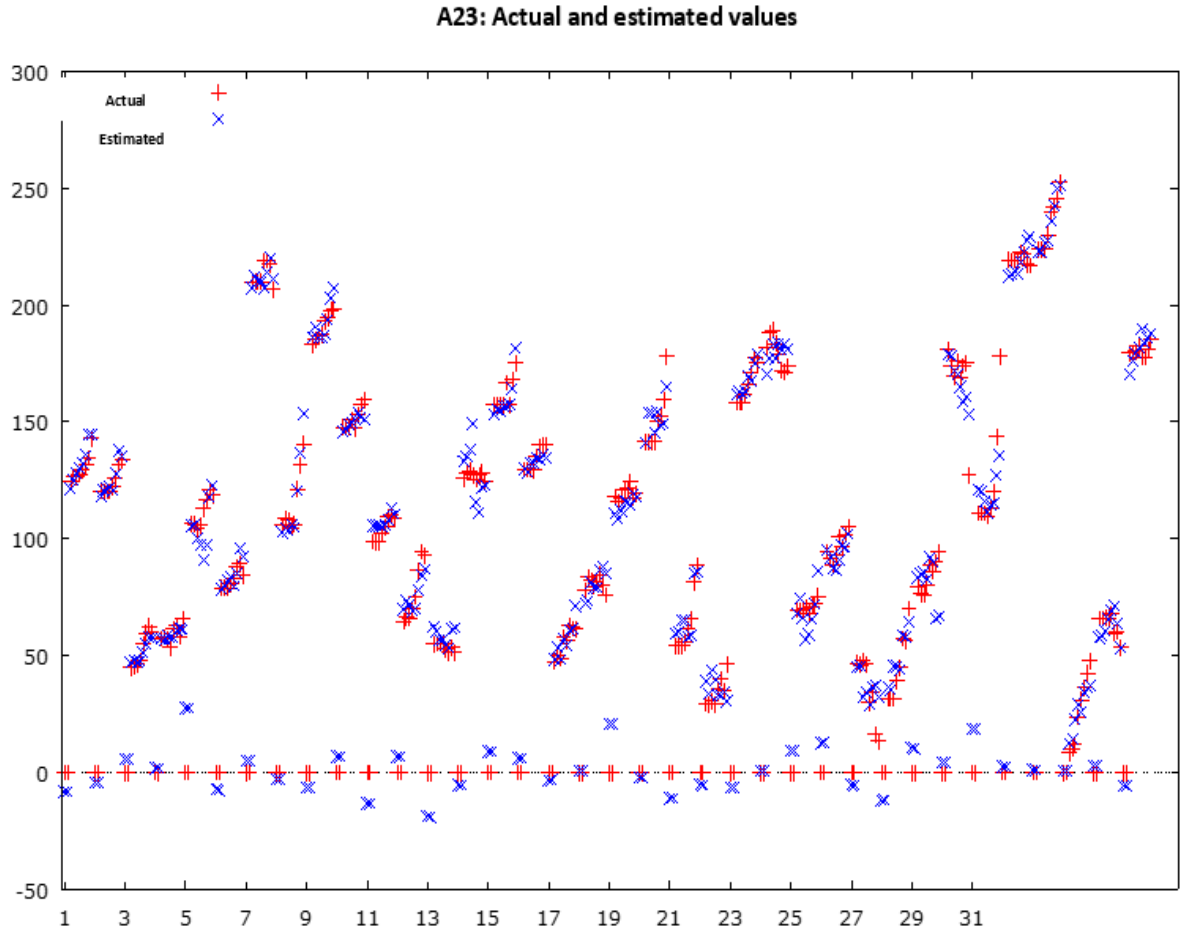


Figura 9. Time series for the group.

Fixed effects, using 360 observations					
36 cross section units included					
Time series length = 10					
Dependent variableA23					
	Coefficient	*Std.Error*	*t*	*p-value*	
const	0,950701	0,985244	0,9649	0,3353	
A1	−0,281140	0,0421248	−6,674	<0,0001	***
A2	2,16125	0,472599	4,573	<0,0001	***
A4	0,128476	0,0381636	3,366	0,0009	***
A7	−0,0547646	0,0217579	−2,517	0,0123	**
A17	−0,645702	0,0826436	−7,813	<0,0001	***
A19	0,106586	0,0204146	5,221	<0,0001	***
A22	−1,50225	0,127555	−11,78	<0,0001	***

A24	1,01073	0,0809934	12,48	<0,0001	***
A30	0,102925	0,0218550	4,709	<0,0001	***
A32	0,310971	0,0234481	13,26	<0,0001	***
A35	−0,157369	0,0314755	−5,000	<0,0001	***
A43	0,230139	0,0353402	6,512	<0,0001	***
A47	0,390616	0,0455926	8,568	<0,0001	***
A50	0,0921525	0,0414482	2,223	0,0269	**
A52	−0,180035	0,0279125	−6,450	<0,0001	***
A59	0,204691	0,0316032	6,477	<0,0001	***

Mean dependent variable	90,89693	Standard Deviation Dependent Variable	68,08024
quadratic sum of residuals	22874,33	Standard Error of the regression	8,617849
R-Squared LSDV	0,986253	R-squaredintra-groups	0,975789
LSDV F(51, 308)	433,2683	P-value(F)	1,2e-257
Log-likelihood	−1258,118	Akaike Criteria	2620,236
Schwarz criteria	2822,313	Hannan-Quinn	2700,586
rho	0,571051	Durbin-Watson	0,744045

Joint test on regressors-
TestStatistics: F(16, 308) = 775,839
p-value = P(F(16, 308) > 775,839) = 5,65204e-238
Group intercept difference test-
Null hypothesis: groups have a common intercept
TestStatistics: F(35, 308) = 11,8856
p-value = P(F(35, 308) > 11,8856) = 2,86177e-039

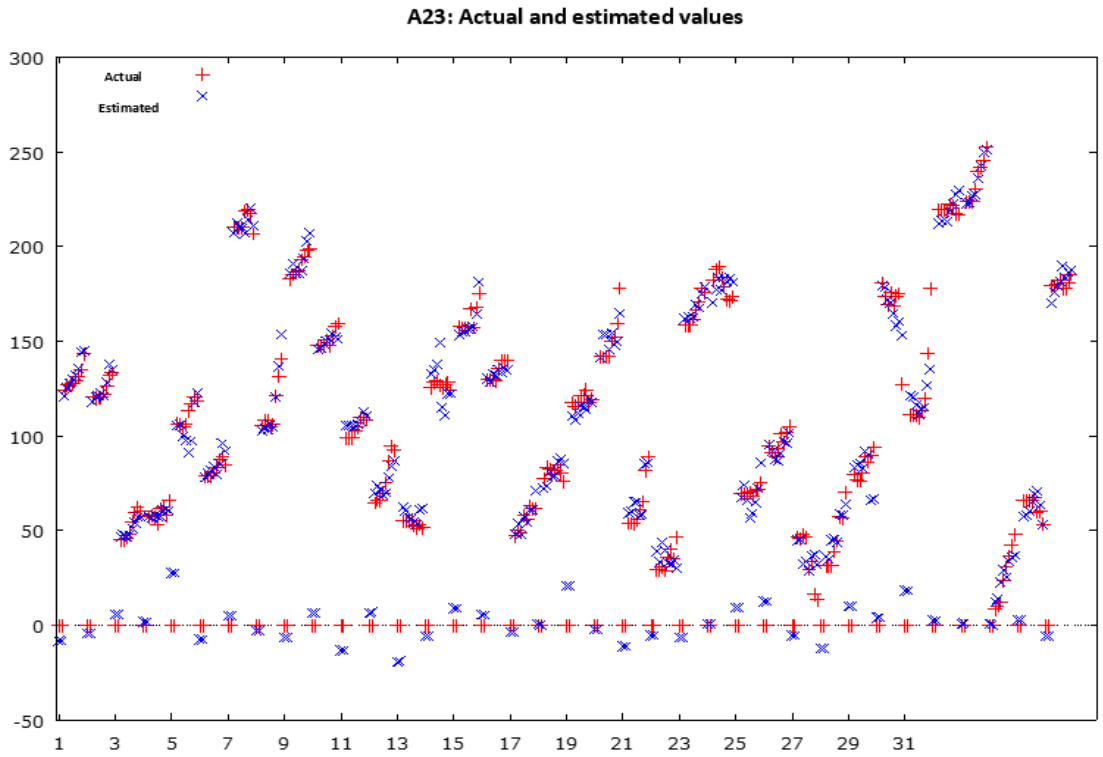


Figura 10. Time series for the group.

Random Effects (GLS), using 360 observations					
With Nerlove transformation					
36 cross section units included					
Time series length = 10					
Dependent variable A23					
	Coefficient	*Std. Error*	*z*	*p-value*	
const	1,05009	1,99078	0,5275	0,5979	
A1	-0,286488	0,0381341	-7,513	<0,0001	***
A2	2,17639	0,460250	4,729	<0,0001	***
A4	0,130041	0,0342329	3,799	0,0001	***
A7	-0,0565783	0,0201893	-2,802	0,0051	***
A17	-0,650796	0,0762643	-8,533	<0,0001	***
A19	0,105156	0,0188219	5,587	<0,0001	***
A22	-1,54931	0,120903	-12,81	<0,0001	***
A24	1,03496	0,0765418	13,52	<0,0001	***
A30	0,105059	0,0204939	5,126	<0,0001	***
A32	0,308908	0,0214607	14,39	<0,0001	***
A35	-0,167549	0,0289389	-5,790	<0,0001	***
A43	0,228324	0,0327990	6,961	<0,0001	***
A47	0,389201	0,0419941	9,268	<0,0001	***
A50	0,0945227	0,0393304	2,403	0,0162	**
A52	-0,183038	0,0264570	-6,918	<0,0001	***
A59	0,206388	0,0292861	7,047	<0,0001	***

Mean dependent variable	90,89693	Standard Deviation dependent variable	68,08024
Quadratic sum of residuals	55392,43	Standard error of the regression	12,68954
Log-likelihood	â˜’1417,315	Akaike Criteria	2868,630
Schwarz Criteria	2934,693	Hannan-Quinn	2894,898
rho	0,571051	Durbin-Watson	0,744045

Variance 'between' = 95,0973
Variance 'within' = 63,5398
Theta used for transformation= 0,749738
Joint test on regressors-
Asymptotic Test Statistics:Chi-quadro(16) = 13274,2
p-value = 0
Test Breusch-Pagan -
Null hypothesis: variance of unit-specific error= 0
Asymptotic Test Statistics:Chi-quadro(1) = 422,071
p-value = 8,64226e-094
Test di Hausman -
Null hypothesis: GLS estimates are consistent
Asymptotic Test Statistics:Chi-quadro(16) = 4,3816
p-value = 0,998072

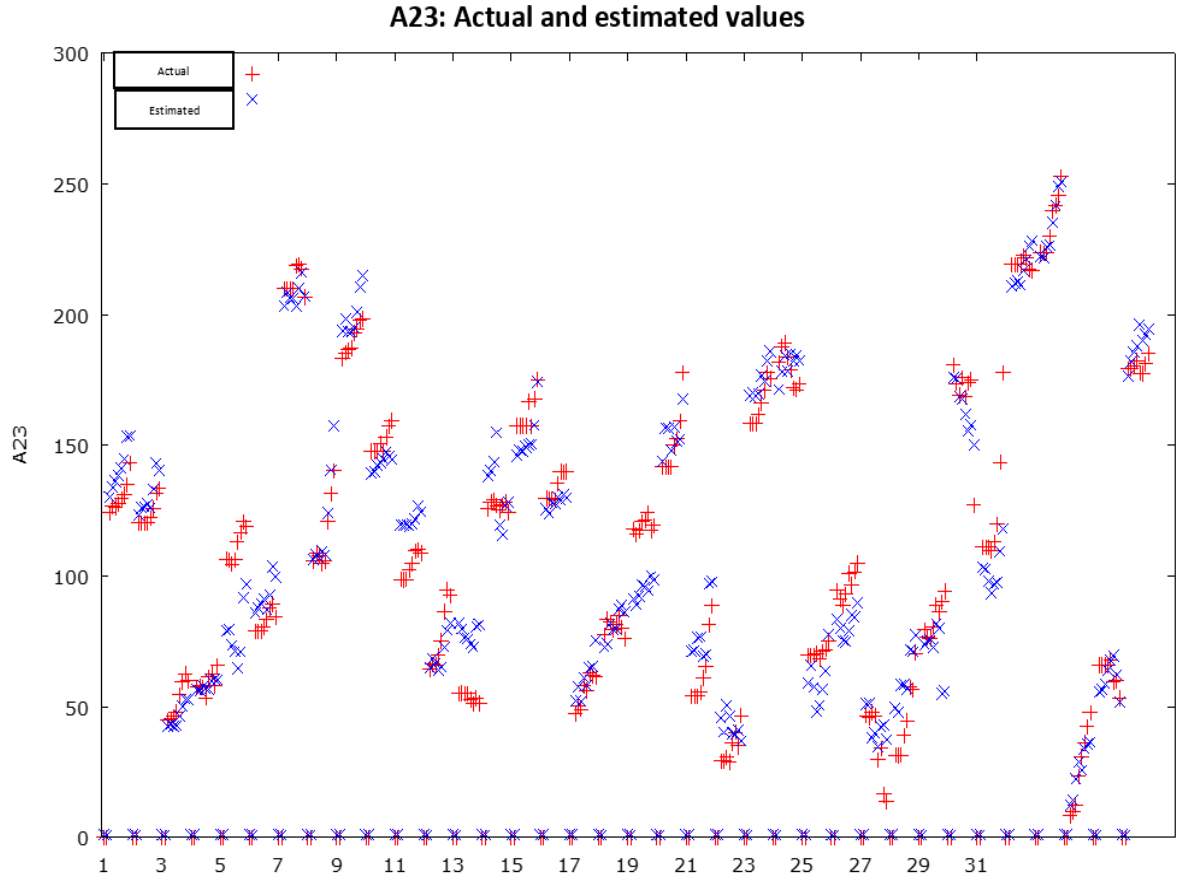


Figura 11. Time series by group

WLS, using 360 observations					
36 cross section units included					
Dependent variable:A23					
Weights based on variances of errors per unit					
	Coefficient	*Std. Error*	*t*	*p-value*	
const	0,604424	0,791174	0,7640	0,4454	
A1	−0,341398	0,0194046	−17,59	<0,0001	***
A2	2,57839	0,407356	6,330	<0,0001	***
A4	0,131435	0,0136121	9,656	<0,0001	***
A7	−0,0688263	0,0116580	−5,904	<0,0001	***
A17	−0,647442	0,0467209	−13,86	<0,0001	***
A19	0,106082	0,0123511	8,589	<0,0001	***
A22	−1,97032	0,0961969	−20,48	<0,0001	***
A24	1,27247	0,0576104	22,09	<0,0001	***
A30	0,107081	0,0135868	7,881	<0,0001	***
A32	0,308306	0,0113442	27,18	<0,0001	***
A35	−0,206108	0,0175445	−11,75	<0,0001	***
A43	0,211704	0,0195301	10,84	<0,0001	***
A47	0,348971	0,0281239	12,41	<0,0001	***
A50	0,0567744	0,0287028	1,978	0,0487	**
A52	−0,248832	0,0179978	−13,83	<0,0001	***
A59	0,176857	0,0183398	9,643	<0,0001	***
Statistics based on weighted data:					
Quadratic sum of residuals	330,0107	Standard Error Of Regression		0,980882	

R-squared	0,989772	Adjusted R-Squared	0,989295
F(16, 343)	2074,521	P-value(F)	0,000000
Log-likelihood	−495,1617	Akaike Criteria	1024,323
Schwarz Criteria	1090,387	Hannan-Quinn	1050,592
Statistics based on original data:			
Dependent variable mean	90,89693	Standard Deviation Dependent Variable	68,08024
Quadratic sum of residuals	55589,28	Standard Error Regression	12,73059

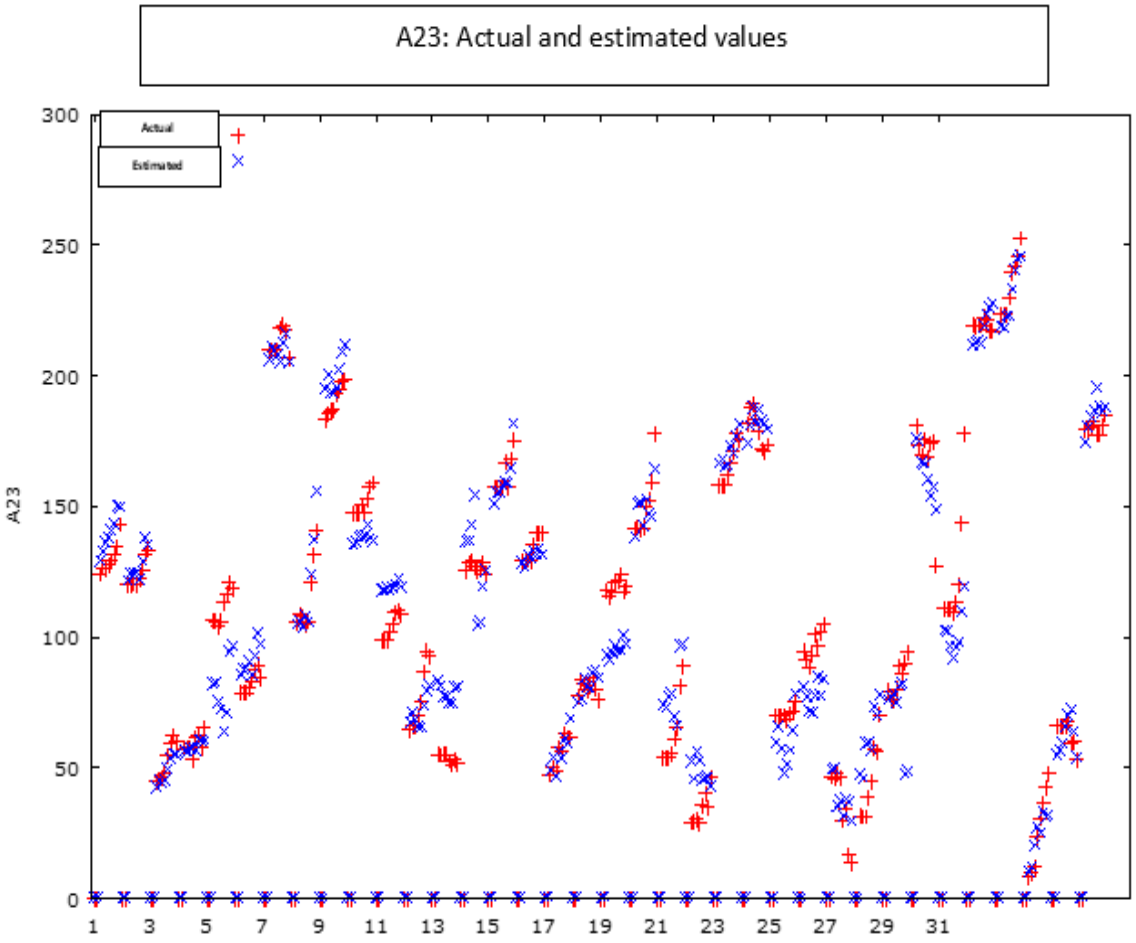


Figura 12. Time series by group