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MODELING OF SOCIO-ECONOMIC DEVELOPMENT IN EUROPEAN UNION COUNTRIES

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Introduction

To study the socio-economic development of the population of the countries of the European Union two approaches will be applied. The first one will be the modeling of the properties of synthetic variables with respect to component variables for individual determinants of socio-economic development, whereas the second one will be based on the classification of the objects under the study (European Union countries) using a cluster analysis.

The purpose of the book is to present the modified index of socio-economic development in comparison with the standard HDI index, as well as to study the socio-economic development of the European Union countries in the years 2008-2018 in terms of dynamics and space.

For this purpose, the data collected from Eurostat databases for the distinguished determinants of socio-economic development of European Union countries will be used. They will include the data from the areas of:

1. Economics and Finance
2. Science and Technology
3. Education
4. Health
5. Living Conditions

The following three dimensions have been applied to build the UN-published HDI socio-economic development index:

1. Health assessed with an index based on average life expectancy.
2. Education assessed by two variables: literacy of adult population (the share of people who can write and read with understanding) and schooling (the average number of years of schooling).
3. Income assessed on the basis of Gross National Product per capita adjusted for purchasing power parity.

The HDI has been described as “yet another redundant composite development indicator” (McGillivray, 1991) and “conceptually weak and empirically unsound” (Srinivasan, 1994). Attempts at improvement of the HDI have also been made, based on increasing the number of its variables; therein, the 2010 Human Development Report (HDR) introduced several changes in the HDI. Life expectancy remains the indicator used for health, while Gross National Income has replaced GDP as the measure used for living standards. The mean number of years of schooling and expected years of schooling now make up the dimension used for education.

In the publication a modified HDI index will be presented. It will be created on the basis of indices belonging to the groups of distinguished determinants, and then it will be shown that the determinants which the index was supplemented

with have a statistically significant impact on the synthetic measure of socio-economic development of European Union countries.

The research objectives corresponded to the research problems diagnosed, therefore they were presented in a similar structure. The main research objective was to compare the situation of European Union countries in the context of socio-economic development using the methodology of calculating the measure of socio-economic development and to present the ranking of the countries of the Economic Community according to this measure, including the presentation of Poland's position in this ranking for 2018 compared to 2008.

The main goal has been achieved on the basis of the following specific goals:

1. An examination of the diversity of socio-economic development in the European Union countries,
2. Modeling of the elasticity of synthetic variables in relation to component variables for individual determinants of socio-economic development in the European Union countries,
3. Spatial-time analysis of the European Union countries for the years 2008-2018 (including creation of rankings of European Union countries according to the synthetic measure of socio-economic development in selected years 2008, 2013 and 2018, as well as an analysis of the Moran's spatial autocorrelation indices).

In order to determine whether there is a differentiation in socio-economic development in the European Union countries, taxometric methods were applied using a synthetic measure of socio-economic development, as well as econometric models of linear and non-linear form.

For the analysis of quantitative variables, taxometric methods should be used and they should not be called taxonomic.

The author of the book warns against the impending financial crisis. The current crisis will be more severe and prolonged than the previous one (Roubini & Rosa, 2018).

European Union countries should remember that their indebtedness during the crisis will increase, and therefore they should limit state budget expenditure. This also includes Poland which spends large amounts from the state budget under the 500+ Program on children without no matter what income the family has. The amount of the subsidy one receives should definitely depend on the income of a family. This program was to support Polish families, as well as increase the fertility rate and improve the demographic situation for Poland.

Europe's economy depends on global economic processes. The current crisis caused by the Covid-19 virus pandemic is assessed as one of the most serious slumps in the last few decades. However, the economic crisis does not affect all countries equally. One of the aims of the sustainable development is to reduce the inequalities in countries and between countries, so it is so important to know the differentiation of socio-economic development in all European Union countries to allocate the necessary resources to the countries that need it most.

In the first chapter there will be presented the essence of the socio-economic development of European Union countries and its following chosen determinants: Economics and finance, Science and technology, Education, Health and the last one Living conditions. The history of Europen Union will be added.

In the second chapter of the book will be discussed the characteristics of empirical material and the analytical methods applied in the book. The third chapter will be about modeling the elasticity of synthetic variables with respect to component variables for individual determinants mentioned above.

Fourth chapter is a research chapter on spatial-time analysis of European Union countries for the period 2008-2018. In this chapter the following aspects will be presented:

1. Rankings of European Union countries according to the synthetic measure of socio-economic development in the selected years 2008, 2013 and 2018,
2. The Moran's spatial autocorrelation indices,
3. The classification of European Union countries,
4. Nonlinear models of socio-economic development for individual countries of the European Union,
5. Poland in comparison to other European Union countries in the context of socio-economic development.

In the last chapter the comparison of the results of research approaches in the analysis of the socio-economic development of European Union countries will be discussed.

Chapter 1. The essence of the socio-economic development of European Union countries and its determinants

1.1. Introduction

The purpose of this chapter is to describe selected terminological proposals presented in the literature on the subject, to indicate similarities and differences, as well as to present own position on the essence of socio-economic development.

The first issue that should be taken when considering the essence of socio-economic development is the information that development is something more than just the economic growth of a given country. Therefore, non-economic factors should also be taken into account in research on this topic.

The concept of socio-economic development in its entirety includes the phenomena that make up the essence of the concepts of "economic growth", "economic development" and "social development". Socio-economic development should be understood as the process of positive quantitative and qualitative changes (consisting in increasing and improving the existing ones and the emergence of new phenomena) in the sphere of all economic, cultural and social activities as well as socio-production and political-system relations (Kupiec, 1995).

Socio-economic development is considered in eight mutually interpenetrating aspects: social, economic, technical, technological, spatial, natural, aesthetic and temporal. There are close links and conditions between these aspects, and depending on the circumstances and conditions, the importance of each of them may be different and determined once. These aspects should be taken into account in the implementation of the socio-economic policy of the country and the region.

The socio-economic development of a country is related to the level of wealth of its inhabitants, as well as their prosperity. Prosperity is understood as the sum of the resources of a given national economy (Słaby, 2007).

Convergence (Latin convergere - to gather, become similar) is a concept that means convergence or its formation. Social convergence is understood as the process of reducing inequalities in socio-economic development between regions and countries (Horx, 2002). Economic development is equated with changes in the general living conditions of the population (Borys, 2005). It should be remembered that economic growth is a process with multilateral and significant socio-economic consequences. It is essential for the development of economies,

the standard of living of households, the size of the demand for labor, the number of employed and unemployed persons. The analyzes of the process of long-term economic growth constitute one of the most important problems of modern marcoeconomics (Tokarski, 2009). However, development is much more than economic growth; therefore, non-economic factors must be included in the analysis of a country's welfare (Milenkovica et at., 2014).

It should be stressed that there is a huge literature on the HDI that includes studies by Acharya and Wall (1994), Cahill (2002, 2004), Gormely (1995), Hicks (1997), Ivanova et al. (1998), Lüchters and Menkhoff (1996, 2000), McGillivray (1991), McGillivray and White (1993, 1994), Morse (2003), Murray (1991), Neumayer (2001), Noorbakhsh (1998a, 1998b, 2002) and Sagar and Najam (1998).

1.2. The history of the European Union

The European Union is an economic and political union of 27 democratic European states. Currently, the Member States of the European Union occupy an area of approx. 4,463,000 km, and their population exceeds 510 million people.

The beginning of post-war European integration was the establishment of the European Coal and Steel Community in 1952. The European Coal and Steel Community (ECSC) was established on the basis of the Treaty of Paris, signed on April 18, 1951 by six countries: Belgium, France, the Netherlands, Luxembourg, West Germany and Italy. The draft treaty was presented on May 9, 1950 by the French Minister of Foreign Affairs - Robert Schumann. It was based on the transnational economic and political integration of Western European states, with particular emphasis on the joint coordination of coal and steel production.

The next stage in the history of the creation of the European Union was the signing of the Treaties of Rome on March 25, 1957. The first of the Treaties of Rome established the European Economic Community (EEC) and the second the European Atomic Energy Community (EURATOM). The Treaties of Rome entered into force on January 1, 1958. As early as 1958, the European Communities had some common bodies (the Parliamentary Assembly and the Court of Justice). The full institutional connection took place on July 1, 1967, when the so-called Fusion Treaty signed on April 8, 1965. The treaty establishing a Single Council and a Single Commission of the European Communities assumed the creation of one Council of Ministers for the Communities after the merger of counterparts from the ECSC, EURATOM and EEC, and the merger of three institutions into one Commission (Community Commission): the ECSC High Authority, the EEC Commission and the EURATOM Commission.

The membership of the communities increased in 1973 as Great Britain, Denmark and Ireland joined them. Norway, which was a candidate at that time, did not decide to accede because of opposition from its citizens.

The second enlargement took place in the 1980s, when Greece (in 1981), Spain and Portugal (in 1986) joined the EEC. In 1985 there was the only case of leaving the communities: Greenland, an autonomous part of Denmark, left. With the reunification of Germany in 1990, the territory of the former German Democratic Republic became part of the European Union.

The European Union was established on November 1, 1993, by virtue of the Maastricht Treaty signed on February 7, 1992, as a result of many years of political, economic and social integration.

The third enlargement (already within the European Union) took place in 1995, when Austria, Sweden and Finland were admitted.

Within the Communities, the creation of a common single market has gradually been achieved by eliminating customs barriers, introducing common legal and technical standards and conducting a common agricultural policy. At the same time, political ties between the countries of the Communities were tightened.

The fifth and so far the largest enlargement of the Union took place on May 1, 2004. At that time, 10 countries joined the EU: Estonia, Latvia, Lithuania, Poland, the Czech Republic, Slovakia, Hungary, Slovenia, Malta and Cyprus.

On April 25, 2005, Bulgaria and Romania signed the accession treaty in Luxembourg, opening the way for these countries to join the European Union on January 1, 2007.

After signing the accession treaty in December 2011, Croatia officially joined the European Union on 1 July 2013, enlarging the EU to 28 member states.

On the night of January 31 to February 1, 2020 the United Kingdom left the European Union as the first country in history.

1.3. Definitions of the concept of socio-economic development

The word “development” usually implies a process of a growth or changes. From a civilizational point of view, development can be defined as anoverall activity in a society, consciously or subconsciously undertaken, aimed at improvements in that society (Stec, Filip, Grzebyk&Pierscieniak, 2014). The qualifier “socioeconomic” is itself a combination of two words and relates to social factors, like education, and occupation, as well as economic factors, like income and assets. Thus, socio-economic development can be defined as a process of changes or improvements in social and economic conditions as they relate to an individual, an organization, or a whole country (Roztocki&Weistroffer, 2016).

Socio-economic development is one of the most popular economic category, related with socio-economic growth and welfare. While, the effect of economic growth is multiplication of production factors, the effects of socio-economic development are broader and include not only economic aspects. The growth is of

an quantitative nature, while the development – qualitative and is also considered at the social level.

Development, as a concept, is ambiguous and is used in variety of contexts. It is, first and foremost, understood as a chain of on-going targeted and irreversible changes in the structures of complex bodies, i.e., systems (Chojnicki, 1989; Grzebyk&Stec, 2014).

Another approach, popularly known as 'Social indicators approach', is built upon the premise that development is a multidimensional process involving the transformation of the whole social system, and an appropriate measure for such a process should therefore incorporate a wide range of social and economic indicators reflecting the various aspects of the society (Khan, 1991).

There is a new urgency based on a strong sense that traditional indicators are inadequate. Furthermore, the social indicators available to date have provided an inadequate understanding of how the development process proceeds (Andrews, 1973).

In the United States a strong preference for the subjective approach to quality of life gained acceptance, while in Europe – at least in Scandinavia and to a certain degree in other parts of Europe – more emphasis was given to objective indicators which measure social conditions in the eyes of statistical experts. In both areas more and more concepts (as well as indicators) have been developed (Glatzer, 2006).

GNP per capita as a general measure of development suffers from many other limitations (McGranahan et al., 1972). One important criticism against the concept is that since it is a market-based production-oriented concept, it does not measure welfare of a society. Nordhaus and Tobin (1973) attempted to adjust GNP so that it would be a better "Measure of Economic Welfare (MEW)". This approach entails adding an estimated value of leisure and the services of consumer durables to GNP and subtracting an arbitrary amount from GNP for defence expenditures and other 'regrettables' (such as disamenities of urbanisation, pollution, crime, and so on).

The European Commission in its communication (Stiglitz, Sen&Fitoussi, 2009) clearly indicated the need to “move away from GDP” for synthetic indicators that would describe in a more comprehensive way the functioning and well-being of individuals and entire communities. Currently, these indicators may be the Human Development Index measuring the level of social development and ranking countries on the level of: material standard of living, knowledge and life expectancy, and quality of health, or the Quality of Life Index, measuring the quality of life in terms of: costs of living, education, health, democracy, safety and the environment (Kasprzyk, 2013).

The Human Development Index (HDI) was created by M. ul Haq in 1990 with the help and advice of A. K. Sen, who established the first assumptions of comprehensive measurement of socio-economic development (Anand&Sen, 1994). The index operationalized the broad concept of human development

by combining health, education and income into a composite index (Aguña&Kovacevic, 2010). The indicator itself was systematically improved. The most significant change was made in 2010 and was a reflection of several assumptions made by M. ul Haq, inter alia: a possibility of measuring the basic concept of human development to expand humans' choices; including only a limited number of variables (to keep it simply and manageable); to be constructed rather than using plethora of separate indices; covering both social and economic choices; with the use of quite flexible methodology and resistance to missing data (ul Haq, 2003). HDI is a synthetic measure based on the average of indicators covering three basic spheres of life:

1. The sphere of health, which is assessed by the ratio of the average life expectancy.
2. The sphere of education, which is assessed on the basis of the rate of educational attainment, as measured by two indicators of educational designated for the adult population, ie.: literacy (the share of people who could read and write with understanding) and schooling (the average time of education, understood as the average number years of schooling).
3. The sphere of income, which is assessed on the basis of GNP (US $) per capita, calculated according to purchasing power parity (PPP $).

The Human Development Index (HDI) is one of the most frequently used measures of socio-economic development. Until 2010, HDI was calculated according to the following procedure - it consisted of three components:

1. Gross domestic product per capita,
2. Human life expectancy,
3. The level of education of citizens measured by the enrollment index.

The indices for individual components were calculated according to the following formula:

$$I = \frac{P_f - P_{min}}{P_{max} - P_{min}} \tag{1}$$

where:

I – general index formula,
P_f – actual value of the variable,
P_{min} – minimum value of the variable,
P_{max} – maximum value of the variable.

$$HDI = \frac{1}{3} I_{le} + \frac{1}{3} I_e + \frac{1}{3} I_{PKB} \tag{2}$$

where:

I_{le} – index for the average length of human life,
I_e – index for the Gross Enrollment Ratio (GER),
I_{PKB} – index for GDP per capita.

In 2010, the method of calculating HDI was changed. Currently, it is calculated on the basis of four diagnostic variables: average life expectancy, national income *per capita* according to the purchasing power parity, the average number of years of education for residents aged 25+ and the expected number of years of education for children starting education.

The Human Development Index (HDI) is a composite measure of health, education and income, where its first result was published by the United Nations Development Programme (UNDP), in the first Human Development Report on 1990 (Maccari, 2014). The HDI is a composite index which intends to capture the idea of human development by focusing on three dimensions: a long and healthy life, knowledge and a decent standard of living. Four indicators have been selected to measure these concepts: life expectancy at birth, mean years of schooling, expected years of schooling, and Gross National Income (GNI) per capita (Aguña&Kovacevic, 2011).

The innovative feature of the HDI was the creation of a single statistic, as a summary measure of human development, able to describe both social and economic development. With HDI the progress of a country is assessed against minimum levels that a society needs to survive over time. Indeed, on the technical point of view the HDI is normalized establishing a minimum and a maximum value for each dimension, called goalposts, in such a way that each country is marked in relation to these goalposts, within a value between 0 and 1. This method allows reaching a rank of the countries, based on the human development achievement. Before 2010, HDI was calculated combining three indices: life expectancy index (LEI), educational index (EI) and income index (II) with a simple mean. At a later stage, with Human Development Report 2010, a new methodology of calculation through a geometric mean of the same three components was introduced. Unlike the old HDI, the new HDI takes into account differences in attainment across dimensions. In this way, poor performance in any dimension is directly reflected in the new HDI, which captures how well a country's performance is across the three dimensions (Human Development Report, 2011).

1.4. The characteristics of determinants of socio-economic development

1.4.1. Introduction

The publication distinguishes the following determinants of socio-economic development:

1. Economics and Finance
2. Science and Technology
3. Health

4. Education
5. Living Conditions

On the basis of the literature on the subject and the recommendations of scientists, it was concluded that it was necessary to enrich the HDI index with determinants related to Science and Technology, as well as to Living Conditions. Both of these determinants play a significant role in the socio-economic development of the European Union countries and cannot be omitted from the analysis.

In the following sections of the book, the essence of each of the determinants of socio-economic development will be discussed. The figure 1 shows the impact of individual determinants on the socio-economic development.

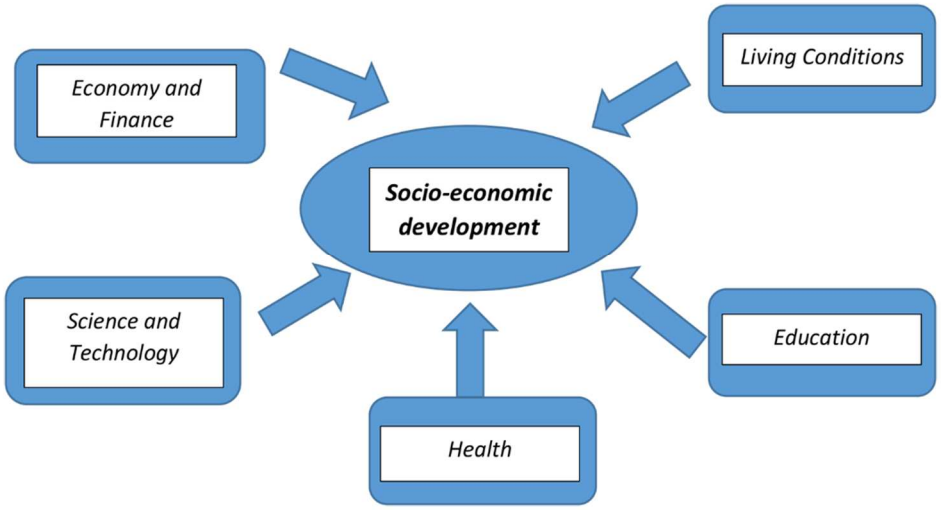

Fig. 1. The impact of individual determinants on the socio-economic development (*Source: author's own study*)

1.4.2. Economy and Finance

Economic growth means changes that involve growing the entire economy due to the ones taking place in its composite elements. Economic growth is, therefore, a measure of short-term quantitative economic changes. It is expressed with the help of economic growth indicators that include qualitative changes in the country's socio-economic structures. (Stec et al., 2014).

According to Nowa Encyklopedia Powszechna PWN (2004), economic development is qualitative and structural changes in the national economy that result from economic growth. The Encyclopedia Britannica (2013) defines economic development as a process involving quantitative and qualitative changes, as a result of which primitive low-income economies are transformed

into higher-income economies. According to The Princeton Encyclopedia of the World Economy, economic development covers three areas beyond per capita income growth, namely (Rejnert&Rajan, 2009):

- development of the country's economic system - economic development is to be facilitated by structural changes, including urbanization, an increase in the size of enterprises, a relative decline in the importance of the agricultural sector (both in employment and in GDP creation), for the benefit of the processing industry and services, geographical expansion of markets, increase in diversity manufactured and exchanged products;
- distributing the benefits of economic development that reduces the poverty area;
- sustainable development which is defined as development that allows meeting the needs of current generations at a level that does not limit an ability to meet the needs of future generations.

One of the main objectives of the European Union is to promote economic, social and territorial cohesion and solidarity between the member states. One of the main ways to achieve a coherent target is to finance projects in regions where GDP per capita is less than 75% of the European Union average. 81.5% of the budget allocated to the increase in cohesion in the years 2007-2013 was spent for this purpose. Recognizing that cohesion is not only limited for relatively poor regions, another important way to achieve it is to provide funding to boost the performance of richer regions with the aim of achieving indirect EU-wide effects and subsequently eradicating poverty in poorer regions.

The “Europe 2020” strategy, due to the specific moment of its creation, was a response to the economic crisis. At the same time, it took into account the long-term challenges facing Europe related to globalization, aging of societies and the growing need for rational use of resources. As in the Lisbon Strategy, economic growth continues to be the main focus, but particular attention was paid to the sustainability of this process. The implementation of the Europe 2020 Strategy was to be a knowledge-based, low-carbon economy that promoted environmentally friendly technologies, conserved resources, created new "green" jobs, while maintaining care for social cohesion.

The main goal of the strategy was to build a sustainable future. To get it, it was necessary to go beyond the horizon of short-term goals. The main goal for Europe was to get back on track and then stay on the path of development. Its assumptions are more jobs and a higher standard of living. The strategy shows that Europe can develop in an intelligent and sustainable way, can promote social inclusion, can find a way to create new jobs and define the direction of development of societies.

In order to meet the assumptions of the “Europe 2020” program, a strong economic governance model will be needed, which would allow to show which determinants have the greatest impact on the socio-economic development in the

EU countries. The most urgent task for the Union will be to overcome the crisis. However, even before the crisis, in many areas the Union did not develop fast enough. This applies to the following:

- the average rate of growth in Europe was structurally lower than that of our largest economic partners – mainly due to differences in productivity levels increasing over the last decade. This mainly results from the differences in business structures, a lower level of investment in R&D and innovation, insufficient use of information and communication technologies, the reluctance of some of our societies to innovate, difficulties in market access and a less dynamic business environment;
- despite progress, employment rates in Europe are still significantly lower than in other parts of the world;
- societies are aging faster and faster, a smaller working population and an increase in the number of pensioners will put an additional burden on welfare systems.

In the past, the EU and its Member States managed to overcome problems in the face of difficulties. The largest single market in the world with a single currency was created in Europe in the 1990s. A few years later the division of Europe ended; New Member States joined the Union, while others began seeking membership or closer relations with the Union. Actions under the European Economic Recovery Plan helped avert economic collapse and welfare systems protected citizens from even greater poverty.

Europe can mobilize itself in times of crisis and adapt its economy and society to the new situation. Today, Europeans must face change again to prevent the effects of the crisis, to remedy Europe's structural weaknesses and to deal with increasingly serious international challenges.

Open Europe operating under international regulation is the best way to reap the benefits of globalization, leading to a growth and employment. At the same time, Europe should strengthen its position on the international stage by playing a leading role in shaping the future global economic order in the G20 forum and pursuing European interests by actively using all available tools.

Cooperation within the EU is producing results. The Union will only be able to influence global politics if it acts together. The financial crisis of 2008 showed what could happen when mathematical models were not used and decisions about further sustainable development were not made on their basis.

The main task facing the European Union today is economic recovery. Other long-term challenges are globalization, the need for scarce resources and an aging population. For nearly twenty years unemployment in Western Europe has been the most important social problem and a sign of unused resources, while at the same time the needs are not fully met.

Many people question the importance of GDP as a measure of welfare. When assessing welfare, one should not only rely on material goods and income, but also take into account other elements influencing the quality of life and welfare that are not included in the GDP account, such as the health of residents or the quality of education.

GDP as a measure of welfare is not without its drawbacks, as it overlooks many important factors that affect the standard of living. One of them is the amount of time off work. GDP also does not provide information on the distribution of income. The amount of GDP per capita informs about the situation of the average inhabitant of the country, but this average ignores differences in the situation of various people.

Previous researchers (Davidson, 2000) have addressed the hypothesis that GNP (or GDP) per capita cannot be considered the only and crucial indicator of a country's performance, as it does not capture the overall well-being of its population (Milenkovica et al., 2014).

1.4.3. Science and Technology

The main reason why the standard of living is higher today than in the last century is the advancement of technological knowledge. A smart growth means increasing the role of knowledge and innovation as the driving forces of our future development. This requires improving the quality of education, improving the results of research activities, supporting the transfer of innovation and knowledge in the European Union countries, full use of information and communication technologies, and ensuring that innovative ideas turn into new products and services that would contribute to an increasing growth, job creation and solving social problems in Europe and in the world.

The development of science and higher education causes economic growth. It is assumed that rich countries (the national product is the main reason here) can afford to allocate more funds to the development of scientific and research potential than poor countries (Grabiński, 2003).

The fundamental condition for the flow of scientific and research knowledge, especially accumulated in new technologies, is the development of economic cooperation with countries better equipped with human capital and new technologies. The best conditions for the development of international economic cooperation are created by markets that are not isolated by tariff barriers, administrative barriers and state protectionist policies that limit the free exchange of goods, services, capital and labor (Woźniak et al., 2009).

1.4.4. Education

Education as a social process has been associated with a man since the very beginning of their existence. The definition of this process comes from the Latin word educatio, which means upbringing, training.

Education is a process that facilitates learning or acquiring knowledge, skills, values, beliefs and habits. Educational methods include a discussion, teaching, training and targeted research (Dewey, 1944).

The education system can and does to a greater or lesser extent perform three basic functions (Kłóska&Howaniec, 2001):

- shaping the social structure according to the level of education and the related level of income and prestige,
- increasing the modernization potential of the society,
- adjusting the structure of education to the needs and structure of the labor market.

Today, most economists believe that knowledge is a new factor of increasing importance. The primary task of the education system is to impart knowledge and practical skills. A well-trained workforce is essential for sustained economic growth and development (Roman, 2005). In the post-industrial society, more and more often referred to as the "knowledge-based society", the role of schools is changing. Its primary task is no longer to impart encyclopedic knowledge, but to teach how to learn. Education and the labor market are two social spheres that influence each other. The development of the economy depends to a large extent on the quality of human resources provided by the education system.

1.4.5. Health

According to the WHO, health is "a state of complete physical, social and mental well-being and not merely the absence of disease or infirmity" (WHO, 2011). As such, health is considered a fundamental contributor to the welfare of every country.

Health is one of the most important factors affecting both life expectancy and standard of living. Health is defined as a state of physical, mental and social well-being (Health for All 2000 Report). Thus, this definition does not only mean the absence of disease or disability, but also an ability to fulfill social roles, an ability to adapt, i.e. adapt to changing environmental conditions, and to deal with these changes as effectively as possible. Therefore, health is a generator of well-being, joy in life, i.e. what directly determines the quality of life and the degree of satisfaction with it (Tylka, 2000). Health is currently treated as (Tuszyńska-Bogucka&Bogucki, 2005):

- value that allows an individual to fully meet their needs, aspirations and satisfaction, as well as adaptively cope with their environment,

- a resource thanks to which a person can fully develop, and thus contribute to the development of society,
- a means to achieve a better end.

Therefore, health should be protected (through prophylaxis), improved (through health promotion) and also multiplied (through treatment and rehabilitation). "Improving health and the related quality of life" is a strategic goal set by the World Health Organization for the European Union. This goal can be achieved through the implementation of the following activities (Kassyk-Rokicka, 1999):

- changes in the lifestyle of the population,
- shaping healthy working environment,
- reducing inequalities in health status and access to health services.

1.4.6. Living Conditions

Living conditions are one of the basic determinants of socio-economic development. They also indicate the material position of anindividual. Adequate residence is a matter of living in dignity. The house is a place of rest and physical regeneration (Sen, 1987). Moreover, it is the center of family life where next generations are born and brought up (Quality of life in Europe, 2004).

Living conditions are an important determinant of the standard of living of the population. When describing the living conditions, the average usable floor space per household member is taken into account, as well as its equipment, among others, with sanitary installations, water supply system and central heating. However, nowadays, the above-mentioned installations are not a major challenge, and therefore it should be considered whether these aspects should be taken into account in the study of socio-economic development. A more key issue in the analysis of living conditions are problems related to financial issues, i.e. income and expenses of an individual. Significant variables in this group are: the average monthly disposable income per person, the amount of the average wage and the amount of the minimum wage (Kuc, 2016).

Living in dangerous or insufficiently good conditions increases the risk of social exclusion (Wilson, 2006). The conditions which a person lives in also affect their health, as well as the sense of security.

The living standard is one of the most important subject matters in public statistics (Piecuch, Chudy-Laskowska, Szczygieł, 2019). The living conditions, in general, define the entirety of factors determining the satisfaction of human needs, while the living standard refers to the degree of satisfaction of these needs (US Łódź, 2010). The living standard can be treated as the synonym of the broadest meaning of living conditions (Piasny, 1993).

In the conditions of the crisis, the following negative economic phenomena have been observed (Zioło, 2013; Kołodko, 2011):

- limiting consumption and, as a result, reducing employment in the production sphere and increasing the number of unemployed people (especially men),
- reducing the number of companies,
- deterioration in the standard of living of the population.

Poverty issues are linked to living conditions aspects. Poverty according to the State Scientific Publishing House Encyclopedia (PWN) this is a 'social phenomenon based on the lack of sufficient means to satisfy the basic needs of a human or a family'. Webster's New College Dictionary defines poverty as 'a state of being poor, having very little money or being in need of a specific quality'. The World Bank, however, claims that the poor 'do not have enough resources to satisfy the basic needs'.

Definition adopted by UNO on the summit in Copenhagen in 1995 is two-dimensional. It consists of absolute poverty that is characterised by the inability to satisfy basic needs of a human: food, water, washing facilities, health, accommodation and information. It depends not only on income of the household but also on the access to the basic services which in some situations depend on the income. The general poverty takes into account both economic and social aspect of the phenomenon (the lack of possibility to make decisions and participate in cultural, civil and social life) which is reflected by "powerlessness", "no decision making", "deprivation of dignity" (Lisner, 2007).

1.5. Other measures of the standard of living

To measure human development more comprehensively, the Human Development Report also presents four other composite indices. The Inequalityadjusted HDI discounts the HDI according to the extent of inequality. The Gender Development Index compares female and male HDI values. The Gender Inequality Index highlights women's empowerment. And the Multidimensional Poverty Index measures non-income dimensions of poverty.

1. ***Living Conditions Index (LCI)*** which measures housing, nutrition, health and healthcare, cultural and sports activities, ecology, mobility, and leisure activities.
2. ***Quality of Life Index (QOL)*** according to Britannica, is the degree to which an individual is healthy, comfortable, and able to participate in or enjoy life events. It is based on a methodology that combines the results of subjective life satisfaction surveys with objective factors of the quality of life in various countries, and additionally covers safety, family and friendship status, working conditions, migrations, and GDP per capita, unemployment and poverty.
3. ***Human Development Index (HDI)*** is used to assess the level of social development of a given country or a region against the background of

others or in comparison with the results from previous years. It is determined on the basis of measures relating to the three dimensions of social development; they are: life expectancy, enrollment and GDP per capita (according to PPP).

4. ***Human Poverty Index (HPI)*** is a measure established by the United Nations. It is a synthetic measure that represents the level of poverty of society in relation to the development of the population. It determines the scale of "impoverishment" in such dimensions of social life as: health status, life expectancy, level of educational achievement, as well as income distribution and standard of living. It is commonly considered to be more reliable than the HDI Human Development Index, or even GDP – because in the case of HPI not only earnings in relation to the demographic structure are taken into account, but also the comparison of the degree of poverty with the level of intellectual development.

HPI-1 for developing countries *(a=3)*:

$$HPI1 = \left[\frac{(P_1^a + P_2^a + P_3^a)}{3} \right]^{1/a} \tag{3}$$

P_1 – probability of underlife up to 40 years (x100),
P_2 – an index of the lack of literacy skills,
P_3 – unweighted average of the number of people without access to drinking water sources and children with underweight.

HPI-2 for developed countries *(a=3)*:

$$HPI2 = \left[\frac{(P_1^a + P_2^a + P_3^a + P_4^a)}{4} \right]^{1/a} \tag{4}$$

P_1 – probability of underlife up to ***60*** years (x100),
P_2 – an index of the lack of **functional** reading and writing skills,
P_3 – population below the poverty level (< 50% of the median income),
P_4 – long-term (> 12 months) unemployment rate.

As the a parameter increases, more weight is assumed for more specific (non-constitutive) factors. Currently, this index has been replaced by the Multidimensional Poverty Index.

5. ***Human Wellbeing Index (HWI)*** and its approach known as a "health assessment" mainly deals with the relationship between humans and the ecosystem and their interactions with each other (Prescott-Allen, 2001). Health assessment is related to five dimensions of human anxiety, each of which is characterized by bipolarity:
   - health and population are linked to the goal of people enjoying a long healthy life, thus keeping abundance within human and natural resources,
   - private household and state assets suggest that individuals and households have material and income assets to meet basic needs and a prosperous livelihood, and that society has the resources to support economic activity and ensure prosperity,
   - knowledge allows people to have the skills to modernize and deal with a change, to lead a prosperous and sustainable life and to fulfill its potential, and culture deals with spiritual development, creativity and self-expression,
   - society means freedom and rule - human rights are fully respected, and an individual can choose and influence who decides about the order and order of society,
   - 'gender justice' and households allows an equal distribution of benefits and losses between households, men and women.
6. ***Weighted Index of Social Progress (WISP)*** is an index that was built in 1976 by R. Estes of the University of Pennsylvania. It was presented in two forms: as International Index of Social Progress (ISP) and its weighted version – Weighted Index of Social Progress (WISP). PSI and WISP are estimated on the basis of 46 social indicators organized into 10 groups, such as: education, health care, women's status, social welfare, demography, geographic conditions, political status, economic situation, cultural diversity and defense. Each factor is scored a "plus" or "minus", depending on whether it has a positive or negative impact on social development. Interestingly, only countries with a population of more than 1 million are taken into account when compiling the rankings. According to R. Estes, ISP is to be a measure that will allow measuring not only the level of advancement of social development in a given country, but also estimating the level of economic development and information on the political situation. Additionally, R. Estes wanted the index to identify the country's ability to provide its citizens with maximum welfare. Over time, both ISP indices and the weighted WISP, namely changes in their values, have become a frequently used starting point to determine whether and to what extent a nation has improved its ability to meet the basic social needs of the general public. Both the ISP and WISP indices are published every 5 years (Estes, 2006).

7. ***Better Life Index (BLI)*** was introduced in 2010 by the OECD to measure socio-economic well-being in member countries. It measures 20 different indicators across 11 sectors of the economy. It includes an assessment of income earned, assets owned, living conditions (including the number of rooms per person, the share of housing expenses, access to the bathroom), the situation in the labor market, the level of unemployment and its structure, employment conditions, the level of education, the state of the natural environment, community bonds and social commitment, health, life satisfaction, safety and balance between work and leisure.
8. ***Life Expectancy Index (LEI)*** – Life expectancy is a statistical measure of the average time an organism is expected to live, based on the year of its birth, its current age and other demographic factors including gender. *Life Expectancy Index (LEI)* is one of the indicators considered in the human development index of a country. LEI equels 1 when life expectancy at birth is 85 and equels 0 when life expectancy at birth is 20. The most commonly used measure is life expectancy at birth (LEB), which can be defined in two ways. Cohort LEB is the mean length of life of an actual birth cohort (all individuals born a given year) and can be computed only for cohorts born many decades ago, so that all their members have died. Period LEB is the mean length of life of a hypothetical cohort assumed to be exposed, from birth through death, to the mortality rates observed at a given year (Shryok, Siegel, 1973).
9. ***Multidimensional Poverty Index (MPI)*** – in the global MPI, people are counted as multidimensionally poor if they are deprived in one-third or more of 10 indices, where each index is equally weighted within its dimension, so the health and education indices are weighted 1/6 each and the standard of living indicators are weighted 1/18 each. The intensity of multidimensionally of the poor is measured by the average number of weighted deprivations they experience. The MPI is the product of the incidence of poverty (proportion of poor people) and the intensity of poverty (average deprivation score of poor people) and is, therefore, sensitive to changes in both components. The MPI ranges from 0 to 1 and higher values imply higher poverty.

Chapter 2. The characteristics of empirical material and analytical methods applied

2.1. The characteristics of empirical material

The necessity of finding a new measurement of the quality of life of societies is emphasized by international organizations and especially scientists. That is why the author decided to modify the standard measure. Nowadays important factors are also science and technology and the standard of human living.

That is why, in this paper the following determinants of socio-economic development will be used:

1. Economy and Finance
2. Science and Technology
3. Health
4. Education
5. Living Conditions

The construction of the synthetic measure of development requires the division of diagnostic variables set to stimulants and destimulants. Variables included in the set of stimulants have been marked with the sign (+), while the (-) granted destimulants. The transformation of destimulants to stimulants was made according to the following formula:

$$x_{ij}^{\{S\}} = \max_i x_{ij}^{\{D\}} - x_{ij}^{\{D\}} \tag{5}$$

where:

x_{ij} – value of the j-th variable for the i-th country,

S – symbol indicates stimulant, while the symbol D destimulant.

Then, after the transformation of destimulants to stimulants, the normalization of variables was used according to the following formula:

$$u_{ij} = \frac{x_{ij}}{\max_i \{x_{ij}\}} (i = 1,...,n; j = 1,...,m) \tag{6}$$

where:

u_{ij} – normalized value of the j-th variable for the i-th country,
n – number of countries,
m – number of variables.

Synthetic measure of the socio-economic development was calculated by the following formula:

$$u_i = \frac{1}{r}\sum_{q=1}^{r} u_{iq},\ (i = 1,...,n;\ q = 1,...,r) \tag{7}$$

where:

u_{iq} – synthetic variable value for the i-th country calculated on the basis of the variables belonging to the q-th determinant,
r – number of determinants.

In contrast, measures of socio-economic development according to separate determinants was calculated using the following formula (Zeliaś, 2004):

$$u_{iq} = \frac{1}{m}\sum_{j=1}^{m} u_{ij},\ (i = 1,...,n;\ j = 1,....,m) \tag{8}$$

A detailed list of indicators used for the construction of indicators for individual determinants of socio-economic development has been given below. Indicators have been selected based on the availability of Eurostat data.

I. Economy and Finance

1. Unemployment rate (-)
2. GDP per capita 1 (+)
3. Indicator of real expenditure per 1 inhabitant (+)

II. Science and Technology

1. Gross domestic expenditure on R&D (% of total expenses) (+)
2. Human resources in science and technology (% of the active population) (+)
3. The number of patent applications submitted to the European Patent Office per million inhabitants (+)
4. The number of researchers per 1000 inhabitants (+)

III. Health

1. Life expectancy (+)
2. Self-perceived long-standing limitations in usual activities due to health problem (-)
3. Self-reported unmet needs for medical care due to being too expensive (-)
4. Number of beds in hospitals per 100 000 inhabitants (+)

IV. Education

1. Participation rate in education and training (persons aged 25 to 64 years old) (+)
2. The percentage of people with at most lower secondary education and with no further education at the age of 18-24 years old (-)
3. The percentage of people gaining or with higher education aged 15 to 64 (+)

V. Living Conditions

1. The percentage of people who are unable to make 'ends meet' (-)
2. The rate of people at risk of poverty (-)
3. Share of people living in under-occupied dwellings (+)

In the following Table 1 the descriptive statistics for the synthetic measure in the analyzed years 2008-2018 are presented.

It can be observed that the value of the mean of the synthetic measure still increases in the analyzed period. The minimum value was obtained in the year 2010. The maximum values were obtained in the years 2017 and 2018. In all the analyzed years, the left-hand asymmetry should be noted, which means that for most of the countries analyzed, the values of the socio-economic development measure were higher than the average value for the European Union. Coefficients of variation for all analyzed years are higher than 10% which means that there is a sufficiently large variation in the indicator in individual years.

For the European Union the coefficient of variation equels 14.38% in 2018, while for the HDI the same coefficient equels 4.24% which means that HDI indicator is characterized by too little diversity of socio-economic development in the case of EU countries.

Table 1. Descriptive statistics for the synthetic measure of socio-economic development in the European Union for the years 2008-2018

Variable	Descriptive statistics (Synthetic measure)								
	Mean	Median	Min	Max	Low quartile	High quartile	Std. deviation	Coeffi-cient of variation	Asy-mmetry
Synthetic measure 2008	0.59	0.59	0.41	0.74	0.53	0.66	0.09	15.60	-0.17
Synthetic measure 2009	0.59	0.58	0.42	0.74	0.52	0.67	0.10	16.45	-0.03
Synthetic measure 2010	0.59	0.58	0.38	0.75	0.51	0.68	0.11	18.77	-0.17
Synthetic measure 2011	0.60	0.60	0.39	0.76	0.51	0.69	0.11	18.27	-0.18
Synthetic measure 2012	0.60	0.60	0.40	0.76	0.51	0.70	0.11	18.28	-0.15
Synthetic measure 2013	0.60	0.59	0.41	0.76	0.52	0.70	0.11	18.39	-0.15
Synthetic measure 2014	0.61	0.59	0.43	0.76	0.53	0.70	0.11	17.61	-0.15
Synthetic measure 2015	0.62	0.61	0.45	0.77	0.54	0.70	0.10	16.14	-0.20
Synthetic measure 2016	0.62	0.61	0.42	0.77	0.55	0.70	0.10	16.15	-0.29
Synthetic measure 2017	0.63	0.63	0.45	0.78	0.56	0.72	0.10	15.35	-0.38
Synthetic measure 2018	0.64	0.64	0.47	0.78	0.58	0.73	0.09	14.38	-0.45

(*Source: author's own research*)

In the Table 2 rankings of the European Union countries according to HDI indicator and the synthetic measure of socio-economic development for the year 2018 are presented. The first three places are taken by Sweden, the Netherlands and Ireland in HDI ranking and Sweden, Finland and Denmark in synthetic measure ranking both of them for the year 2018. It can be also observed that there are changes for particular countries, the biggest one are for Greece and Italy as well as for Hungary. In the figure 2 the comparison of Human Development Index values and synthetic measure of socio-economic development in the European Union countries for the year 2018 were presented.

Table 2. Rankings of the European Union countries according to HDI indicator and the synthetic measure of socio-economic development for the year 2018

No.	Country	HDI 2018	Ranking HDI 2018	Synthetic measure 2018	Ranking SM 2018	Position difference
1	Sweden	0,945	1	0,777	1	0
2	The Netherlands	0,944	2	0,733	6	4
3	Ireland	0,942	3	0,735	5	2
4	Germany	0,939	4	0,721	8	4
5	Denmark	0,93	5	0,751	3	-2
6	Finland	0,925	6	0,757	2	-4
7	The United Kingdom	0,92	7	0,707	10	3
8	Belgium	0,919	8	0,720	9	1
9	Luxembourg	0,916	9	0,731	7	-2
10	Austria	0,914	10	0,737	4	-6
11	Slovenia	0,902	11	0,701	12	1
12	France	0,901	12	0,704	11	-1
13	Spain	0,893	13	0,606	20	7
14	Czechia	0,891	14	0,687	13	-1
15	Malta	0,885	15	0,643	14	-1
16	Italy	0,883	16	0,550	24	8
17	Estonia	0,882	17	0,630	16	-1
18	Cyprus	0,873	18	0,639	15	-3
19	Greece	0,872	19	0,466	28	9
20	Poland	0,872	20	0,609	19	-1
21	Lithuania	0,869	21	0,586	21	0
22	Slovakia	0,857	22	0,612	18	-4
23	Latvia	0,854	23	0,497	25	2
24	Portugal	0,85	24	0,568	22	-2
25	Hungary	0,845	25	0,615	17	-8
26	Croatia	0,837	26	0,565	23	-3
27	Bulgaria	0,816	27	0,489	26	-1
28	Romania	0,816	28	0,483	27	-1

(*Source: author's own research*)

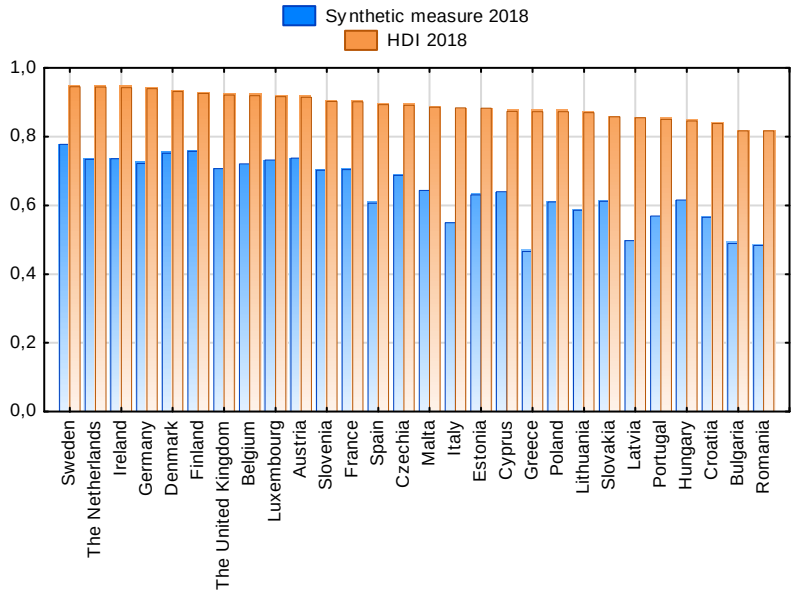

Fig. 2. The comparison of Human Development Index values and synthetic measure of socio-economic development in the European Union countries for the year 2018 (*Source: author's calculations*)

In the Figure 3 the scatter chart of Human Development Index values and synthetic measure of socio-economic development in the European Union countries for the year 2018 is shown. The correlation coefficient between the HDI indicator and synthetic measure of socioeconomic development was calculated and it equals 0,88. It is stastically significant.

The chart 4 presents the values of the measure for the Economic and Finance determinant for 2008 and 2018. The countries that in 2018 took the highest place in the ranking for the Economic and Finance determinant were Luxembourg, Denmark and Austria. The last three places in the ranking were taken by Romania, Spain and Greece. When analyzing the determinant of Economics and Finance, it was noticed that Luxembourg was the leader in the European Union in 2018. The position of this country did not changed compared to 2008. The countries that achieved the highest growth for this determinant compared to 2008 were Germany and Slovakia. Each of these countries achieved an increase of 8 places compared to 2008. In the ranking for 2018, the position of Poland increased by 6 places compared to 2008. The largest decrease was recorded for Cyprus and Greece. In these countries the economic crisis was most clearly visible in this aspect of socio-economic development.

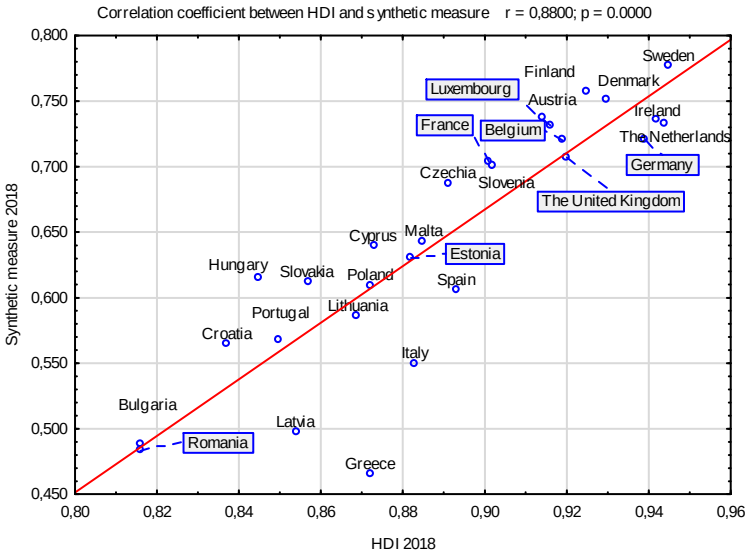

Fig. 3. The scatter chart of Human Development Index values and synthetic measure of socio-economic development in the European Union countries for the year 2018
(Source: author's calculations)

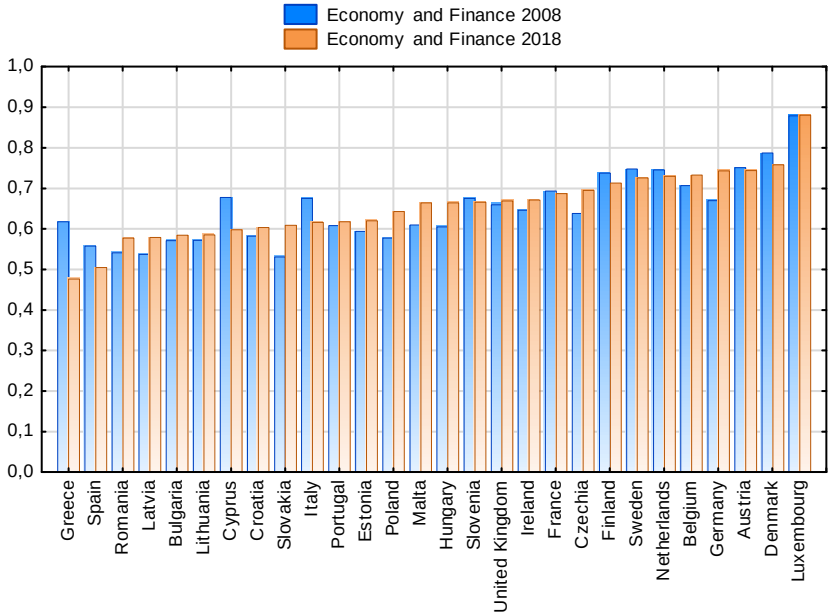

Fig. 4. The comparison of Economy and Finance determinant in European Union countries for the years 2008 and 2018
(*Source: author's calculations*)

Germany was the country that in 2018 achieved the highest position for the determinant of Science and Technology and maintained its leading position compared to 2008. The last three places were taken by Greece, Cyprus and Latvia. When analyzing the Science and Technology determinant, the largest increase in the period analyzed was recorded for Austria and Poland. The largest decreases were recorded for Finland, Malta and Ireland. The results obtained are presented in figure 5.

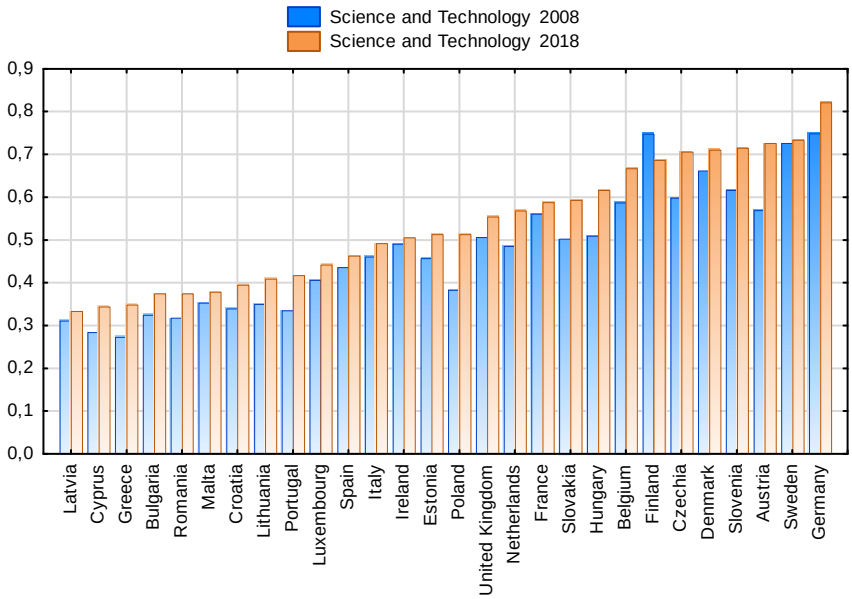

Fig. 5. The comparison of Science and Technology determinant in European Union countries for the years 2008 and 2018 (*Source: author's calculations*)

In 2018, the countries that ranked highest for the Health determinant were Ireland, Cyprus and Austria. For this determinant, the highest increase compared to 2008 was recorded in Croatia and Bulgaria. The largest decreases were recorded for Belgium and Greece. Poland in the health ranking fell by 4 positions compared to 2008. The lowest values in this respect were achieved by the following European Union countries - Portugal, Lithuania and Latvia. The obtained results are presented in figure 6.

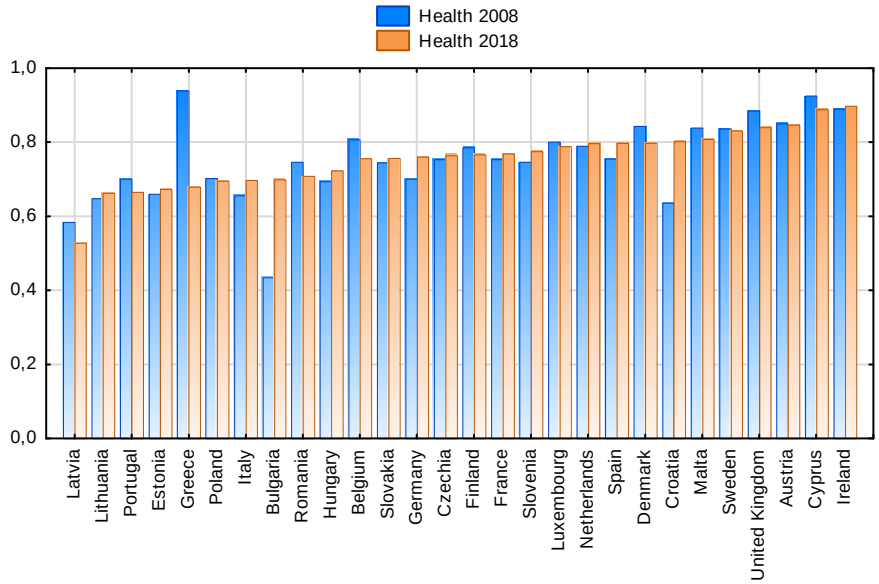

Fig. 6. The comparison of Health determinant in European Union countries for the years 2008 and 2018
(*Source: author's calculations*)

In 2018, Sweden, Finland and Luxembourg took the highest places in the Education ranking. Luxembourg was the country with the highest growth for this determinant compared to 2008. The country's position increased by 11 places in the ranking for 2018 compared to 2008 and this was the largest increase in the case of the measure created for the determinant Education. Outside Luxembourg, the largest increases were recorded for France, Greece and Portugal. On the other hand, the largest decreases were recorded for Slovenia and Germany. Poland's situation turned to a disadvantage in terms of education, as its position fell by 3 places. The last three places in the ranking for Education were taken by Bulgaria, Italy and Romania. The obtained results are presented in figure 7.

The last of the determinants analyzed are Living conditions. When presenting the results for this determinant, it was observed that Malta was the leader in 2018 in the European Union. The country grew by 3 places compared to 2008. The next places were taken by Ireland and the Netherlands. The greatest increase in value for this determinant was achieved by Great Britain and Hungary. The largest decline in the ranking in terms of living conditions was recorded for Croatia and Cyprus. Poland took 21st place in the ranking for Living Conditions, compared to 2008 it increased by 1 position. The lowest values were obtained by Romania, Bulgaria and Greece. The obtained results are presented in figure 8.

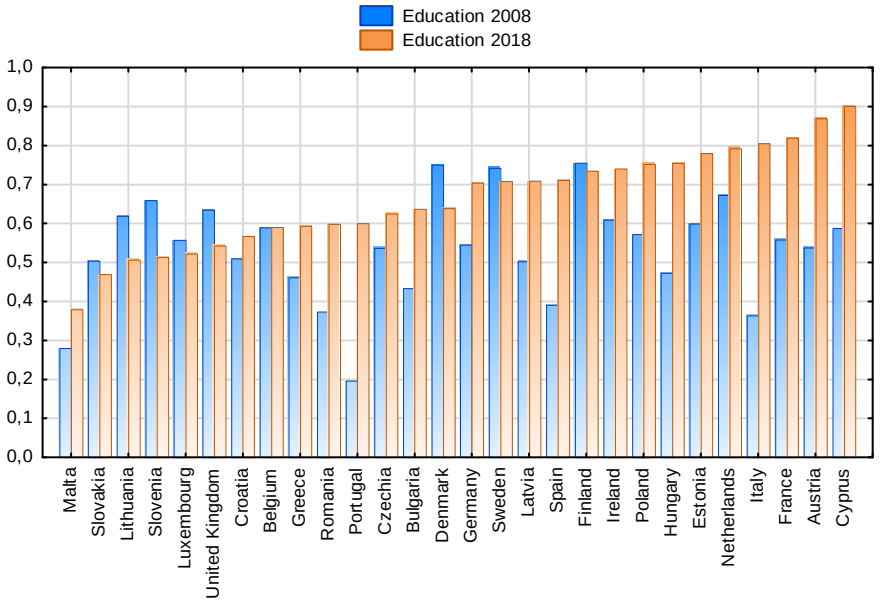

Fig. 7. The comparison of Education determinant in European Union countries for the years 2008 and 2018
(*Source: author's calculations*)

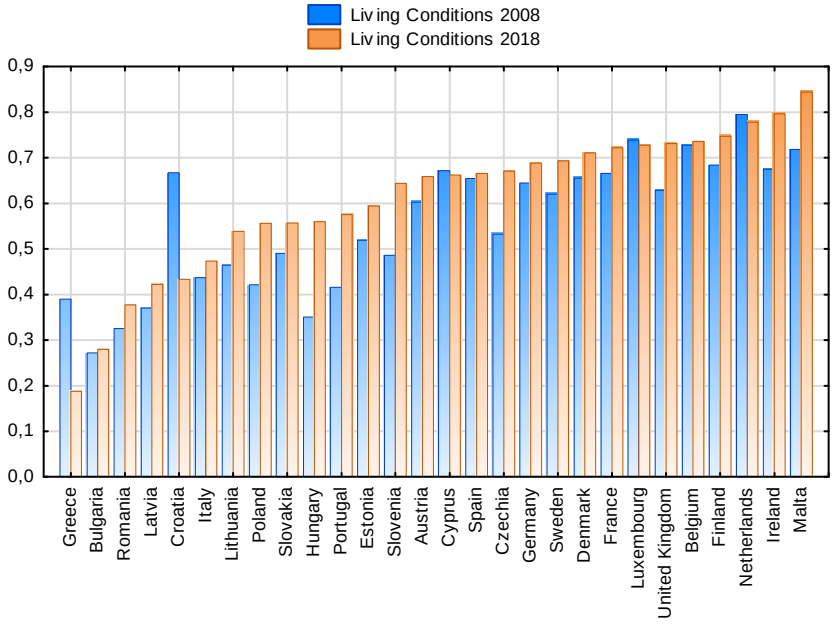

Fig. 8. The comparison of Living Conditions determinant in European Union countries for the years 2008 and 2018
(*Source: author's calculations*)

2.2. The characteristics of the analytical methods used

Synthetic measures are created by transforming the units described by several variables into one-dimensional space, obtaining the so-called synthetic variable (Grabiński, 1992). The following stages of the transformation described above should be distinguished:

1. determination of a set of diagnostic variables,
2. reduction of the dimension of the classification space,
3. determining the direction of variable preferences,
4. determining the system of weights for variables,
5. bringing the variables to mutual comparability,
6. determining the value of a synthetic variable based on the selected aggregation formula (Zeliaś, 2000).

In studies on the assessment of the standard of living of the population, the basic problem is the selection of diagnostic variables that characterize the studied phenomenon (Kowerski, 1983; Michalos, 2006). These variables are usually selected arbitrarily by the authors of the study (examples of categories of variables are presented in the section on the methods of measuring the standard of living).

The next stage in the construction of synthetic measures is the reduction of the dimensions of the classification space. From a practical point of view, simple methods are of particular importance in the process of reducing diagnostic variables, both in terms of conceptual and numerical significance (Malina&Zeliaś, 1998). One of the simple methods of eliminating diagnostic variables is the coefficient of variation:

$$v_j = \frac{s_j}{\left|\bar{x}_j\right|} \quad (j = 1, ..., k) \tag{10}$$

where:

s_j – standard deviation,

$\bar{x}_j$ – arythmetic mean.

Diagnostic variables for which the inequality is satisfied are eliminated:

$$v_j \leq \varepsilon \tag{11}$$

where ε is an arbitrarily given small positive number. Usually, it is assumed that $\varepsilon = 0.1$.

The substantive and formal importance of a given variable is determined not only by its high variability, but most of all by the difficulty in achieving its high values (Rusnak, Siedlecka&Siedlecki, 1982). This means that the variable is all the more important, the fewer tested objects achieve its high values.

The third stage of creating an aggregate variable is determining the direction of variable preferences in relation to the considered property of the structure. This stage requires the division of variables into:

- stimulants,
- destimulants,
- nominants.

A stimulant is understood as a variable whose high values allow classifying a given object as better from the point of view of the aggregate criterion. In the case of a destimulant, the situation is opposite, i.e. high values indicate that a given object is classified as worse. On the other hand, a nominant is a feature whose certain values, defined as "normal", allow classifying a given object as better from the point of view of the aggregate criterion, while the objects described by all other values are worse due to this criterion (Zeliaś, 2000).

The fourth step in the synthetic measures development is to determine the system of weights for the set of final diagnostic variables. The biggest problem of this stage is the fact that there is no unambiguous way of determining the weighting system for variables included in the final list of diagnostic variables (Grabiński, Wydymus&Zeliaś, 1989). In empirical research, fixed or differentiated weights can be used. When determining differentiated weights, two approaches to the problem analyzed can be distinguished. The first is the so-called an expert judgment method based on non-statistical information. On the other hand, the second approach is based on statistical information and the evaluation of the information value of individual variables obtained on this basis (Kowerski, 1983).

The fifth stage of synthetic measures development consists in bringing diagnostic variables to mutual comparability. Mutual comparability of variables is obtained by applying normalization methods, the general formula of which can be written as follows:

$$z_{ij} = \left(\frac{x_{ij} - a}{b} \right)^p \tag{12}$$

where:

x_{ij} – real variable,
z_{ij} – transformed variable,
a, b ($b \neq 0$), p – normalization parameters.

One can distinguish the following normalization methods:

a. Standardization – when a is equal to the arithmetic mean, b is the standard deviation, and $p = 1, 2, ...,$
b. Uniitarization – when a equals zero, the lowest or the highest value, b is the range, and p = ½, 1, 2, ...,
c. Ratio transformations – when a equals zero, b is any number different from the range value, $p = 1$.

The last step in the procedure of "constructing" a synthetic variable is determining its value based on the selected method of aggregation of diagnostic variables. There are two types of diagnostic variable aggregation methods: standard and non-standard. A typical representative of synthetic pattern variables is the so-called taxonomic measure of Hellwig's development (Hellwig, 1968). Alternative proposals for a synthetic measure of development were presented in their works by, among others Cieślak (1974), Bartosiewicz (1976), Strahl (1978), Borys (1978) and Nowak (1990).

In the case of non-standard synthetic measures of development, the average values from the observations characterizing the objects are most often used, based on the arithmetic, harmonic or geometric mean. For instance, additive synthetic measures based on the arithmetic and harmonic mean are defined by the following formulas (assuming that weights are constant for all diagnostic variables):

$$z_i = \frac{1}{k}\sum_{j=1}^{k} z_{ij} \quad (i = 1,...,m) \tag{13}$$

$$z_i = \frac{k}{\sum_{j=1}^{k} \frac{1}{z_{ij}}} \quad (i = 1,...,m) \tag{14}$$

where:

z_i – i-th realization of the synthetic variable Z.

The synthetic measure of development constructed in this way has the following interpretation: the i-th object is characterized by the higher level of development, the higher the value of the measure z_i is.

Multiplicative synthetic measures based on the geometric mean or on common factors occurring in factor analysis are less frequently used in practice (Pociecha, Podolec, Sokołowski&Zając, 1988).

Chapter 3. Modeling the elasticity of a synthetic measure in relation to component variables for individual determinants

3.1. Introduction

An econometric model is an equation or a system of equations that presents the essential quantitative relationships between the considered econometric phenomena:

$$Y = f(X_1, X_2, X_3, ..., X_n, \varepsilon).$$

$$Y = \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \cdots + \alpha_n X_n + \boldsymbol{\varepsilon} \quad (15)$$

The structure of each econometric model is defined by:

- variables,
- type of functional relationship,
- model parameters,
- random component.

Types of variables in the econometric model:

- endogenous (explained) – variables, the shaping of which is explained by the econometric model by means of a functional notation of dependencies,
- exogenous (explanatory) – variables that allow the explanation of the model of the shaping of endogenous variables, but are not the subject of the model's analysis themselves.

Shaping of the random component in the econometric model is one of the basic sources of knowledge on whether the model has been built correctly. Its value is the difference between the empirical value in a given period and the estimated theoretical value for the values of explanatory variables in a given period (or earlier, in the case of series with time-delayed endogenous variables). By definition, a model (in a broad sense) is a simplified picture of reality. Building an econometric model, certain phenomena occurring in economics are "simplified" to the form of a function. At the same time, it is expected that the model will reflect reality as closely as possible, and the difference between the actual value (empirical value) and what was calculated on the basis of the model (theoretical value) will be as small as possible that is, as close to zero as possible.

3.2. Model building (aspect of correct data quality) and model verification

3.2.1. Construction of the model

The construction of the model should start with the formulation of an economic problem, then one should decide on the variables that will belong to the group of explanatory variables, and the ones which belong to the group of explained variables. An important aspect is also the selection of appropriate empirical data. Be aware of the quality of the data used. The data should be obtained from reliable sources. The development and preparation of the data for an analysis is another important aspect in the procedure of building an econometric model and an analysis based on the evaluation of the estimated structural parameters.

The process of determining the econometric model can be divided into the following stages:

Step 1. Model specification,

Step 2. Estimation of model parameters,

Step 3. Model verification,

Step 4. Use a model for forecasting.

Verification of the model consists in assessing the matching of the econometric model to empirical data. The verification of the model consists in answering the question whether the econometric model explains the shaping of the dependent variable to a sufficiently high degree. For this purpose various measures of model compliance with empirical data are applied. The basic measures of this type are: the standard deviation of the residuals, the coefficient of random variation, the coefficient of convergence and the coefficient of determination.

The measures for assessing the matching of the econometric model to empirical data include:

1. **Residual variance**
   The formula for the residual variance is as follows:

$$S_e^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-k} \tag{16}$$

2. **Standard deviation of the residual component**
   The residual standard deviation, i.e. the average absolute error, is the square root of the variance of the residual term, which is an estimate of the variance of the random term. It is calculated from the following formula:

$$S_e = \sqrt{S_e^2} \tag{17}$$

The standard deviation of the residual component informs how much on average the theoretical values (calculated on the basis of the estimated form of the econometric model) deviate from the empirical values. It informs about the average deviations of the empirical (real) values of the dependent variable from its theoretical values calculated from the model, i.e. by how much, on average, the model is wrong when estimating the value of the dependent variable (the size of this "error" is expressed in units of this variable).

3. **The coefficient of residual variation** informs about what part of the mean value of the explained variable is **the standard deviation of the residual component,** i.e. to what extent the variable explained is influenced by random (random) factors. It is usually expressed as a percentage, and determined using the formula:

$$\boldsymbol{V_e = \frac{S_e}{\bar{y}} 100\%} \tag{18}$$

4. **The coefficient of convergence** informs to what extent the general variability of the dependent variable is not explained by the econometric model:

$$\boldsymbol{\varphi^2 = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y}_i)^2}} \tag{19}$$

5. **The coefficient of determination** informs about the extent to which the general variability of the variable is explained by the econometric model, or what part of the variability (variance) of the explained variable in the sample coincides with the correlations with the variables included in the model. It is, therefore, a measure of the extent to which the model fits into the sample. The coefficient of determination takes values from the interval [0; 1] if the model has an intercept and the least squares method was used to estimate the parameters. Its values are most often expressed as a percentage. The fit of the model is the better the closer the value of R^2 is to one. It is expressed by the formula:

$$\boldsymbol{R^2 = 1 - \varphi^2} \tag{20}$$

$$\boldsymbol{R^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y}_i)^2}} \tag{21}$$

Model verification is aimed at checking whether the econometric model is acceptable for its use and is performed according to the following stages:

- An assessment of the error that the estimated equation is burdened with,
- An assessment of errors in estimating structural parameters,
- An assessment of the level of model fit to empirical data,
- Research on properties of random deviations.

3.2.2. Veryfication of the model

1. **Testing the significance of the structural parameters of the model**
   We put the null hypothesis against the alternative hypothesis:

$$H_0 : \alpha_i = 0$$
$$H_1 : \alpha_i \neq 0 \tag{22}$$

The null hypothesis assumes that the α_i parameter is insignificantly different from zero, i.e. that the X_i variable, on which it stands, has an insignificant influence on the dependent variable. Rejecting the H_0 hypothesis means accepting the alternative hypothesis H_1 which states that the parameter value differs significantly from zero (i.e. the variable X_i has a significant impact on the variable explained).
The significance test that allows verifying the hypothesis H_0: $\alpha_i = 0$ is based on the distribution of the Student's *t* statistic determined by the formula:

$$t_{a_i} = \frac{a_i - \alpha_i}{D(a_i)} \tag{23}$$

where:
a_i – evaluation of the *i*-th parameter,
α_i – the real value of the parameter (according to the null hypothesis $\alpha_i = 0$),
$D(a_i)$ – the mean error of the parameter estimate.

2. **Research on the properties of the residual component**
   The batch test (also called the Stevens batch test or the Wald-Wolfowitz batch test) is used to test the randomness of the residual component. It is a non-parametric sample randomness test. It is used, inter alia, to check if the results of the experiment meet the postulate of sample randomness.
   The null and alternative hypotheses are formulated as follows:
   H_0: the selection of units for the sample is random; the model is linear.
   H_1: the selection of units for the sample is not random; the model is non-linear.

One of the methods of verifying the above-mentioned hypothesis is the series test.

3. **An examination of the symmetry of the residual component**
   The study of the symmetry of the distribution of residuals for a sample is based on the verification of the hypothesis that the number of positive residues does not differ significantly from the number of negative residues. The null and alternative hypotheses in the study of the symmetry of the residual term take the following form:

   $H_0: \left[\frac{m}{n} = \frac{1}{2}\right]$ that is, the distribution of the residuals is symmetrical
   $H_1: \left[\frac{m}{n} \neq \frac{1}{2}\right]$ that is, the distribution of the residuals is not symmetrical

   The test of this hypothesis is the statistics:

$$t_0 = \frac{\left[\frac{m}{n} - \frac{1}{2}\right]}{\sqrt{\frac{\frac{m}{n}\left(1 - \frac{m}{n}\right)}{n-1}}} \tag{24}$$

   where:
   m – number of positive (or negative) residues;
   n – total number of residues.

4. **Study on the autocorrelation of the random component. Durbin Watson test.**
   In order to test the autocorrelation of the residual component, a null hypothesis should be made, stating that the autocorrelation coefficient of the model residuals is statistically equal to zero, and therefore an alternative hypothesis for which the autocorrelation coefficient of the model residuals is statistically different from zero.

   $H_0: \rho_1 = 0$
   $H_1: \rho_1 \neq 0$

   ρ_1 is called the autocorrelation coefficient (correlation dependence of random components ε_t and their first lags ε_{t-1}) which can be expressed by the formula:

$$\rho_1 = \frac{cov(\varepsilon_t, \varepsilon_{t-1})}{D(\varepsilon_t)D(\varepsilon_{t-1})} \tag{25}$$

One of the most popular statistics used to verify the hypothesis of the **lack of first-order autocorrelation** of the disturbing components in static models is the Durbin-Watson statistic. In this statistic, two sets of hypotheses are possible. If the correlation of the residuals in the sample is positive then:

H_0: $\rho_1 = 0$
H_1: $\rho_1 > 0$

This means that as the null hypothesis we assume the absence of **autocorrelation** of **random components** because the autocorrelation coefficient of residuals takes values close to zero. It is verified in favor of an alternative hypothesis, which assumes a positive time correlation of random components, which is statistically significant.
The second set of hypotheses is:

H_0: $\rho_i = 0$
H_1: $\rho_i < 0$

In this case, the null hypothesis also excludes any correlation in the residual values of the model. However, in this system, the alternative hypothesis assumes a statistically significant **negative autocorrelation**.
Unknown random terms cannot be used because they are not known and therefore the observations of the residuals e_1, e_2, e_3,…, e_n are used instead to calculate the rest of the model,
The Durbin-Watson test statistic is expressed by the formula:

$$d = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2} \tag{26}$$

The tables of the Durbin-Watson test present the critical values of d_L and d_U for the appropriate number of observations n and the number of explanatory variables k.
The Durbin-Watson statistic is calculated as the quotient of the sum of squared residual increments and the sum of squared residuals. After appropriate mathematical transformations, this statistic can be written in an approximate form as a twice the difference 1 and the **residual autocorrelation** coefficient.

$$DW = 2(1-\rho_1) \tag{27}$$

This approximation is the more accurate the larger the sample size. The Durbin-Watson statistic takes values from 0 to 4. The closer to the extreme

values of the DW occurrence interval, the closer the **autocorrelation coefficient** is to the absolute value of 1. If DW takes values close to 0, then ρ_1 is close to one, while ρ1 is close to -1 when DW is equal to 4. Lack of autocorrelation of random terms occurs when DW is equal to 2.

Critical values d_L and d_U are used to verify the null hypothesis. If the obtained DW value is within the range (d_L; 0), then we have grounds to reject the null hypothesis of the absence of **autocorrelation** in favor of the alternative hypothesis of the presence of a statistically significant, positive **correlation of random components**. When DW is in the range (2; d_U), we have no grounds to reject the null hypothesis. The range, the boundaries of which are determined by d_L and d_U, is called the inconsistency area. In the event that DW belongs to this range, the test does not resolve the issue of autocorrelation, we cannot decide to accept or reject the null hypothesis. As mentioned before, the greater the number of observations results in a greater accuracy of approximation of the DW statistics, and thus the greater the sample size, the smaller the area of inconsistency.

5 **An investigation of homogeneity of variance of a random component**

One of the assumptions for the use of the Least Squares is the homogeneity of variance, the so-called homoscedasticity of variance. The homoscedasticity of variance can be checked with the use of many tests, one of which is the Goldfeld-Quandt test. In this test, the following hypotheses are formulated for two parts of the population. They are presumed to be characterized by different variances of the random component:

$\boldsymbol{H_0}$: $\boldsymbol{\sigma_1^2 = \sigma_2^2}$ **the random component is homoscedastic (homogeneous)**
$\boldsymbol{H_1}$: $\boldsymbol{\sigma_1^2 > \sigma_2^2}$ **the random component is heteroscedastic (non-homogeneous)**

The Fisher-Snedecor statistic is used to verify the H_0 hypothesis. If H_0 is true, the following statistic has a Fisher-Snedecor F distribution.

$$F = \frac{s_1^2}{s_2^2}, \quad s_1^2 > s_2^2 \tag{28}$$

6. **Normality**

In the case of large samples, verification of the hypotheses about the normality of the random component distribution can be made using the Jarque-Bera test. In this test, the similarity of the third and fourth moments of the disturbance distribution to the known values of these moments in the normal distribution is verified.

The Jarque-Ber (JB) test presents the following statistical hypotheses:

H_0: the distribution of a random term is a normal distribution
H_1: the distribution of the random term is not a normal distribution

The test of the JB test is the statistics:

$$JB = n\left[\frac{1}{6}B_1 + \frac{1}{24}(B_2 - 3)^2\right] \tag{29}$$

$$A = \sqrt{B_1} \qquad B_2 = K$$

$$A = \frac{\frac{1}{n}\sum_{i=1}^{n} e_i^3}{\left(\sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}\right)^3} \tag{30}$$

$$K = \frac{\frac{1}{n}\sum_{i=1}^{n} e_i^4}{\left(\sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}\right)^4} \tag{31}$$

The JB statistic has an asymptotic chi-square distribution with two degrees of freedom. The area of rejection of the null hypothesis is right-sided. This means that for a predetermined significance level, α H_0 is rejected if JB> chi-square alpha (the random term has no normal distribution). In case if JB ≤ chi-square alpha, then there is no reason to reject H_0.

3.3. Models of the synthetic measure in relation to the component variables for the determinant of Economics and Finance

In the next part of the book, nonlinear models were applied, namely a second degree polynomial. The estimated parameters of the models will make it possible to examine the impact of individual indicators used in the book on the synthetic measure of socio-economic development. In the next stage of the analysis, static panel models were estimated regarding the relationship between economic growth and the level of socio-economic development and its determinants.

Economic growth stimulates entrepreneurship and fosters the creation of new jobs, which at the same time translates into an improvement in the material situation of the population. The pace of changes in GDP was also positively influenced by the pace of changes in the synthetic variable related to housing conditions.

Table 3 presents the values of Pearson's linear correlation coefficients between the economic indicators and the synthetic measure of socio-economic development of European Union countries. The following economic indicators were used in the research: total general government revenue, unemployment rate, GDP per capita.

Table 3. Correlation coefficients between economic indicators and synthetic measure of socio-economic development in European Union countries

Variable	Correlations (marked correlations are significant with p < ,05000)					
	Mean	**s**	**Total general government revenue**	**Unemployment rate**	**GDP per capita in PPS**	**Synthetic measure of socio-economic development**
Total general government revenue	42,56	6,30	1,00	-0,11	0,28	0,52
Unemployment rate	9,15	4,60	-0,11	1,00	-0,31	-0,50
GDP per capita in PPS	99,88	42,21	0,28	-0,31	1,00	0,70
Synthetic measure of socio-economic development	0,61	0,10	0,52	-0,50	0,70	1,00

(*Source: author's calculations based on Eurostat databases*)

The analysis shows that GDP per capita in PPS has a strong, statistically significant effect on the synthetic measure of socio-economic development. This is demonstrated by the value of the Pearson's linear correlation coefficient (r = 0.7). Total general government revenue has a moderate, positive statistically significant effect on the synthetic measure of socio-economic development (r = 0.52). In the case of unemployment rate it was obtained that this variable had the moderate, negative impact on the synthetic measure of socio-economic development (r = -0.5).

Models of regression functions (presented in figures 9-11) allowed obtaining estimated parameters for each of the economic measures used in this analysis. Their interpretation will allow stating if the synthetic measure increases or decreases, if each variable increases by 1. This will allow estimating which

determinant has the greatest impact on the socio-economic development of EU countries.

The models of regression functions (presented in figures 9-11) provide estimates of marginal effects for each of the particular economic indicator, as well as the model fit statistics. The marginal effects reveal the expected magnitudes of change in the synthetic measure associated with one unit increases in the value of each variable used. The model fit statistics allows assessing which of the economic indicators has the greatest individual ability to predict the socio-economic development of EU countries. It can be observed that the indicator GDP per capita (r = 0.7) has the greatest impact on socio-economic development.

The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to decrease in the synthetic measure by 0.01 if the unemployment rate is a determinant. The estimated marginal effects reveal that a one unit growth in measurement of the determinant is expected to increase in the synthetic measure by 0.002 if GDP per capita is the determinant. The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to increase in the synthetic measure by 0.009 if the total general government revenue is the determinant. The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to decrease in the synthetic measure by 0.01 if the people at risk of poverty are a determinant. All the parameters are statistically significant.

The implementation of the objective required the use of descriptive-statistical methods, in particular regression method (Least Squares Method – LSM).

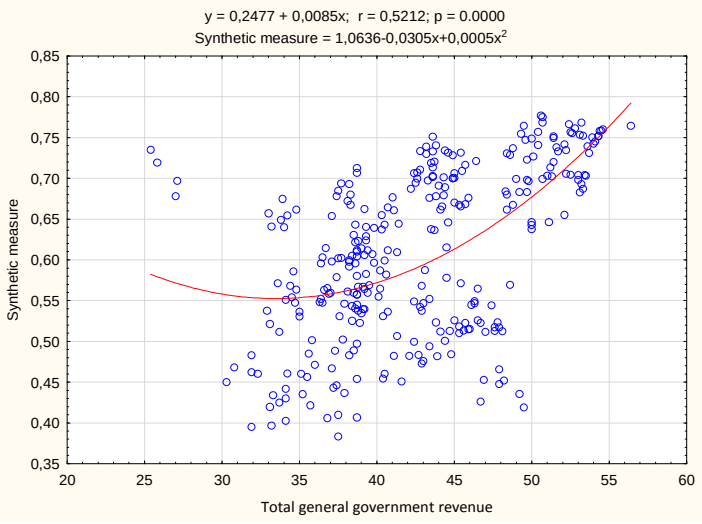

Fig. 9. Regression function parameters – synthetic measure in terms of the total general government revenue
(*Source: author's calculations*)

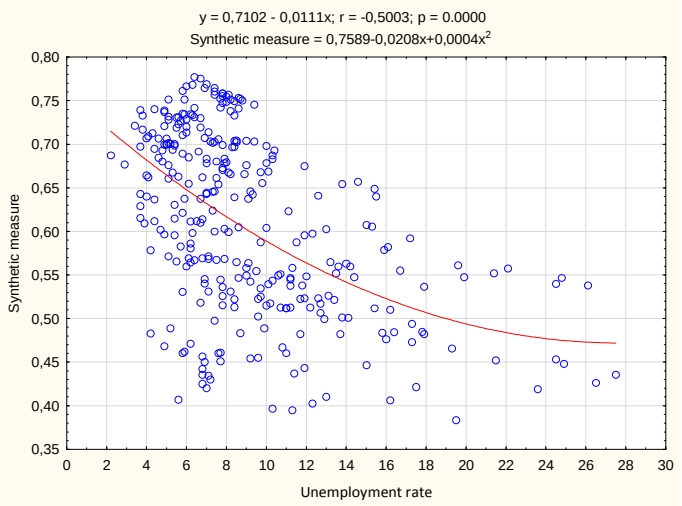

Fig. 10. Regression function parameters – synthetic measure in terms of unemployment rate
(*Source: author's calculations*)

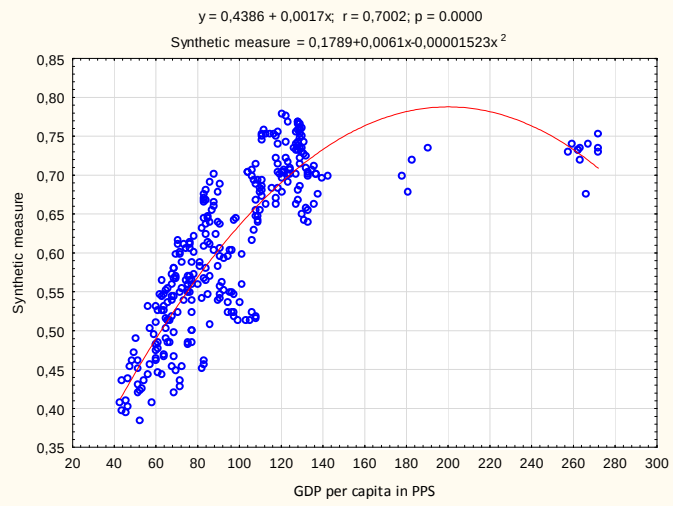

Fig. 11. Regression function parameters – synthetic measure in terms of GDP per capita
(*Source: author's calculations*)

3.4. Models of the synthetic measure in relation to the component variables for the determinant of Science and Technology

Table 4 presents the values of Pearson's linear correlation coefficients between the component variables for the determinant of Science and Technology and the synthetic measure of socio-economic development of EU countries. The following indicators were used in the research: research and development expenditure, human resources in Science and Technology and employment in high- and medium-high technology manufacturing sectors and knowledge-intensive service sectors.

Table 4. Correlations between the synthetic measure and the component variables for the determinant of Science and Technology

Variable	Correlations (marked correlations are significant with p < ,05000)					
	Mean	s	Research and development expenditure	Human Resources in Science and Technology	Employment in high- and medium-high technology manufacturing sectors and knowledge-intensive service sectors	Synthetic measure of socio--economic development
Research and development expenditures	1,56	0,88	1,00	0,58	0,31	0,79
Human Resources in Science and Technology	43,31	8,89	0,58	1,00	-0,20	0,83
Employment in high- and medium-high technology manufacturing sectors and knowledge-intensive service sectors	4,81	2,69	0,31	-0,20	1,00	0,20
Synthetic measure of socio-economic development	0,61	0,10	0,79	0,83	0,20	1,00

(*Source: author's calculations*)

In figures 12-14, estimated linear regression functions are presented, in which research and development expenditures, human resources in science and technology, employment in high- and medium-high technology manufacturing sectors and knowledge-intensive service sectors are independent variables of the model, while the created synthetic measure has become a dependent variable. In this way, we obtain information on how the increase of the independent variable by 1 affects the dependent variable of the model.

For the models created for the Science and Technology determinant, where the explained variable is a synthetical measure of socio-economic development, it was obtained that the number of scientists per 1000 inhabitants (human resources in Science and Technology) had the greatest impact on socio-economic development in the EU countries. This is evidenced by the correlation coefficient at the level of 0.83. Next, research and development expenditures are correlated with the measure of socio-economic development (correlation coefficient at the level of r = 0.79).

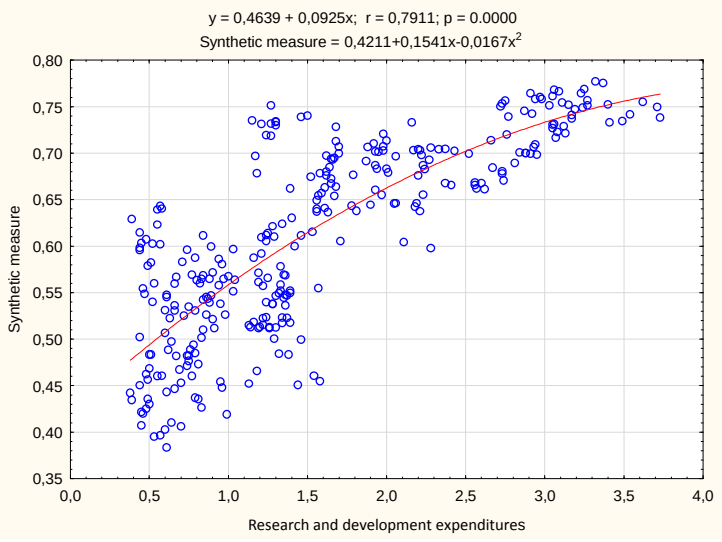

Fig. 12. Regression function parameters - synthetic measure in terms of research and development expenditures
(*Source: author's calculations*)

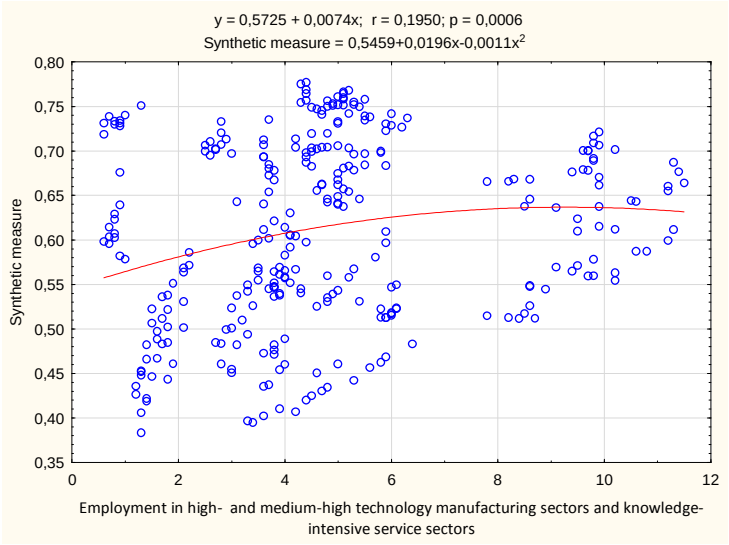

Fig. 13. Regression function parameters employment in high- and medium-technologymanufacturing sectors and knowledge-intensive service sectors (*Source: author's calculations*)

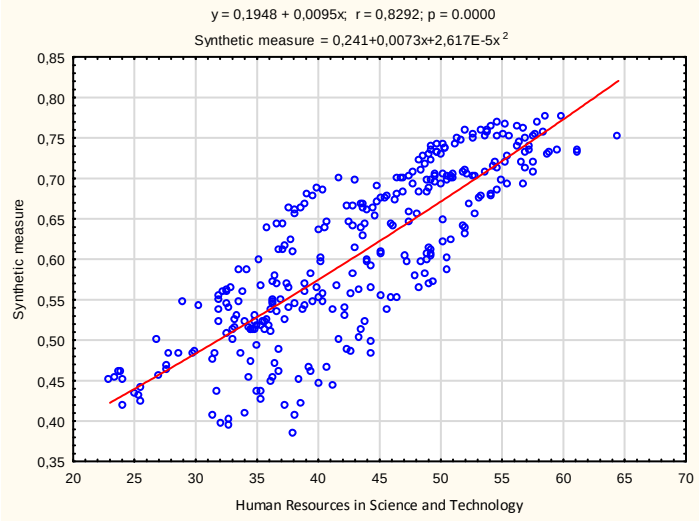

Fig. 14. Regression function parameters – synthetic measure in terms of human resources in Science and Technology (*Source: author's calculations*)

The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to increase in the synthetic measure by 0.09 if the research and development expenditures are the independent variable. The

estimated marginal effects reveal that a one unit growth in measurement of the determinant is expected to increase in the synthetic measure by 0.007 if employment in high- and medium- technology manufacturing sectors and knowledge-intensive service sectors is the independent variable. The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to increase in the synthetic measure by 0.0095 if the human resources in Science and Technology are the independent variable.

3.5. Models of the synthetic measure in relation to the component variables for the determinant of Health

Table 5 presents the values of Pearson's linear correlation coefficients between the component variables for the determinant of health and the synthetic measure of socio-economic development of EU countries. The following indicators were used in the research: life expectancy, self-reported unmet needs for medical examinationa and self-perceived health.

Table 5. Correlations between the synthetic measure and the component variables for the determinant of Health

Variable	Correlations (marked correlations are significant with p < ,05000)					
	Mean	**s**	**Life expec-tancy**	**Self-reported unmet needs for medical examination**	**Self-perceived health**	**Synthetic measure of socio-economic development**
Life expectancy	79,42	2,92	1,00	-0,16	0,45	0,60
Self-reported unmet needs for medical examination	0,94	1,27	-0,16	1,00	0,10	-0,53
Self-perceived health	23,38	11,17	0,45	0,10	1,00	0,30
Synthetic measure of socio-economic development	0,61	0,10	0,60	-0,53	0,30	1,00

(*Source: author's calculations*)

In figures 15-17, estimated linear regression functions are presented, in which life expectancy, self-reported unmet needs for medical examination, self-

perceived health are independent variables of the model, while the created synthetic measure has become a dependent variable. In this way, the information is obtained how the increase of the independent variable by 1 affects the dependent variable of the model.

For the models created for the Health determinant, where the dependent variable is the synthetical measure of socio-economic development, it was obtained that the life expectancy influences the most socio-economic development in the European Union countries. This is evidenced by the correlation coefficient at the level of 0.60. Next, the variable self-reported unmet needs for medical examination (correlation coefficient r = -0.54) is correlated with the measure of socio-economic development. For the self-reported unmet needs for medical examination variable, a negative, moderate correlation with the synthetic measure of socio-economic development was obtained. For the self-perceived health variable, a positive, low correlation was obtained with the synthetic measure of socio-economic development (r = 0.3).

The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to increase in the synthetic measure by 0.02 if the life expectancy is the independent variable. The estimated marginal effects reveal that a one unit growth in measurement of the determinant is expected to decrease in the synthetic measure by 0.04 if self-reported unmet needs for medical examination due to being too expensive are the independent variable. The estimated marginal effects reveal that a one unit increase in measurement of the

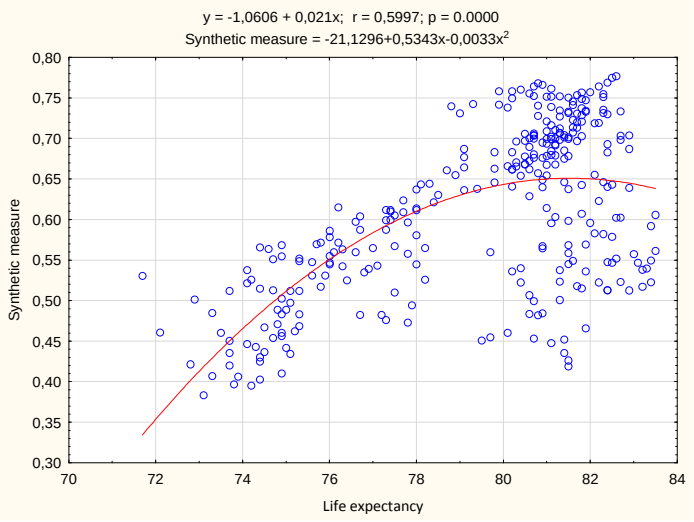

Fig. 15. Regression function parameters – synthetic measure in terms of life expectancy
(*Source: author's calculations*)

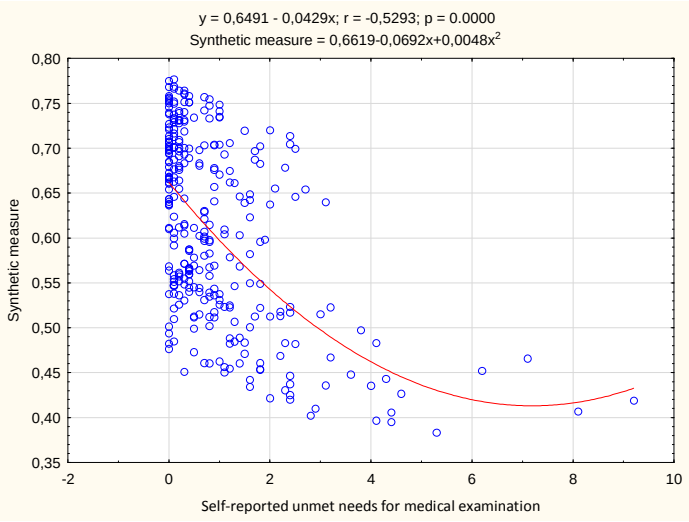

Fig. 16. Regression function parameters – synthetic measure in terms of self-reported unmet needs for medical examination due to being too expensive (*Source: author's calculations*)

Fig. 17. Regression function parameters – synthetic measure in terms of self-perceived long-standing limitations in usual activities due to health problems (*Source: author's calculations*)

determinant is expected to increase in the synthetic measure by 0.003 if the self-perceived long-standing limitations in usual activities due to health problems are the independent variable.

3.6. Models of the synthetic measure in relation to the component variables for the determinant of Education

Table 6 presents the values of Pearson's linear correlation coefficients between the component variables for the determinant of education and the synthetic measure of socio-economic development of EU countries. The following indicators were used in the research: the percentage of people gaining or with higher education aged 15-64, participation rate in education and training, early leavers from education and training.

Table 6. Correlations between the synthetic measure and the component variables for the determinant of Education

Variable	Correlations (marked correlations are significant with p < ,05000)					
	Mean	**s**	**The percentage of people gaining or with higher education aged 15-64**	**Participation rate in education and training**	**Early leavers from education and training**	**Synthetic measure of socio-economic develop-ment**
The percentage of people gaining or with higher education aged 15-64	25,61	7,47	1,00	0,48	-0,26	0,58
The participation rate in education and training	16,64	7,23	0,48	1,00	-0,21	0,76
Early leavers from education and training	10,84	5,52	-0,26	-0,21	1,00	-0,35
Synthetic measure of socio-economic development	0,61	0,10	0,58	0,76	-0,35	1,00

(*Source: author's calculations*)

In figures 18-20, estimated linear regression functions are presented, in which the percentage of people gaining or with higher education aged 15-64, the participation rate in education and training, early leavers from education and training are independent variables of the model, while the created synthetic measure has become a dependent variable. In this way, we obtain information on

how the increase of the independent variable by 1 affects the dependent variable of the model.

Fig. 18. Regression function parameters – synthetic measure in terms of the percentage of people gaining or with higher education aged from 15 to 64 (*Source: author's calculations*)

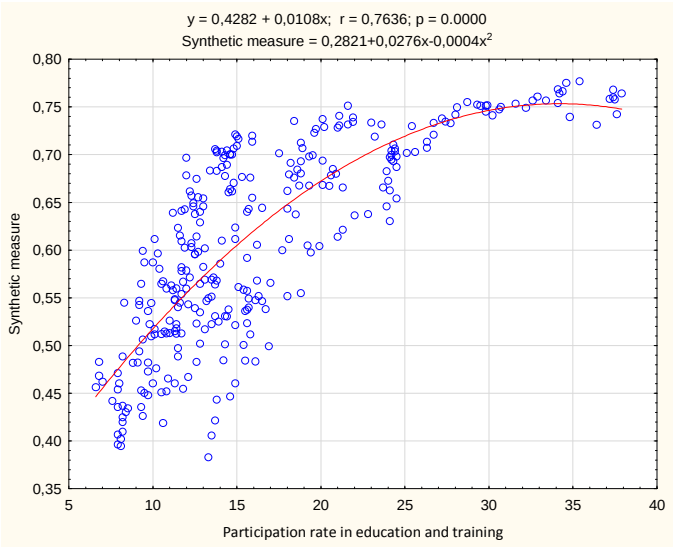

Fig. 19. Regression function parameters – synthetic measure in terms of participation rate in education and training (*Source: author's calculations*)

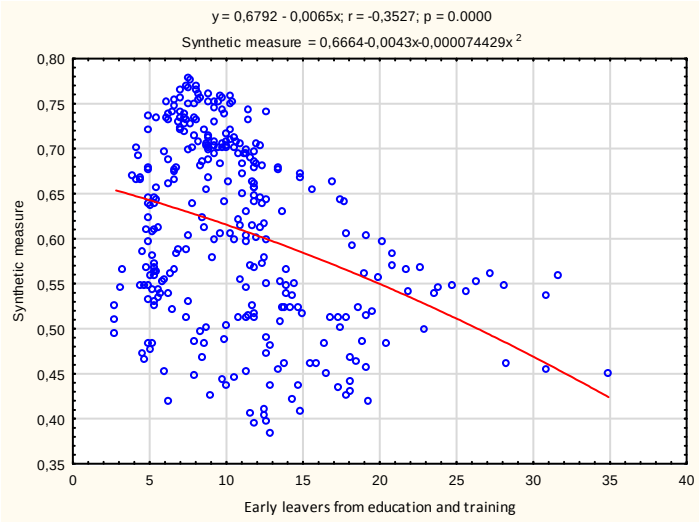

Fig. 20. Regression function parameters – synthetic measure
in terms of early leavers from education and training
(*Source: author's calculations*)

For the models created for the Education determinant, where the dependent variable is a synthetical measure of socio-economic development, it was obtained that the greatest extent to socio-economic development in EU countries was participation rate in education and training. This is evidenced by the correlation coefficient at the level of 0.76. Next, the percentage of people gaining or with higher education aged from 15 to 64 (correlation coefficient r = 0.58) is correlated with the measure of socio-economic development. For the variable early leavers from education and training, a negative, low correlation was obtained with the synthetic measure of socio-economic development.

The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to increase in the synthetic measure by 0.008 if the percentage of people gaining or with higher education aged from 15 to 64 is the independent variable. The estimated marginal effects reveal that a one unit growth in measurement of the determinant is expected to decrease in the synthetic measure by 0.01 if the participation rate in education and training is the independent variable. The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to decrease in the synthetic measure by 0.0065 if the early leavers from education and training are the independent variable.

3.7. Models of the synthetic measure in relation to the component variables for the determinant of Living conditions

Table 7 presents the values of Pearson's linear correlation coefficients between the component variables for the determinant of education and the synthetic measure of socio-economic development of EU countries. The following indicators were used in the research: share of people living in under-occupied dwellings, inability to make ends meet, people at risk of poverty.

Table 7. Correlations between the synthetic measure and the component variables for the determinant of living conditions

Variable	Correlations (marked correlations are significant with p < ,05000)					
	Mean	s	Share of people living in under-occupied dwellings	Inability to make ends meet	People at risk of poverty	Synthetic measure of socio-economic development
Share of people living in under-occupied dwellings	34,44	22,04	1,00	-0,34	-0,39	0,62
Inability to make ends meet	12,11	8,93	-0,34	1,00	0,70	-0,81
People at risk of poverty	24,02	6,80	-0,39	0,70	1,00	-0,76
Synthetic measure of socio-economic development	0,61	0,10	0,62	-0,81	-0,76	1,00

(*Source: author's calculations*)

In figures 21-23, estimated linear regression functions are presented, in which share of people living in under-occupied dwellings, inability to make ends meet, people at risk of poverty are independent variables of the model, while the created synthetic measure has become a dependent variable. In this way, we obtain information on how the increase of the independent variable by 1 affects the dependent variable of the model.

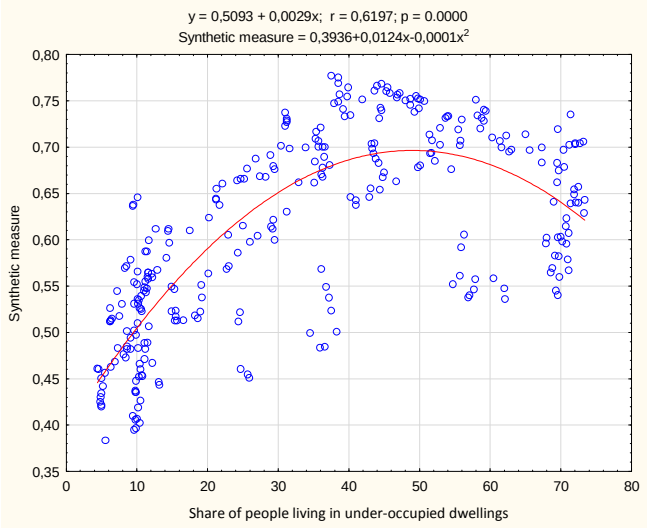

Fig. 21. Regression function parameters – synthetic measure in terms of share of people living in under-occupied dwellings (*Source: author's calculations*)

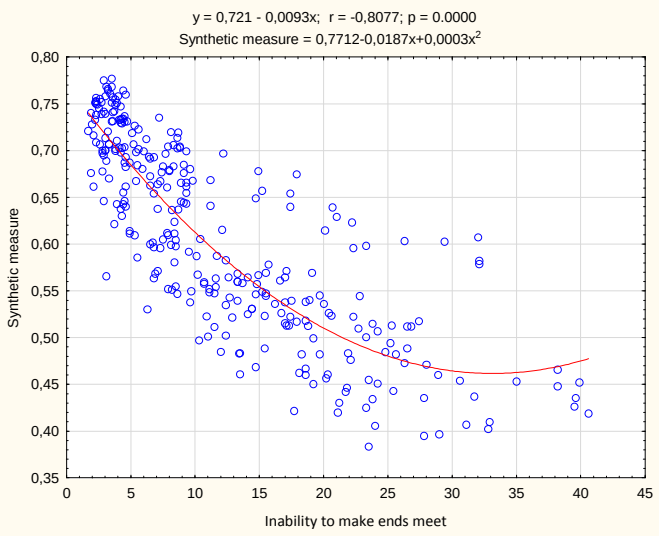

Fig. 22. Regression function parameters – synthetic measure in terms of the percentage of people who are unable to make 'ends meet' (*Source: author's calculations*)

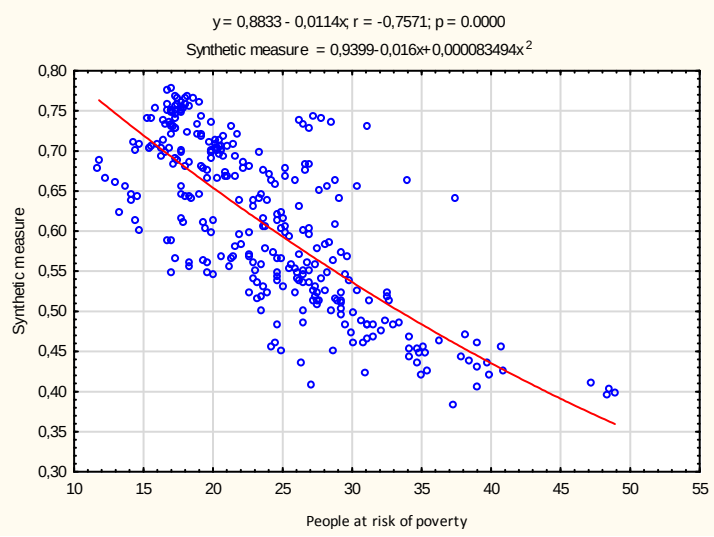

Fig. 23. Regression function parameters – synthetic measure
in terms of the rate of people at risk of poverty
(*Source: author's calculations*)

For the models created for the Living Conditions determinant, where the dependent variable is a synthetical measure of socio-economic development, it was obtained that the greatest extent to socio-economic development in EU countries is the percentage of people who are unable to make 'ends meet'. This is evidenced by the correlation coefficient at the level of -0.81. Next, the rate of people at risk of poverty (correlation coefficient r = -0.76) is correlated with the measure of socio-economic development. For the variable share of people living in under-occupied dwellings, a positive, moderate relationship with a synthetic measure of socio-economic development was obtained (r = 0.62).

The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to increase in the synthetic measure by 0.003 if the share of people living in under-occupied dwellings is the independent variable. The estimated marginal effects reveal that a one unit growth in measurement of the determinant is expected to decrease in the synthetic measure by 0.009 if the percentage of people who are unable to make 'ends meet' is the independent variable. The estimated marginal effects reveal that a one unit increase in measurement of the determinant is expected to increase in the synthetic measure by 0.01 if the rate of people at risk of poverty is the independent variable.

Chapter 4. Spatial-time analysis of EU countries for 2008-2018

4.1. Rankings of European Union countries according to the synthetic measure of socio-economic development in the selected years 2008, 2013 and 2018

Subsection 4.1 presents the ranking of European Union countries for 2008, 2013 and 2018. In order to perform the research, the linear ordering method was used.

T. Grabiński (1984) states that MCA (Multidimensional comparative analysis) deals with methods and techniques of comparing multi-feature objects. MCA considers the issue of linear hierarchization (linear ordering) of a set of objects in multidimensional feature spaces from the point of view of a certain characteristic that cannot be measured directly. It is the creation of measures based mainly on the determination of a taxonomic development pattern, i.e. a specific object ideal for a given field, and then the determination of the distance of individual objects from the established multi-characteristic optimum. The next step on this path is the construction of the synthetic gauge (Markowska, 2012).

In linear ordering, when constructing a synthetic measure of development, sometimes there is a need to standardize the nature of the variables in order to ensure a uniform preference of the variables. Variable destimulants and nominants are transformed into stimulants using linear and non-linear functions (Walesiak, 2011).

The figure 24 shows the relationship between the values of the synthetic indicator for years 2008 and 2018. Minimal differences in the change in the position of the analysed countries during the period considered, with the exception of Greece, can be observed. The results of the obtained rankings are presented in tables 8-13.

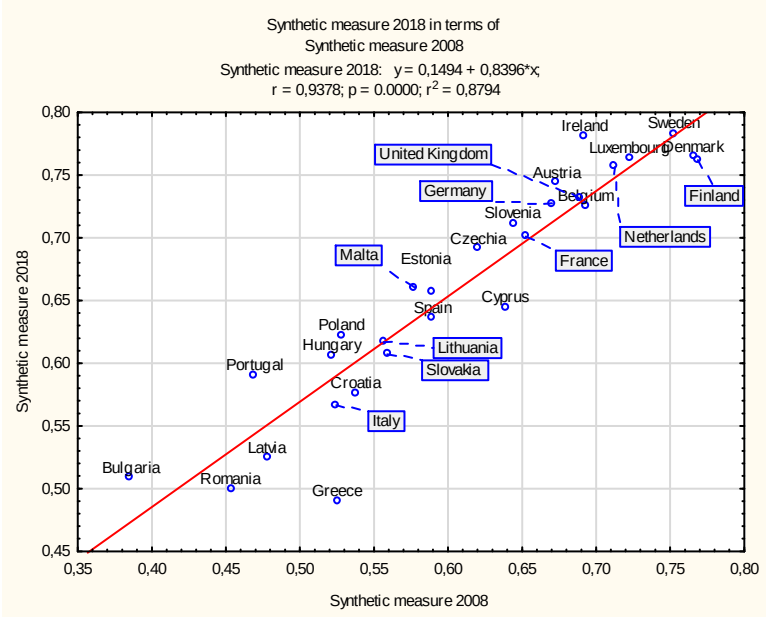

Fig. 24. Synthetic measure 2018 in terms of Synthetic measure 2008
(Source: author's calculations)

The next subchapter presents the tables and figures with the values of the synthetic measure for the selected years 2008, 2013 and 2018, as well as for individual determinants of socio-economic development. When analyzing the socio-economic development in the European Union countries with the use of the modified HDI measure, it should be stated that the first place in the ranking for 2018 was taken by Sweden. The next two positions were taken by Finland and Denmark. The last three positions in the ranking were taken by Bulgaria, Romania and Greece (table 8).

The highest increase for the measure analyzed was recorded for Hungary and Portugal. Hungary position increased by 6 places (from position 23 to 17), for Portugal we can observe increase from position 27 to 22. Poland's position increased by 2 places in the ranking in 2018 compared to 2008 (from the position 21 to 19). The largest decrease was observed for Greece (from position 20 to 28), Croatia (from position 19 to 23) and Belgium (from position 5 to 9) in the analyzed years. The obtained values for synthetic measure and position difference between years 2018 and 2008 are presented in the figure 25.

Table 8. The comparison of the synthetic measure values for years 2008, 2013 and 2018

Country	Synthetic measure 2008	Ranking 2008	Synthetic measure 2013	Ranking 2013	Synthetic measure 2018	Ranking 2018	Position difference 2018 and 2008
Sweden	0,73	3	0,76	2	0,78	1	2
Finland	0,74	1	0,75	3	0,76	2	-1
Denmark	0,74	2	0,76	1	0,75	3	-1
Austria	0,66	8	0,70	8	0,74	4	4
Ireland	0,66	9	0,65	12	0,74	5	4
The Netherlands	0,70	4	0,70	6	0,73	6	-2
Luxembourg	0,68	6	0,73	4	0,73	7	-1
Germany	0,66	10	0,70	7	0,72	8	2
Belgium	0,68	5	0,70	5	0,72	9	-4
The United Kingdom	0,66	7	0,68	10	0,71	10	-3
France	0,65	11	0,68	9	0,70	11	0
Slovenia	0,64	12	0,67	11	0,70	12	0
Czechia	0,61	14	0,64	13	0,69	13	1
Malta	0,56	16	0,57	16	0,64	14	2
Cyprus	0,63	13	0,58	15	0,64	15	-2
Estonia	0,57	15	0,61	14	0,63	16	-1
Hungary	0,53	23	0,52	21	0,62	17	6
Slovakia	0,55	18	0,56	17	0,61	18	0
Poland	0,53	21	0,54	18	0,61	19	2
Spain	0,56	17	0,54	19	0,61	20	-3
Lithuania	0,53	22	0,54	20	0,59	21	1
Portugal	0,45	27	0,48	23	0,57	22	5
Croatia	0,55	19	0,47	24	0,56	23	-4
Italy	0,52	24	0,51	22	0,55	24	0
Latvia	0,46	25	0,44	25	0,50	25	0
Bulgaria	0,41	28	0,41	28	0,49	26	2
Romania	0,46	26	0,43	27	0,48	27	-1
Greece	0,54	20	0,44	26	0,47	28	-8

(*Source: author's calculations*)

Table 9. The comparison of the Economy and Finance measure values for years 2008, 2013 and 2018

Country	Economy nad Finance 2008	Ranking 2008	Economy and Finance 2013	Ranking 2013	Economy and Finance 2018	Ranking 2018	Position difference 2018 and 2008
Luxembourg	0,88	1	0,87	1	0,88	1	0
Denmark	0,79	2	0,75	3	0,76	2	0
Austria	0,75	3	0,75	2	0,74	3	0
Germany	0,67	12	0,71	6	0,74	4	8
Belgium	0,71	7	0,71	5	0,73	5	2
The Netherlands	0,74	5	0,69	8	0,73	6	-1
Sweden	0,75	4	0,71	7	0,73	7	-3
Finland	0,74	6	0,72	4	0,71	8	-2
Czechia	0,64	15	0,62	12	0,69	9	6
France	0,69	8	0,68	9	0,69	10	-2
Ireland	0,65	14	0,55	17	0,67	11	3
The United Kingdom	0,66	13	0,63	10	0,67	12	1
Slovenia	0,67	10	0,6	14	0,66	13	-3
Hungary	0,6	19	0,59	15	0,66	14	5
Malta	0,61	17	0,62	11	0,66	15	2
Poland	0,58	22	0,54	18	0,64	16	6
Estonia	0,59	20	0,57	16	0,62	17	3
Portugal	0,61	18	0,51	20	0,62	18	0
Italy	0,67	11	0,61	13	0,62	19	-8
Slovakia	0,53	28	0,5	21	0,61	20	8
Croatia	0,58	21	0,46	26	0,6	21	0
Cyprus	0,68	9	0,48	24	0,6	22	-13
Lithuania	0,57	23	0,49	23	0,58	23	0
Bulgaria	0,57	24	0,47	25	0,58	24	0
Latvia	0,54	27	0,5	22	0,58	25	2
Romania	0,54	26	0,53	19	0,58	26	0
Spain	0,56	25	0,36	28	0,5	27	-2
Greece	0,62	16	0,38	27	0,48	28	-12

(*Source: author's calculations*)

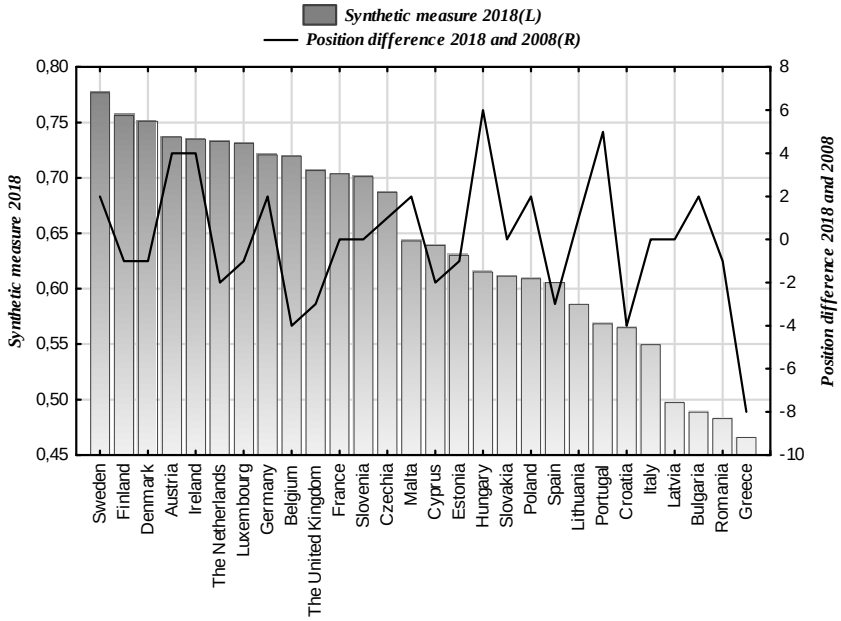

Fig. 25. Values of the synthetic measure for European Union countries
for the years 2008 and 2018 and position difference between years 2018 and 2008
(*Source: author's calculations*)

When analyzing the Economy and Finance determinant, it can be observed that Luxembourg was the leader in 2018 in the European Union. The next two positions were taken by Denmark and Austria. The last three positions in the ranking were taken by Romania, Spain and Greece (table 9).

The highest increase for the analyzed determinant was recorded for Slovakia. Slovakia position increased by 8 places (from position 28 to 20). Poland and Czechia are the countries with the highest increase in their positions after Slovakia. Poland's position increased by 6 places in the ranking in 2018 compared to 2008 (from the position 22 to 16). For Czechia it can be observed increase from position 15 to 9. The largest decrease was observed for Cyprus (from position 9 to 22) and Greece (from position 16 to 28) in the analyzed years. The obtained values for Economy and finance determinant and position difference between years 2018 and 2008 are presented in the figure 26.

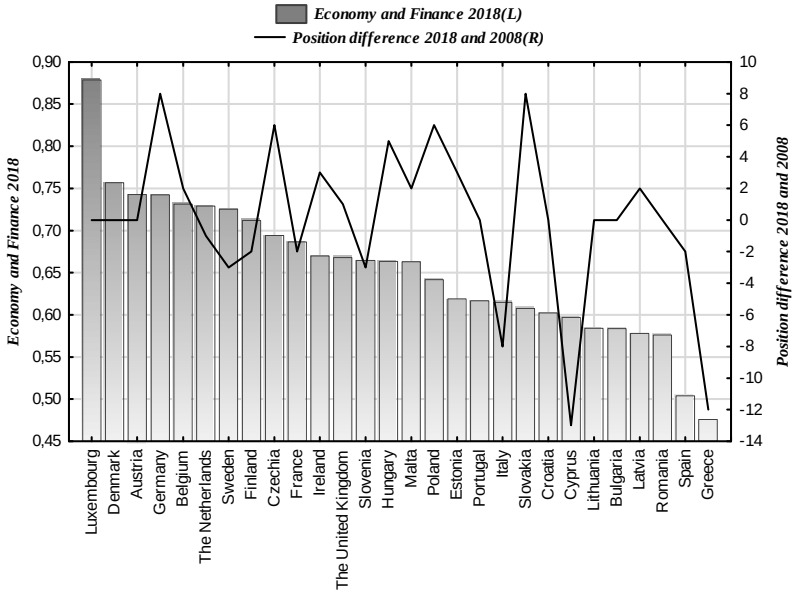

Fig. 26. Values of the Economy and finance determinant for European Union countries for the years 2008 and 2018 and position difference between years 2018 and 2008 (*Source: author's calculations*)

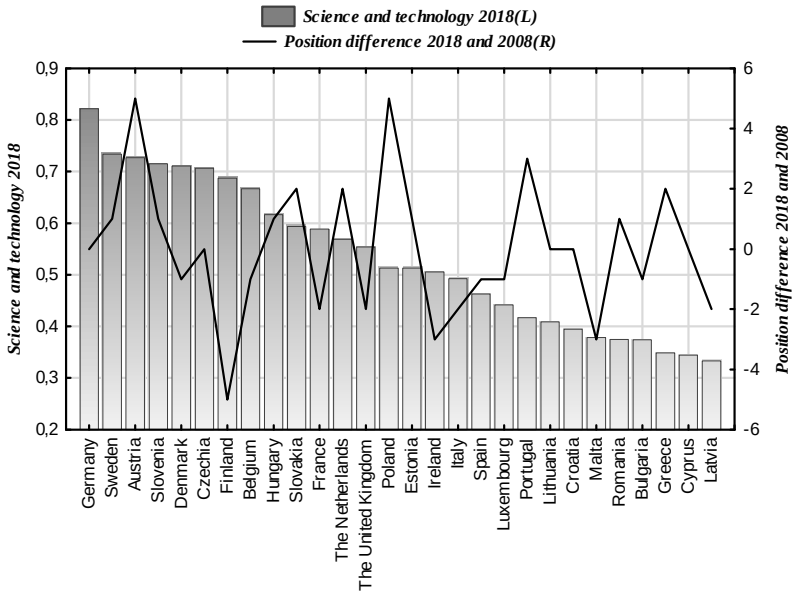

Fig. 27. Values of the Science and technology determinant for European Union countries for the years 2008 and 2018 and position difference between years 2018 and 2008 (*Source: author's calculations*)

Table 10. The comparison of the Science and Technology measure values for years 2008, 2013 and 2018

Country	Science and techno-logy 2008	Ranking 2008	Science and techno-logy 2013	Ranking 2013	Science and technology 2018	Ranking 2018	Position difference 2018 and 2008
Germany	0,75	1	0,77	1	0,82	1	0
Sweden	0,73	3	0,70	3	0,73	2	1
Austria	0,57	8	0,65	7	0,73	3	5
Slovenia	0,62	5	0,69	4	0,71	4	1
Denmark	0,66	4	0,69	5	0,71	5	-1
Czechia	0,60	6	0,67	6	0,71	6	0
Finland	0,75	2	0,72	2	0,69	7	-5
Belgium	0,59	7	0,60	8	0,67	8	-1
Hungary	0,51	10	0,56	11	0,62	9	1
Slovakia	0,50	12	0,53	13	0,59	10	2
France	0,56	9	0,58	9	0,59	11	-2
The Netherlands	0,48	14	0,52	15	0,57	12	2
The United Kingdom	0,51	11	0,53	12	0,55	13	-2
Poland	0,38	19	0,42	19	0,51	14	5
Estonia	0,46	16	0,52	14	0,51	15	1
Ireland	0,49	13	0,56	10	0,51	16	-3
Italy	0,46	15	0,47	16	0,49	17	-2
Spain	0,44	17	0,44	18	0,46	18	-1
Luxembourg	0,41	18	0,46	17	0,44	19	-1
Portugal	0,33	23	0,35	23	0,42	20	3
Lithuania	0,35	21	0,37	21	0,41	21	0
Croatia	0,34	22	0,36	22	0,39	22	0
Malta	0,35	20	0,38	20	0,38	23	-3
Romania	0,32	25	0,30	27	0,37	24	1
Bulgaria	0,32	24	0,35	24	0,37	25	-1
Greece	0,27	28	0,29	28	0,35	26	2
Cyprus	0,28	27	0,32	25	0,34	27	0
Latvia	0,31	26	0,32	26	0,33	28	-2

(*Source: author's calculations*)

In 2018, the countries that achieved the highest positions in the ranking for the Science and Technology determinant were Germany, Sweden and Austria. The last three positions in the ranking were taken by Greece, Cyprus and Latvia (table 10).

When analyzing the Science and Technology determinant, the highest increases were observed for Austria (from position 8 to 3) and Poland (from position 19 to 14) in the analyzed period. The largest decrease was observed for Finland (from the position 2 to 7) (fig. 27).

In 2018, the countries that achieved the highest positions in the ranking for the determinant of Health were Ireland, Cyprus and Austria. The last three positions in the ranking were taken by Portugal, Lithuania and Latvia (table 11).

When analyzing the above determinant, the highest increase was observed for Croatia (from position 26 to 7) and Bulgaria (from position 28 to 21) in the analyzed period. The largest decreases were recorded for Greece (from position 1 to 24) and Belgium (from position 9 to 18) (fig. 28).

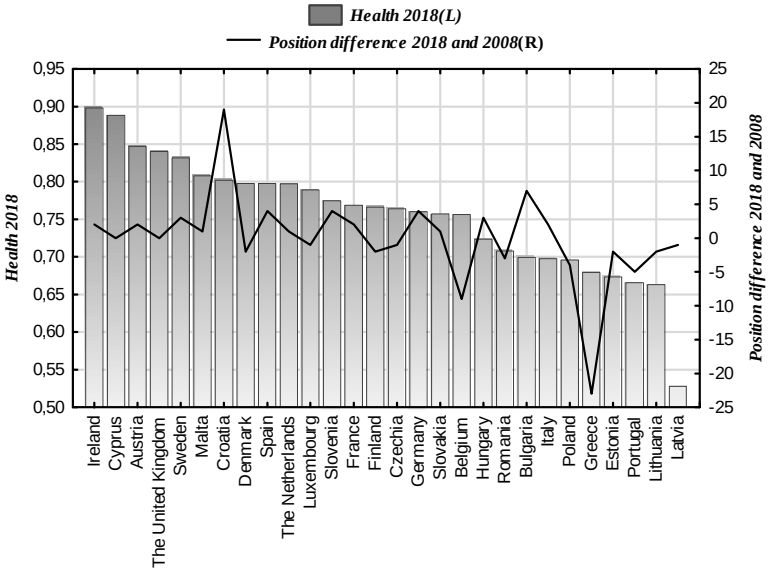

Fig. 28. Values of the Health determinant for European Union countries
for the years 2008 and 2018 and position difference between years 2018 and 2008
(*Source: author's calculations*)

Table 11. The comparison of the Health measure values for years 2008, 2013 and 2018

Country	Health 2008	Ranking 2008	Health 2013	Ranking 2013	Health 2018	Ranking 2018	Position difference 2018 and 2008
Ireland	0,89	3	0,81	7	0,90	1	2
Cyprus	0,93	2	0,89	1	0,89	2	0
Austria	0,85	5	0,84	3	0,85	3	2
The United Kingdom	0,89	4	0,87	2	0,84	4	0
Sweden	0,84	8	0,84	4	0,83	5	3
Malta	0,84	7	0,74	18	0,81	6	1
Croatia	0,64	26	0,72	20	0,80	7	19
Denmark	0,84	6	0,81	6	0,80	8	-2
Spain	0,76	13	0,78	12	0,80	9	4
The Netherlands	0,79	11	0,78	10	0,80	10	1
Luxembourg	0,80	10	0,78	11	0,79	11	-1
Slovenia	0,75	16	0,79	8	0,78	12	4
France	0,75	15	0,73	19	0,77	13	2
Finland	0,79	12	0,75	14	0,77	14	-2
Czechia	0,75	14	0,74	16	0,76	15	-1
Germany	0,70	20	0,75	13	0,76	16	4
Slovakia	0,75	18	0,75	15	0,76	17	1
Belgium	0,81	9	0,79	9	0,76	18	-9
Hungary	0,69	22	0,70	22	0,72	19	3
Romania	0,75	17	0,74	17	0,71	20	-3
Bulgaria	0,43	28	0,63	27	0,70	21	7
Italy	0,66	24	0,69	23	0,70	22	2
Poland	0,70	19	0,71	21	0,70	23	-4
Greece	0,94	1	0,82	5	0,68	24	-23
Estonia	0,66	23	0,69	24	0,67	25	-2
Portugal	0,70	21	0,67	26	0,67	26	-5
Lithuania	0,65	25	0,68	25	0,66	27	-2
Latvia	0,58	27	0,50	28	0,53	28	-1

(*Source: author's calculations*)

Table 12. The comparison of the Education measure values for years 2008, 2013 and 2018

Country	Education 2008	Ranking 2008	Education 2013	Ranking 2013	Education 2018	Ranking 2018	Position difference 2018 and 2008
Sweden	0,74	3	0,84	2	0,90	1	2
Finland	0,76	1	0,80	3	0,87	2	-1
Luxembourg	0,56	14	0,78	4	0,82	3	11
Ireland	0,61	8	0,69	10	0,81	4	4
The Netherlands	0,67	4	0,73	5	0,79	5	-1
Denmark	0,75	2	0,84	1	0,78	6	-4
France	0,56	13	0,71	7	0,75	7	6
Estonia	0,60	9	0,70	9	0,75	8	1
The United Kingdom	0,64	6	0,71	6	0,74	9	-3
Lithuania	0,62	7	0,67	11	0,73	10	-3
Austria	0,54	16	0,60	16	0,71	11	5
Belgium	0,59	10	0,63	13	0,71	12	-2
Slovenia	0,66	5	0,70	8	0,71	13	-8
Cyprus	0,59	11	0,66	12	0,70	14	-3
Poland	0,57	12	0,60	17	0,64	15	-3
Greece	0,46	22	0,54	20	0,64	16	6
Latvia	0,50	20	0,60	14	0,63	17	3
Czechia	0,54	17	0,60	15	0,60	18	-1
Spain	0,39	24	0,52	22	0,60	19	5
Germany	0,55	15	0,60	18	0,59	20	-5
Croatia	0,51	18	0,54	19	0,59	21	-3
Portugal	0,20	28	0,45	25	0,57	22	6
Slovakia	0,50	19	0,54	21	0,54	23	-4
Malta	0,28	27	0,41	26	0,52	24	3
Hungary	0,47	21	0,49	23	0,51	25	-4
Bulgaria	0,43	23	0,49	24	0,51	26	-3
Italy	0,36	26	0,41	27	0,47	27	-1
Romania	0,37	25	0,37	28	0,38	28	-3

(*Source: author's calculations*)

In 2018, the countries that achieved the highest positions in the ranking for the determinant Education were Sweden, Finland and Luxembourg. The last three positions in the ranking were taken by Bulgaria, Italy and Romania (table 12).

The country that grew the most for this determinant is Luxembourg. The position of this country increased by 11 places in the ranking for 2018 compared to 2008 and this is the largest increase for this determinant (from the position 14 to 3). Beyond Luxembourg, the largest increases were recorded for France (from the position 13 to 7), Greece (from the position 22 to 16) and Portugal (from the position 28 to 22). The largest decreases were recorded for Slovenia (from the position 5 to 13), Slovakia (from the position 19 to 23) and Hungary (from the position 21 to 25) (fig. 29).

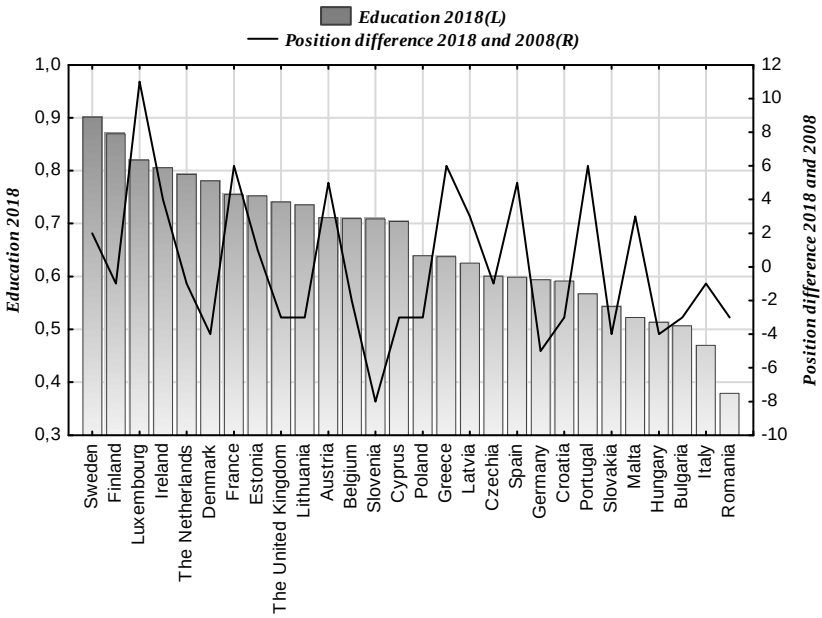

Fig. 29. Values of the Education determinant for European Union countries for the years 2008 and 2018 and position difference between years 2018 and 2008 (*Source: author's calculations*)

Table 13. The comparison of the Living Condition measure values for years 2008, 2013 and 2018

Country	Living conditions 2008	Ran-king 2008	Living conditions 2013	Ran-king 2013	Living conditions 2018	Ran-king 2018	Position difference 2018 and 2008
Malta	0,72	4	0,7	7	0,84	1	3
Ireland	0,67	6	0,66	11	0,8	2	4
The Netherlands	0,79	1	0,78	2	0,78	3	-2
Finland	0,68	5	0,76	4	0,75	4	1
Belgium	0,73	3	0,78	1	0,74	5	-2
The United Kingdom	0,63	13	0,66	10	0,73	6	7
Luxembourg	0,74	2	0,78	3	0,73	7	-5
France	0,67	9	0,71	5	0,72	8	1
Denmark	0,66	10	0,7	6	0,71	9	1
Sweden	0,62	14	0,69	8	0,69	10	4
Germany	0,64	12	0,67	9	0,69	11	1
Czechia	0,53	16	0,59	14	0,67	12	4
Spain	0,65	11	0,59	13	0,67	13	-2
Cyprus	0,67	7	0,54	17	0,66	14	-7
Austria	0,6	15	0,64	12	0,66	15	0
Slovenia	0,49	19	0,56	15	0,64	16	3
Estonia	0,52	17	0,55	16	0,59	17	0
Portugal	0,42	23	0,45	20	0,57	18	5
Hungary	0,35	26	0,25	25	0,56	19	7
Slovakia	0,49	18	0,48	18	0,56	20	-2
Poland	0,42	22	0,45	21	0,56	21	1
Lithuania	0,46	20	0,47	19	0,54	22	-2
Italy	0,44	21	0,39	22	0,47	23	-2
Croatia	0,67	8	0,28	24	0,43	24	-16
Latvia	0,37	25	0,28	23	0,42	25	0
Romania	0,32	27	0,22	26	0,38	26	1
Bulgaria	0,27	28	0,12	28	0,28	27	1
Greece	0,39	24	0,15	27	0,19	28	-4

(*Source: author's calculations*)

When analyzing the Living Conditions determinant, it was observed that Malta was the leader in 2018 in the European Union, which grew by 3 positions compared to 2008. Ireland and the Netherlands followed. The lowest values were obtained by Romania, Bulgaria and Greece (table 13).

The greatest increase in the value for this determinant was achieved by the United Kingdom (from position 13 to 6) and Hungary (from position 26 to 19). Croatia was characterized by the greatest decline in value (from position 8 to 24) (fig. 30).

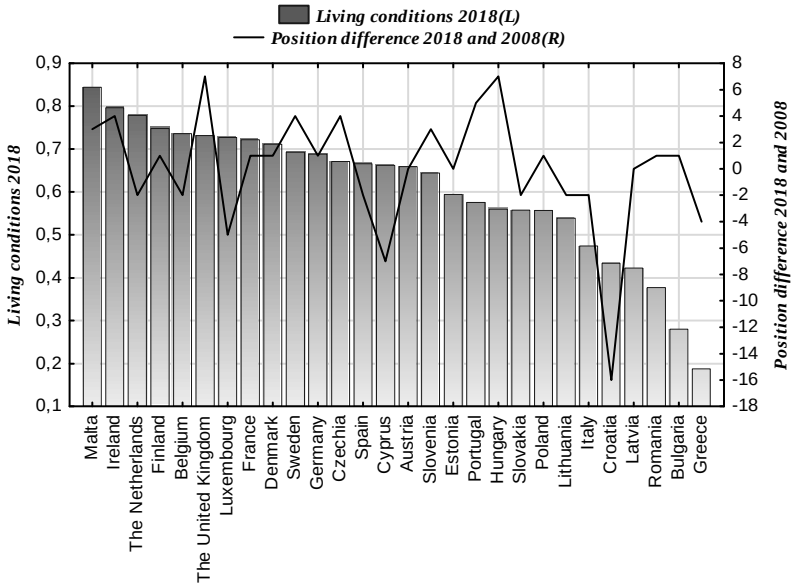

Fig. 30. Values of the Living Conditions determinant for European Union countries for the years 2008 and 2018 and position difference between years 2018 and 2008 (*Source: author's calculations*)

Table 14. Descriptive statistics of the synthetic measure for years 2008-2018

Country	Descriptive Statistics (synthetic measure 2008-2018)								
	Mean	**Median**	**Min**	**Max**	**Lower quartile**	**Upper quartile**	**Standard deviation**	**Coefficient of variation**	**Skew-ness**
Belgium	0.70	0.70	0.68	0.72	0.70	0.71	0.01	1.58	-0.36
Bulgaria	0.43	0.44	0.39	0.49	0.40	0.46	0.03	7.56	0.39
Czechia	0.65	0.64	0.61	0.69	0.62	0.66	0.03	3.88	-0.03
Denmark	0.75	0.76	0.73	0.77	0.74	0.76	0.01	1.60	-0.88
Germany	0.70	0.70	0.66	0.72	0.68	0.71	0.02	2.73	-0.59
Estonia	0.60	0.60	0.55	0.63	0.57	0.61	0.03	4.47	-0.75
Ireland	0.67	0.66	0.64	0.74	0.65	0.70	0.03	4.70	0.95
Greece	0.47	0.45	0.42	0.54	0.44	0.51	0.04	8.39	0.61
Spain	0.56	0.55	0.54	0.61	0.54	0.56	0.02	3.98	1.40
France	0.67	0.68	0.64	0.70	0.65	0.70	0.03	3.98	-0.12
Croatia	0.51	0.51	0.47	0.56	0.48	0.54	0.03	6.50	0.20
Italy	0.52	0.52	0.51	0.55	0.51	0.52	0.01	2.50	1.54
Cyprus	0.61	0.60	0.58	0.64	0.60	0.62	0.02	3.08	0.21
Latvia	0.45	0.46	0.38	0.50	0.42	0.49	0.04	8.52	-0.55
Lithuania	0.54	0.54	0.48	0.59	0.51	0.57	0.03	5.97	-0.21
Luxembourg	0.73	0.73	0.68	0.75	0.73	0.74	0.02	2.64	-2.26
Hungary	0.54	0.53	0.51	0.62	0.51	0.57	0.04	6.53	0.90
Malta	0.58	0.57	0.54	0.64	0.56	0.60	0.03	5.95	0.78
The Netherlands	0.71	0.71	0.69	0.73	0.70	0.71	0.01	1.58	1.18
Austria	0.70	0.70	0.66	0.74	0.68	0.73	0.03	3.86	-0.26
Poland	0.56	0.54	0.53	0.61	0.53	0.58	0.03	5.19	0.80
Portugal	0.50	0.50	0.45	0.57	0.46	0.54	0.04	7.88	0.34
Romania	0.45	0.45	0.42	0.48	0.43	0.46	0.02	4.43	0.15
Slovenia	0.67	0.67	0.64	0.70	0.65	0.68	0.02	3.09	-0.05
Slovakia	0.57	0.56	0.55	0.61	0.55	0.59	0.02	3.78	0.76
Finland	0.75	0.75	0.74	0.76	0.75	0.75	0.01	0.76	-1.00
Sweden	0.75	0.75	0.73	0.78	0.74	0.77	0.02	2.04	0.07
The United Kingdom	0.68	0.68	0.65	0.71	0.67	0.69	0.02	2.66	0.21

(*Source: author's calculations*)

The table 14 presents the average values of the synthetic measure of socio-economic development in the European Union countries, the values of the lower and upper quartiles, minimum, maximum, and the values of the coefficient of variation and asymmetry.

The minimum values of the synthetic measure of socio-economic development were achieved by the European Union countries in 2010-2011, when the economic crisis has finished. The highest values of the measure were obtained in years 2017-2018.

Latvia and Greece are the countries characterized by the greatest coefficient of variation in the value of the synthetic measure of socio-economic development.

The chart 31 shows a tendency that the average values of the synthetic measure of socio-economic development for the first three years remain at the same level of 0.59. They start to rise from 2011, although for this year and the next two years they remain at the same level of 0.6. Since 2014, an increase in the average value of the synthetic measure of socio-economic development in the European Union countries has been observed. The highest value of 0.64 was achieved in 2018.

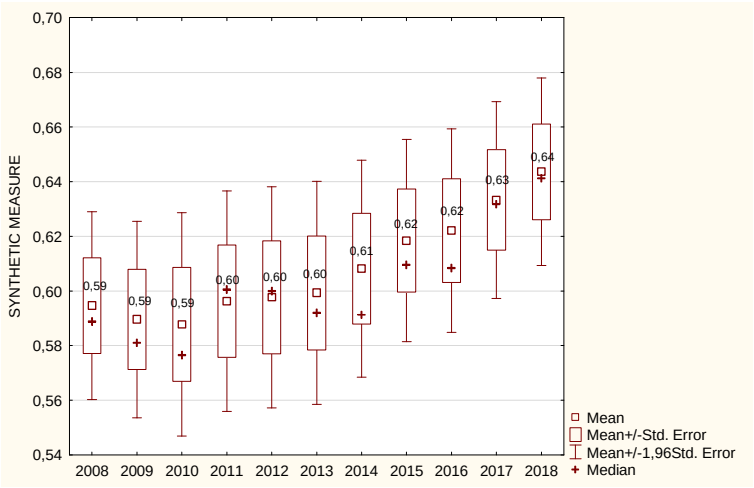

Fig. 31. Boxplot of the synthetic measure of socio-economic development values for European Union countries for the years 2008-2018 (*Source: author's calculations*)

The EU countries achieved the minimum values of the synthetic measure of socio-economic development in 2009-2010, which means that the negative impact of the financial crisis on the obtained values of the synthetic measure of socio-economic development is visible.

The chart 32 shows the mean values and median values for the Economic and Finance determinant for the EU countries for 2008-2018. The impact of the financial crisis on the determinant analyzed can be observed. In 2009, the average value dropped to the level of 0.61, in the years 2010-2011 the average value was 0.6, and in the years 2012-2013 it reached the minimum value of 0.59. Only since 2014, an increase in the mean value for the determinant analyzed can be observed from the level of 0.6 to the level of 0.65. In 2018, the average value for the Economics and Finance determinant reached the maximum level of 0.65.

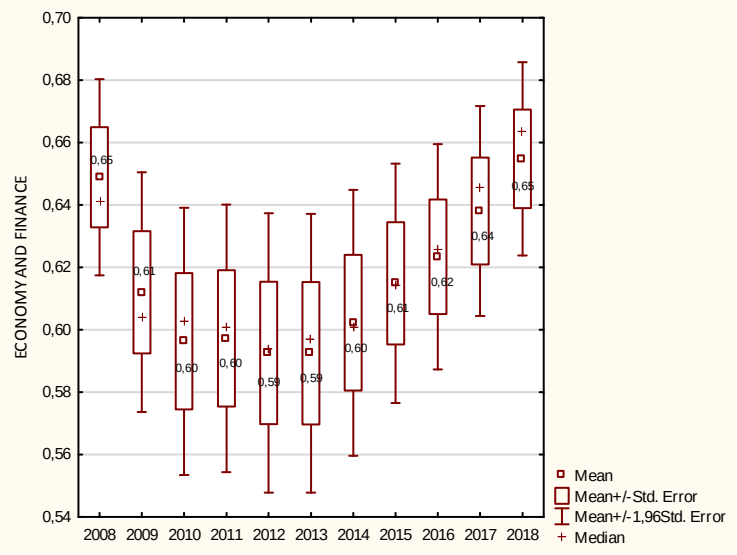

Fig. 32. Boxplot for the Economy and Finance determinant
for European Union countries in 2008-2018
(*Source: author's calculations*)

The chart 33 shows that for the Science and Technology determinant a development trend can be observed in the period analyzed. Since 2011, an increase in the mean values for the Science and Technology determinant can be observed. For the first three years, the average values remained at the same level and amounted to 0.48. A similar situation could be observed for the years 2015--2017 for which the average values were also the same and amount to 0.52 for each of the periods mentioned. For 2018, the average value reached the highest level of 0.54. The chart shows the average values as well as the median values of the determinant analyzed.

The chart 34 shows that a constant tendency can be observed for Health determinant in the period analyzed. For the three years of 2015, 2017 and 2018, the determinant obtained the value of 0.76. For the remaining years, the value was 0.75.

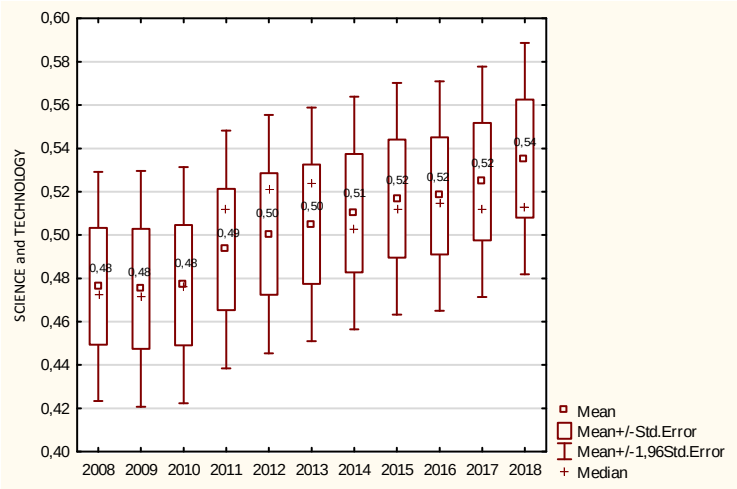

Fig. 33. Boxplot for the Science and Technology determinant
for European Union countries in 2008-2018
(*Source: author's calculations*)

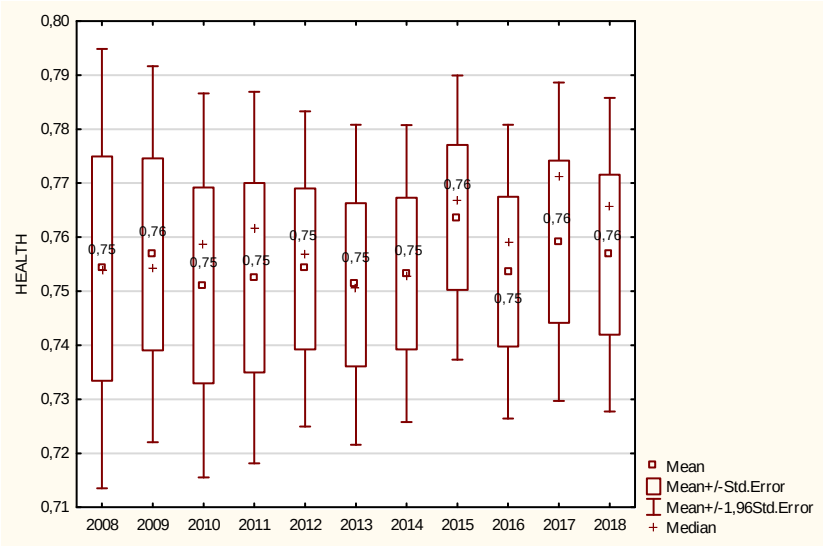

Fig. 34. Boxplot for the Health determinant
for European Union countries in 2008-2018
(*Source: author's calculations*)

The charts show the average values as well as the median values of the determinant analyzed. The chart 35 shows that for the Education determinant a development tendency can be observed in the period analyzed. Since 2008, an increase in average values was visible, starting from the value of the indicator of

0.54 to the value of 0.66 for 2018. For 2018, the average value reached the highest level of 0.66. For this determinant, the financial crisis did not affect its value in any way.

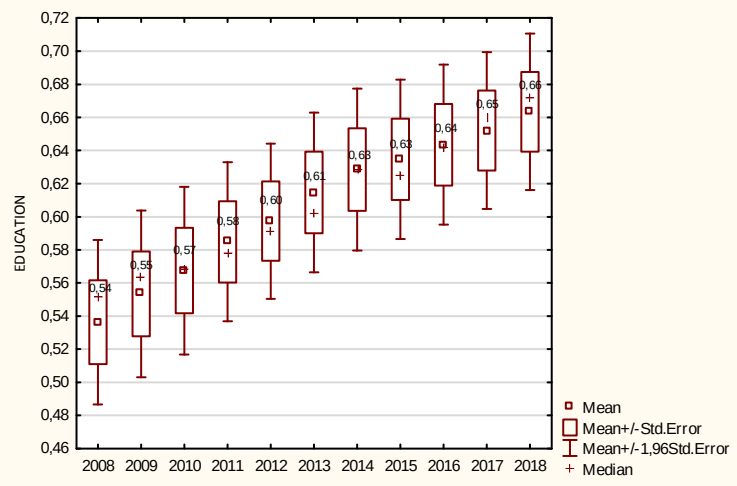

Fig. 35. Boxplot for the Education determinant
for European Union countries in 2008-2018
(*Source: author's calculations*)

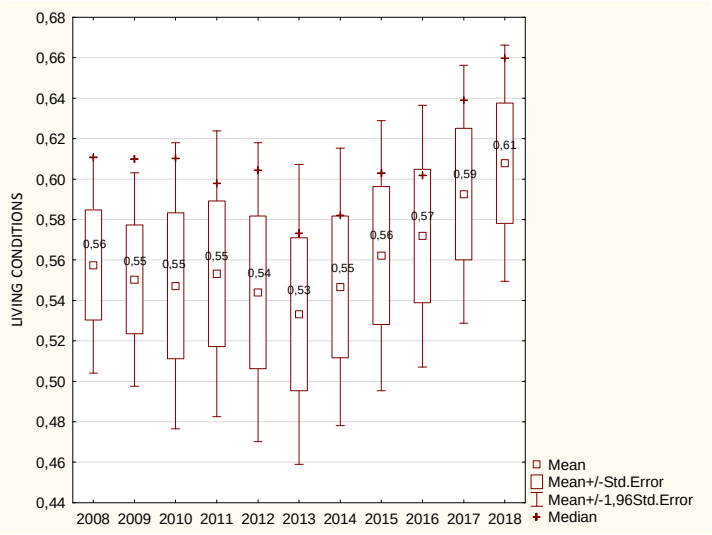

Fig. 36. Boxplot for the Living conditions determinant
for European Union countries in 2008-2018
(*Source: author's calculations*)

For the determinant, the living conditions the values obtained oscillate around 0.6. In the initial period, the values decreased from 2008 to 2013, from 0.56 to 0.53. Then, an increase in these values is visible until 2018. For 2018, the average value reached the highest level of 0.6 (fig. 36).

4.2. Beta, Sigma and Gamma convergences study for the European Union countries

4.2.1. Beta convergence and methods of its measurement

This section analyses the convergence of the synthetic measure of socio-economic development and its determinant for the countries of the European Union. The analysis of the social convergence process for the European Union countries in the years 2008-2018 has been started with a study on the occurrence of beta-convergence.

Beta convergence arises from the fundamental assumptions of the neoclassical growth theory, where the physical capital factor is characterized by diminishing marginal returns. Hence, the accumulation of this production factor brings greater benefits in the form of per capita income growth to poorer countries as compared to richer countries. Sigma convergence occurs when the disproportions measured, for example, by the standard deviation of the logarithms of per capita income between countries decrease over time (Próchniak, 2004).

Beta convergence, with poor countries having higher rates of growth than rich countries, is a necessary but not sufficient condition for sigma convergence.

The hypothesis about the presence of beta convergence is verified on the basis of a simple regression model in which the dependent variable is the growth rate of the analyzed feature:

$$g_i = a + b\log\left(y_{i,0}\right) + \varepsilon, \quad \text{(i = 1, …, } n\text{)} \tag{32}$$

where:

$y_{i,0}$ – value of the analyzed variable in the i-th object in the base year,

a, b – structural parameters of the model,

ε – random component,

g_i – the rate of change of the variable analyzed calculated as:

$$g_i = \frac{1}{T}\log\left(\frac{y_{i,T}}{y_{i,0}}\right) \quad \text{(i = 1, …, } n\text{)} \tag{33}$$

where:

T – number of observations,

$y_{i,T}$ – value of the variable analyzed in the i-th object in the year T.

On the basis of the value of the b estimate, it is possible to determine the β convergence coefficient significant from the point of view of the convergence analyzes:

$$\beta = -\frac{\ln(1+b)}{T} \tag{34}$$

where:

T – length of the period analyzed.

The presence of beta convergence is evidenced by the fact that the parameter b in the equation is negative and statistically significant. On the other hand, if the parameter b in the equation is positive and statistically significant, it means the occurrence of the divergence phenomenon. On the other hand, the statistical insignificance of parameter b means that there is neither convergence nor divergence of the analyzed phenomenon. In such a situation the following set of hypotheses are tested:

H_0: $b = 0$ – no beta convergence or divergence

H_1: $b \neq 0$ – beta convergence or divergence occurs

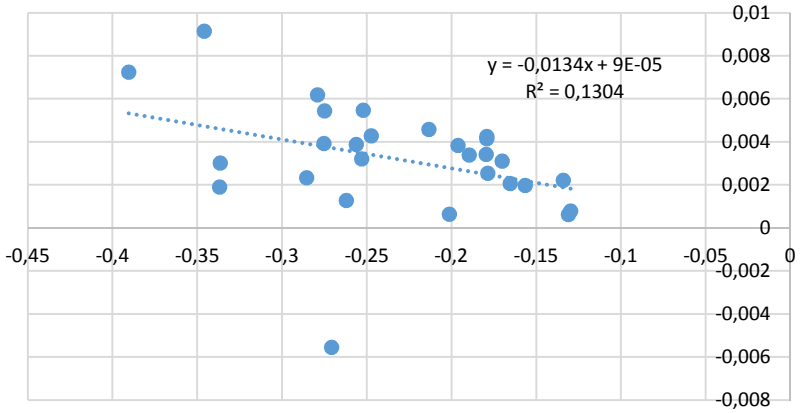

Fig. 37. Simple regression model in which the dependent variable is the growth rate of the analyzed measure (*Source: author's calculations*)

In figure 37 is presented simple regression model, in which dependent variable is the growth of the analyzed synthetic measure of socio-economic

development. It was obtained that the slope is negative, so there is the evidence of beta-convergence in this case.

Table 15. Beta convergence of socio-economic synthetic measure and its determinats in European Union countries in the years 2008-2018

	Regression summary of the dependent variable: Synthetic measure R= ,36112731 R^2= ,13041294 Corrected R^2= ,09696728 F(1,26)=3,8992					
	b*	Std. Er. z b*	b	Std. Er. z b	t(26)	p
Inter-cept			0,000086	0,001640	0,05236	0,958639
Slope	-0,361127	0,182882	-0,013431	0,006802	-1,97465	0,059017
	Regression summary of the dependent variable: Economy and Finance R= ,30722764 R^2= ,09438882 Corrected R^2= ,05955762 F(1,26)=2,7099					
Inter-cept			-0,003117	0,002194	-1,42032	0,167395
Slope	-0,307228	0,186631	-0,018168	0,011036	-1,64618	0,111764
	Regression summary of the dependent variable: Science and Technology R= ,46776023 R^2= ,21879963 Corrected R^2= ,18875346 F(1,26)=7,2821					
Inter-cept			0,001043	0,001535	0,67928	0,502966
Slope	-0,467760	0,173338	-0,011368	0,004213	-2,69854	0,012072
	Regression summary of the dependent variable: Health R= ,73131698 R^2= ,53482453 Corrected R^2= ,51693316 F(1,26)=29,893					
Inter-cept			-0,006369	0,001396	-4,56391	0,000106
Slope	-0,731317	0,133759	-0,052842	0,009665	-5,46744	0,000010
	Regression summary of the dependent variable: Education R= ,73355449 R^2= ,53810219 Corrected R^2= ,52033689 F(1,26)=30,290					
Inter-cept			-0,004234	0,002655	-1,59469	0,122866
Slope	-0,733554	0,133287	-0,046561	0,008460	-5,50359	0,000009
	Regression summary of the dependent variable: Living Conditions R= ,14593053 R^2= ,02129572 F(1,26)=,56574					
Inter-cept			0,000337	0,004025	0,083844	0,933823
Slope	-0,145931	0,194017	-0,010232	0,013603	-0,752155	0,458714

(*Source: author's calculations*)

Beta convergence models of socio-economic synthetic measure and its determinats in European Union countries in the years 2008-2018 are presented in Table 15.

In figure 38 are presented simple regression models, in which dependent variable is the growth of the analyzed determinants of socio-economic development: Economy and Finance, Science and Technology, Health, Education and Living Conditions. It was obtained that the slopes of all the models are negative, so there is the evidence of beta-convergence in every of the analyzed cases.

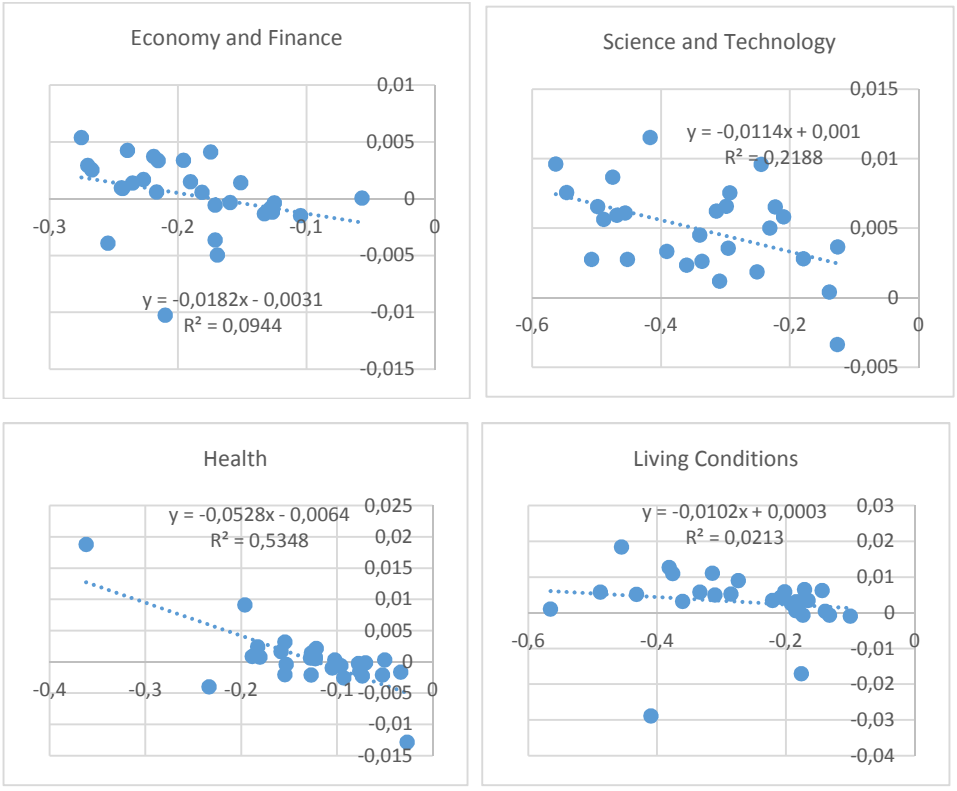

Fig. 38. Simple regression models in which the dependent variable is the growth rate of the analyzed determinants
(*Source: author's calculations*)

Parameter b at the variable $\log(y_{i,0})$ (slope) is negative for all obtained regression functions (Table 15), which means the occurrence of beta convergence both in the case of determinants of Economics and Finance, as well as in the case of other determinants distinguished in the study: Science and Technology, Health,

Education and Living Conditions. The occurrence of beta convergence is a prerequisite for the sigma convergence study.

4.2.2. Sigma convergence and methods of its measurement

This section examines the existence of social convergence identified with the reduction of disparities in the standard of living of the population of the countries of the European Union. For this purpose, sigma convergence analysis was used.

Sigma convergence occurs when the disproportions measured, for example, by the standard deviation of the logarithms of income per capita between countries decrease over time (Próchniak, 2004).

The sigma convergence study is possible on the basis of the following trend model:

$$S_{yt} = \alpha_0 + \alpha_1 t + \varepsilon_t \quad (t = 1, \ldots, n) \tag{35}$$

where:

S_{yt} – standard deviation of the logarithm of the analyzed variable,
α_0, α_1 – structural parameters,
t – time variable,
ε_t – random component of the equation.

The negative and statistically significant parameter α_1 indicates the presence of sigma convergence. The positive and statistically significant parameter α_1 indicates the presence of sigma divergence. In order to investigate the occurrence of the sigma-convergence process, the following set of hypotheses is verified:

$H_0: \sigma_1^2 = \sigma_T^2$ (there is no convergence or divergence)

$H_1: \sigma_1^2 > \sigma_T^2$ $(There\ is\ convergence)$

$or\ H_1: \sigma_1^2 < \sigma_T^2$ $(there\ is\ divergence)$

where:

σ_1^2, σ_T^2 – variance of the feature examined in the first and last period of the study

The statistical insignificance of the parameter α_1 does not allow to conclude on the existence of sigma-convergence or sigma-divergence. It is worth noting that the parameter α_1 has an economic interpretation, and its value allows us to state how much the difference between the analyzed objects decreases ($\alpha_1 < 0$)

or increases($\alpha_1 < 0$). Therefore, it can be concluded that sigma-convergence is used to study changes in the distribution of a feature over time.

In table 16 the results of sigma convergence of EU countries in the years 2008-2018 were presented.

Table 16. Sigma convergence of European Union countries in the years 2008-2018

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Σ	0,069	0,072	0,084	0,081	0,081	0,081	0,078	0,071	0,072	0,069	0,064
σ^2	0,005	0,005	0,007	0,007	0,007	0,007	0,006	0,005	0,005	0,005	0,004

(*Source: author's calculations*)

In figure 39 is presented the trend model for sigma convergence for European Union countries. It was obtained that the parameter α_1 is negative. Table 17 shows the obtained sigma values. For the synthetic indicator, the inequality was obtained $\sigma_1^2 > \sigma_T^2$, so it indicates the presence of sigma convergence in this study.

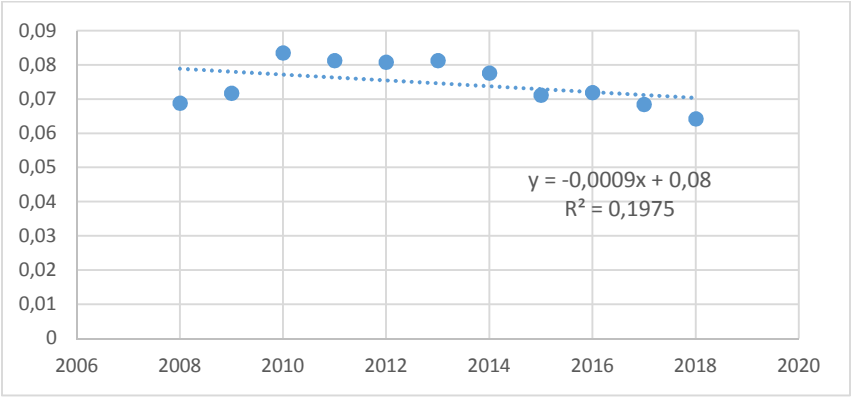

Fig. 39. Trend model for sigma convergence for European Union countries
(*Source: author's calculations*)

Confirmation of the occurrence of sigma convergence processes is a prerequisite for confirming the occurrence of beta convergence processes. As already mentioned, β convergence is a necessary factor, although not sufficient, to achieve σ convergence. Table 17 presents the results of estimation of parameters that make it possible to determine whether there is a sigma convergence of socio-economic synthetic measure and its determinats in European Union countries.

Table 17. Sigma convergence of socio-economic synthetic measure and its determinats in European Union countries in the years 2008-2018

	Regression summary of the dependent variable: Synthetic measure R= ,44442539 R^2= ,19751393 Popraw. R2= ,10834881 F(1,9)=2,2151					
	b*	Bł. std. z b*	b	Bł. std. z b	t(26)	p
Inter-cept			0,079964	0,003977	20,10650	0,000000
Slope	-0,444425	0,298605	-0,000873	0,000586	-1,48834	0,170840
	Regression summary of the dependent variable: : Economy and Finance R= ,26027142 R^2= ,06774121 Popraw. R2= ----- F(1,9)=,65397					
Inter-cept			0,080145	0,008506	9,421801	0,000006
Slope	-0,260271	0,321845	-0,001014	0,001254	-0,808685	0,439549
	Regression summary of the dependent variable: Science and Technology R= ,90413665 R^2= ,81746308 Popraw. R2= ,79718120 F(1,9)=40,305					
Inter-cept			0,137218	0,001884	72,82889	0,000000
Slope	-0,904137	0,142414	-0,001764	0,000278	-6,34863	0,000133
	Regression summary of the dependent variable: Health R= ,78027246 R^2= ,60882512 Popraw. R2= ,56536124 F(1,9)=14,008					
Inter-cept			0,062023	0,003559	17,42776	0,000000
Slope	-0,780272	0,208480	-0,001964	0,000525	-3,74267	0,004606
	Regression summary of the dependent variable: Education R= ,90752082 R^2= ,82359403 Popraw. R2= ,80399337 F(1,9)=42,019					
Inter-cept			0,121877	0,003783	32,21508	0,000000
Slope	-0,907521	0,140002	-0,003616	0,000558	-6,48218	0,000114
	Regression summary of the dependent variable: Living Conditions R= ,25159786 R^2= ,06330148 Popraw. R2= ----- F(1,9)=,60821					
Inter-cept			0,186836	0,019133	9,765356	0,000004
Slope	-0,251598	0,322611	-0,002200	0,002821	-0,779881	0,455480

(*Source: author's calculations*)

Table 18. Sigma convergence of socio-economic development determinants in European Union countries in the years 2008-2018

Year	Economy and Finance		Science and Technology		Health		Education		Living conditions	
	σ	σ^2	σ	σ^2	σ	σ^2	σ	σ^2	σ	σ^2
2008	0,054	0,00294	0,129	0,01654	0,068	0,00460	0,127	0,01621	0,122	0,01482
2009	0,073	0,00534	0,134	0,01809	0,054	0,00292	0,118	0,01384	0,186	0,03464
2010	0,084	0,00707	0,135	0,01826	0,059	0,00351	0,113	0,01286	0,185	0,03427
2011	0,083	0,00682	0,133	0,01768	0,057	0,00320	0,100	0,00996	0,210	0,04422
2012	0,088	0,00777	0,132	0,01741	0,046	0,00209	0,095	0,00901	0,217	0,04703
2013	0,090	0,00802	0,127	0,01623	0,049	0,00235	0,095	0,00896	0,187	0,03492
2014	0,084	0,00710	0,125	0,01561	0,044	0,00194	0,094	0,00885	0,178	0,03160
2015	0,074	0,00554	0,122	0,01489	0,040	0,00156	0,093	0,00862	0,175	0,03061
2016	0,068	0,00459	0,120	0,01440	0,043	0,00182	0,092	0,00840	0,166	0,02755
2017	0,062	0,00380	0,119	0,01406	0,048	0,00231	0,089	0,00793	0,142	0,02030
2018	0,055	0,00301	0,117	0,01359	0,046	0,00216	0,087	0,00751	0,142	0,02030

(*Source: author's calculations*)

On the basis of the calculation it was obtained (table 18) that there is a sigma divergence in Economy and Finance determinant ($\sigma_1^2 < \sigma_T^2$). On the basis of the calculation it was obtained that there is a sigma convergence in Science and Technology determinant ($\sigma_1^2 > \sigma_T^2$). On the basis of the calculation it was obtained that there is a sigma convergence in Health determinant ($\sigma_1^2 > \sigma_T^2$). On the basis of the calculation it was obtained that there is a sigma convergence in Education determinant ($\sigma_1^2 > \sigma_T^2$). On the basis of the calculation it was obtained that there is a sigma divergence in Living Conditions determinant ($\sigma_1^2 < \sigma_T^2$).

4.2.3. Gamma convergence study

In the case of gamma convergence, there is a situation in which the objects with an initially lower level of the variable analyzed develop so quickly that they eventually overtake objects with an initially high value of the feature analyzed. In order to study the presence of gamma convergence, first of all, the objects should be linearly ordered according to the value of the variable as the concept of gamma convergence consists in examining changes in the ranking of objects. To study gamma convergence, any measure that counts the change in the order of the examined objects is used - it can be the Kendall rank correlation coefficient or the Spearman rank correlation coefficient. It should be remembered that the consistency of order can be tested only for extreme periods or for all subsequent years within the analyzed period. A sufficient condition for the occurrence of

gamma convergence is the assumption of non-positive values by the rank correlation coefficient. On the other hand, the positive values of the coefficient require the verification of the following hypotheses:

H0: $\tau = 0$ there is gamma-convergence
H1: $\tau > 0$ there is no gamma-convergence

The statistical insignificance of the rank correlation coefficient proves that the initial ordering is random in relation to the final ordering, so there is gamma-convergence.

The study showed that for the synthetic measure of socio-economic development, the value of the Kendall rank correlation coefficient was 0.8, therefore it was obtained that there was no gamma-convergence for the EU countries in the period under the analysis.

The obtained positive result of the Kendall's tau rank correlation coefficient indicates that gamma-convergence does not occur in the case of a synthetic measure of socio-economic development for the European Union countries in the analyzed period. Table 19 shows the correlation coefficients of Kendall's tau ranks for all determinants and it was obtained that the values of gamma-convergence does not occur in the case of other determinants of socio-economic development in the European Union countries.

Table 19. Kendall's tau rank correlation coefficients

	Kendall's tau rank correlation coefficient
Synthetic measure of socio-economic development 2008 and 2018	0.80
Economy and Finance 2008 and 2018	0.65
Science and Technology2008 and 2018	0.84
Health 2008 and 2018	0.57
Education 2008 and 2018	0.66
Living Conditions 2008 and 2018	0.68

(*Source: author's calculations*)

4.3. Spatial autocorrelation indices for the designated sythetic measure of socio-economic development in the European Union countries

4.3.1. Movan's spatial autocorrelation indices

In 1970, Tobler formulated the first geographic law, also known as the Tobler's First Law and Spatial Analysis, which reads: "Everything is related to

each other, but closer objects are more dependent on each other than the distant ones" (Tobler, 1970).

The spatial autocorrelation coefficient determines the degree of relationship between the value of a variable for a given spatial unit and the value of the same variable in a different unit (location). The consequence of the existence of such the relationship is the spatial grouping of similar values into clusters. Positive autocorrelation is the spatial accumulation of high or low values of the variables observed, and negative autocorrelation can be understood as the reciprocal of positive autocorrelation, i.e. low values appear next to high values of the variables observed. Most often, the study of spatial autocorrelation uses the Moran's correlation index (Ord, Getis, 1995).

Stages of calculating the Moran's spatial autocorrelation index:

1. The values of the measured feature for objects (x_i) (z_i) are standarized;
2. The spatial similarity matrix (e.g. adjacency, higher order adjacency, common border length, reciprocal distance, etc.) of objects [w_{ij}] are defined;
3. The W matrix is normalized by rows (so that the weights in each row add up to 1);
4. The values of the Moran's spatial autocorrelation indices are determined from the formula:

$$I = \frac{1}{n}\sum_{i=1}^{n} z_i \sum_{j=1}^{n} w_{ij} z_j \tag{36}$$

5. The I value is interpreted similarly to the Pearson's linear correlation coefficient, except that it does not assume extreme values (-1 and 1) for all data.

The basic definition of adjacency can be defined as follows: two spatial units can be considered adjacent if they have a common border. For the purposes of statistical calculations, adjacency is determined according to the following scheme:

$$W = \begin{cases} w_{ij} = 1, \text{ when the i-th object is adjacent to the j-th object,} \\ w_{ij} = 0, \text{ when the i-th object is adjacent to the j-th object,} \\ w_{ij} = 0, \text{ when i = j.} \end{cases}$$

where: w_{ij} – is an element of the adjacency matrix.

In the case when two objects (spatial units) are adjacent to each other in the adjacency matrix, it is marked as 1, and in the case when the objects are not adjacent we assign the value 0. We put zeros on the diagonal of the adjacency matrix since the given object cannot be its “neighbor” (Pietrzykowski, 2011). On the following figures there are presented spatial distributions of all analyzed determinants of socioeconomic development of European Union countries. It can be observed that there is division between North and South Europe, especially concerning living conditions and synthetic measure. According economy and finance, as well as science and technology it is visible that there is a division between Northern and Southern countries as well as Western and Eastern countries especially Baltic states. The least variation occurs for the health determinant (fig. 40-42).

The calculated Moran’s spatial autocorrelation indices indicate a moderate spatial relationship. A greater dependence can be observed for the countries of Western and Northern Europe, and less for the countries of Southeastern Europe.

Spatial autocorrelations for all synthetic measures, except health, are quite strong (IM > 0.5). But also for the population health indicator, spatial autocorrelations are statistically significant – except for 2008 and 2016 – although they are much less powerful. Generally, it means that countries with high values of a given measure are adjacent to countries with high values of the measure and similarly for low values. So there are clear "geographic" directions of decreases and increases in quality of life measures – based on the choropleth maps, it is possible to speak of an increase in the quality of life to the north and west, and a decrease to the south and east.

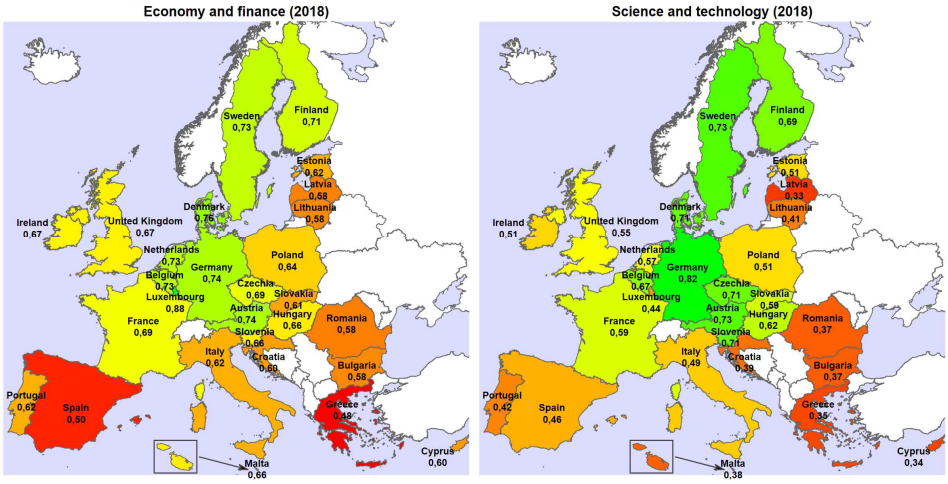

Fig. 40. Spatial distributions of the Economy and Finance, Science and Technology for 2018 (*Source: author’s own research*)

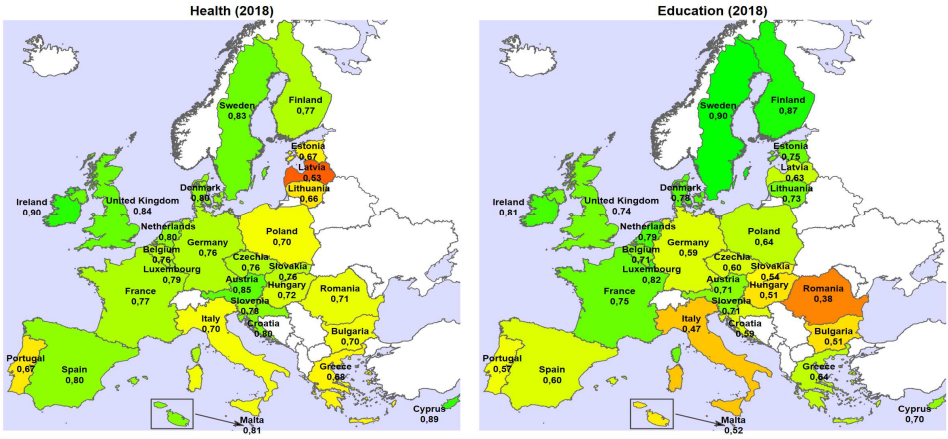

Fig. 41. Spatial distribution of the Health and Education for 2018
(*Source: author's own research*)

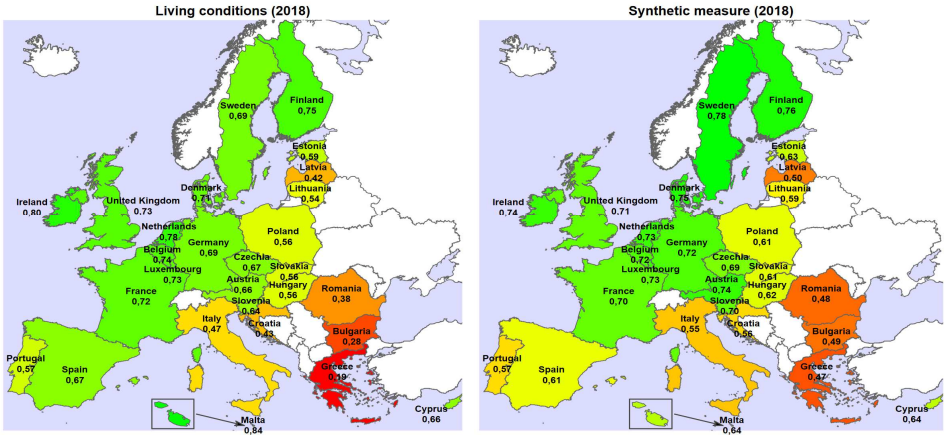

Fig. 42. Spatial distribution of the Living Conditions for 2018
(*Source: author's own research*)

There are interesting results for the living conditions, for which quite clearly lower autocorrelation occurred in 2008 and 2009 (crisis), and a further decline started in 2016 (this can be considered as symptoms of another crisis, visible in the level of living conditions) (table 20).

Table 20. The Moran's spatial autocorrelation indices

Year	Science & technology		Economy & finance		Health		Education		Living conditions		Synthetic measure	
	I_M	p	I_M	p	I_M	p	I_M	p	I_M	p	I_M	P
2008	0.57	0.000	0.47	0.001	0.17	0.095	0.54	0.000	0.41	0.006	0.64	0.000
2009	0.57	0.000	0.53	0.000	0.31	0.025	0.54	0.000	0.45	0.001	0.66	0.000
2010	0.54	0.001	0.56	0.000	0.37	0.004	0.51	0.000	0.61	0.000	0.65	0.000
2011	0.48	0.000	0.57	0.000	0.37	0.004	0.51	0.000	0.56	0.000	0.62	0.000
2012	0.49	0.000	0.57	0.000	0.34	0.009	0.55	0.000	0.58	0.000	0.63	0.000
2013	0.51	0.000	0.58	0.000	0.31	0.011	0.56	0.000	0.60	0.000	0.64	0.000
2014	0.52	0.000	0.54	0.000	0.34	0.008	0.53	0.000	0.60	0.001	0.64	0.000
2015	0.50	0.000	0.54	0.000	0.30	0.010	0.52	0.000	0.59	0.000	0.62	0.000
2016	0.53	0.000	0.58	0.000	0.02	0.347	0.54	0.000	0.57	0.000	0.63	0.000
2017	0.52	0.000	0.56	0.000	0.29	0.021	0.55	0.000	0.51	0.002	0.63	0.000
2018	0.50	0.000	0.53	0.001	0.30	0.015	0.53	0.000	0.42	0.005	0.60	0.000

(*Source: author's own research*)

4.3.2. The Gini index

Important measures for describing income inequality are measures of volatility (including standard deviation or half the coefficient of variation), variance of the income logarithm, the Gini index, Schutz inequality measure, Eleto and Frigyes inequality measures, Thiel coefficient. This section focuses on the Gini index. This inex is a correct and commonly used measure of inequality because it meets all the axioms postulated in this respect (Atkinson, 1983). In order to be able to assess whether the level of inequality determined by this measure for a given country is low, medium or high, a relative scale should be used, i.e. a given value of the ratio should be compared for different countries or compared for a given country to the past values (Kurowska, 2011). The Gini index is the ratio of half of the average absolute difference between the income of a pair of randomly selected individuals to the average income. In terms of income, it can be considered in two perspectives – before and after taxation and social transfers. The Gini index before taxation and social transfers ranges from [0.1], although in the economic reality it usually ranges from 0.2 to 0.6. A value close to 0 shows an even (egalitarian) distribution of income, and a value close to 1 – uneven. The increase in the index value therefore indicates an increase in income inequality.

The values of the Gini coefficient are calculated from the following formula:

$$G_{(jt)} = \frac{\sum_{i=1}^{m}(2i-n-1)y_{jit}}{m^2\bar{y}_{jt}} \quad (37)$$

$G_{(jt)}$ – the value of the Gini coefficient for the synthetic variable of the j-th group in year t,
y_{jit} – the value of the synthetic variable of the j-th group for the ith country in year t
$\bar{y}_{jt}$ – the average value of the synthetic variable in the j-th group in year t
m – number of countries.

Gini coefficient values for synthetic development measure and determinants of socioeconomic development are presented in table 21.

Table 21. Gini coefficient values for synthetic development measure and determinants of socioeconomic development

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Synthetic measure	0,341	0,336	0,333	0,343	0,344	0,346	0,357	0,369	0,373	0,387	0,399
Economy and Finance	0,406	0,361	0,343	0,344	0,339	0,338	0,35	0,365	0,375	0,393	0,413
Science and Technology	0,219	0,218	0,219	0,235	0,242	0,246	0,251	0,258	0,259	0,265	0,276
Health	0,549	0,552	0,544	0,546	0,548	0,544	0,547	0,562	0,548	0,556	0,552
Education	0,277	0,295	0,311	0,330	0,344	0,364	0,381	0,388	0,399	0,410	0,424
Living Conditions	0,300	0,289	0,295	0,285	0,274	0,288	0,305	0,315	0,339	0,356	0,356

(*Source: author's own research*)

The values of the Gini coefficient did not exceed 0.6, therefore, it cannot be concluded that there was a strong variation in the level of life of the population in the European Union countries in the years 2008-2018. However, the values of the Gini coefficient for the synthetic indicator have been increasing since 2010, which means that there are disparities in social and economic development in the European Union countries.

The highest values were obtained for health, followed by education and economics. This means that in these aspects there is the greatest diversity in the countries of the European Union. The lowest gini values were obtained for the Determinant Science and Technology.

4.4. The classification of European Union countries with the use of cluster analysis

In this subchapter the classification of European Union countries will be presented for two analyzed years 2008 and 2018. The cluster analysis method will be used.

Classification and taxonomic procedures are used in many areas of contemporary research. Wherever there is a systematic division of objects or phenomena into classes, subclasses, divisions and subdivisions according to a specific principle, data classification methods are used. Classification in the sense of set theory is a complete division (the sum of sets gives the whole space) of a given set into a number of disjoint subsets. The object of classification is sets of observations of any nature.

Each object of such a set is usually described by many quantitative and qualitative features. A set of features (attributes or properties) is called a classification space. Often in modern research, the data collected for an analysis depends on the units of time. The so-called a data cube is made up of a set of objects, a set of features and a set of time units. The objects under analysis are called operational taxonomic units (OTUs).

One of the many methods for classifying objects is a cluster analysis. It makes it possible to distinguish subgroups of a given set that are internally homogeneous with respect to a certain measure of similarity of objects. An application of this method requires some basic research decisions. The basis for grouping objects is the correct selection of diagnostic variables. Their type and number depend on the purpose of the analysis.

Cluster analysis is a method that allows one to divide a set of observations into subsets (so-called clusters) in such a way that the objects in the same cluster are similar. It is a data mining method. Object similarity relations are determined primarily on the basis of the measure of the distance between objects, therefore it is postulated that the classification space should be a metric space. It is even better when the similarity measure has the property of a metric. Some distance measures should be used with caution and their limitations in mind. The book presents the results of the effectiveness of the proposed test using one of the most commonly used distance measures – the square of the Euclidean distance.

The selected grouping goals are as follows:

- Obtaining homogeneous groups of tested objects, facilitating the isolation of their essential features or obtaining the classification of typical objects,
- Discovery of the unknown structure of the data analyzed and, consequently, the classification of typical objects,

- Reduction of a large amount of primary data to a few basic categories that can be treated as subjects for further analysis,
- Comparison of multi-feature objects.

The division of countries into groups characterized by a low, moderate and high level of socio-economic development were prepared and discussed in the following subchapter. Results of grouping the EU contries are presenting in figure 43 (for the 2018).

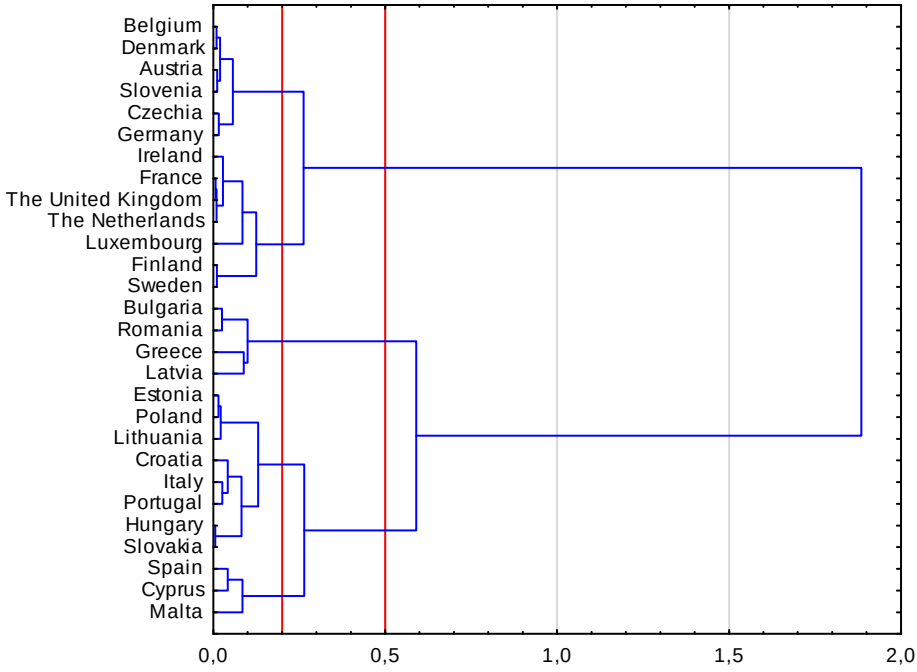

Fig. 43. Results of grouping the EU countries in 2018
(*Source: author's own research*)

The table 22 presents the results of cluster analysis using square of the Euclidean distance and the Ward's method for the year 2018, where three groups of countries were selected. In the table 23 there were five groups of countries selected: very good, good, medium, weak and very weak.

It was obtained from the conducted research, that group A includes the following countries: Belgium, Danmark, Austria, Slovenia, Czechia, Germany, Ireland, France, The United Kingdom, The Netherlands, Luxembourg, Finland, Sweden. Group B countries include: Estonia, Poland, Lithuania, Croatia, Italy, Portugal, Hungary, Slovakia, Spain, Cyprus, Malta. Group C countries include: Bulgaria, Romania, Greece, Latvia.

Table 22. Quotients of the means of individual groups to the total mean for the synthetic measure and its determinants for the year 2018

Group	Synthetic measure 2018	Science and Technology	Economics and Finance	Health	Education	Living Conditions
A	1.13	1.21	1.10	1.06	1.14	1.18
B	0.94	0.73	0.95	1.15	0.94	0.91
C	0.75	0.56	0.86	1.02	0.83	0.49

(*Source: author's own research*)

Group A countries obtained the quotient of the mean to the general mean above 1 for all determinants analyzed, as well as for the value of the synthetic measure of socio-economic development. For countries from group B, only the quotient value for the determinant Health exceeds 1, i.e. these countries have the best conditions for health. The remaining quotients obtained values below 1, oscillating in the range from 0.91 to 0.95, except for Science and Technology, for this determinant the result of the quotient is 0.73.

For the C countries, only one quotient obtained a value above 1 for the determinant which is Health. The remaining values of the quotients are less than 1. For Living Conditions, the quotient value reached the lowest value of 0.49, and the quotient for the Science and Technology determinant has a similar low value of 0.56.

The following results were obtained when divided into 5 groups. Group I includes the following countries: Ireland, France, The United Kingdom, The Netherlands, Luxembourg, Finland, Sweden. Group II countries include: Belgium, Danmark, Austria, Slovenia, Czechia, Germany. Group III countries include: Estonia, Poland, Lithuania, Croatia, Italy, Portugal, Hungary, Slovakia. Group IV countries include Spain, Cyprus, Malta. Group V countries include: Bulgaria, Romania, Greece, Latvia (table 23).

Table 23. Quotients of the means of individual groups to the total mean for the synthetic measure and its determinants for the year 2018

Group	***Synthetic measure 2018***	***Science and Technology***	***Economics and Finance***	***Health***	***Education***	***Living Conditions***
I	1.14	1.09	1.11	1.07	1.22	1.22
II	1.12	1.35	1.10	1.04	1.03	1.13
III	0.98	0.74	0.90	1.10	0.92	1.19
IV	0.92	0.92	0.95	0.94	0.91	0.88
V	0.75	0.67	0.85	0.86	0.81	0.52

(*Source: author's own research*)

When analyzing the results obtained, it should be stated that the quotients for all determinants, as well as for the synthetic measure of socio-economic development for groups I and II, have values above 1, but the countries of group II are better in terms of Science and Technology. The lowest values are obtained by the V group countries for all determinants, as well as for the synthetic measure of socio-economic development. Results of grouping the EU countries are presenting in figure 44 (for the 2008).

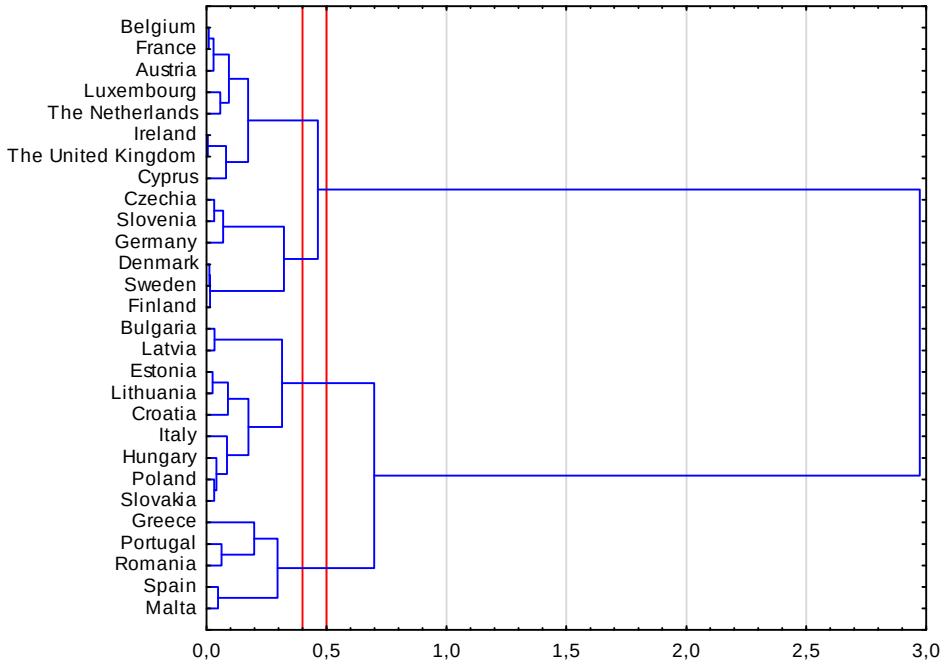

Fig. 44. The results of grouping the EU countries in 2008
(*Source: author's own research*)

The table 24 presents the results of cluster analysis using square of the Euclidean distance and the Ward's method for the year 2008, where three groups of countries were selected: very good, medium and very weak. In the table 25 there were four groups of countries selected: very good, good, weak and very weak.

Group A includes the following countries: Belgium, France, Austria, Luxembourg, The Netherlands, Ireland, The United Kingdom, Cyprus, Czechia, Slovenia, Germany, Danmark, Finland, Sweden. Group B includes the following countries: Bulgaria, Latvia, Estonia, Poland, Lithuania, Croatia, Italy, Hungary, Slovakia. Group C includes the following countries: Portugal, Romania, Greece, Spain, Malta (table 24).

The following results were obtained when divided into four groups. Group I includes the following countries: Belgium, France, Austria, Luxembourg, the Netherlands, Ireland, the United Kingdom and Cyprus. Group II countries include: Czechia, Slovenia, Germany, Denmark, Sweden, Finland. Group III countries include: Bulgaria, Latvia, Estonia, Lithuania, Croatia, Italy, Hungary, Poland and Slovakia. Group IV countries include: Greece, Portugal, Romania, Spain and Malta (table 25).

Table 24. Quotients of the means of individual groups to the total mean for the synthetic measure and its determinants for the year 2008

Group	Synthetic measure 2008	Science and Technology	Economics and Finance	Health	Education	Living Conditions
A	1.32	1.16	1.17	1.24	1.18	1.20
B	0.76	0.84	0.68	0.90	0.78	0.79
C	0.55	0.84	1.10	0.50	0.90	0.81

(*Source: author's own research*)

Table 25. Quotients of the means of individual groups to the total mean for the synthetic measure and its determinants for the year 2008

Group	Synthetic measure 2008	Science and Technology	Economics and Finance	Health	Education	Living Conditions
I	1.19	1.07	1.16	1.24	1.17	1.25
III	0.79	0.76	0.84	0.68	0.90	0.78
II	1.23	1.65	1.16	1.09	1.34	1.08
IV	0.81	0.55	0.84	1.10	0.50	0.90

(*Source: author's own research*)

In the analysis of the research results, the methods of statistical multivariate analysis (allowing to determine the correlation between variables in specific configurations) and the taxonometric methods, especially the synthetic variable procedure, enabling the hierarchization of objects according to the level of a given feature, turned out to be extremely useful from the point of view of interpretative possibilities.

4.5. Nonlinear models of socio-economic development for individual countries of the European Union

In subchapter 4.5 nonlinear models of socio-economic development for individual coutries of European Union will be created.

The following charts present models of socio-economic development created on the basis of the synthetic measure for all European Union countries for 2008-2018 presented in the book.

Sweden (fig. 45) is the leader of the European Union for the synthetic measure of socio-economic development in 2018. For Sweden, a continuous increase in the value of the measure of socio-economic development can be observed in the period analyzed. The values of the measure for this country are high, however, this growth is not as dynamic as it was in the case of the countries that joined the European Union, inter alia, in 2004.

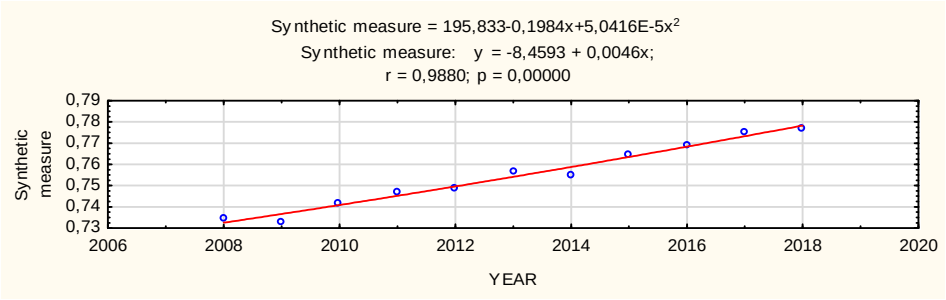

Fig. 45. Values of the synthetic measure for Sweden for the years 2008-2018
(*Source: author's calculations*)

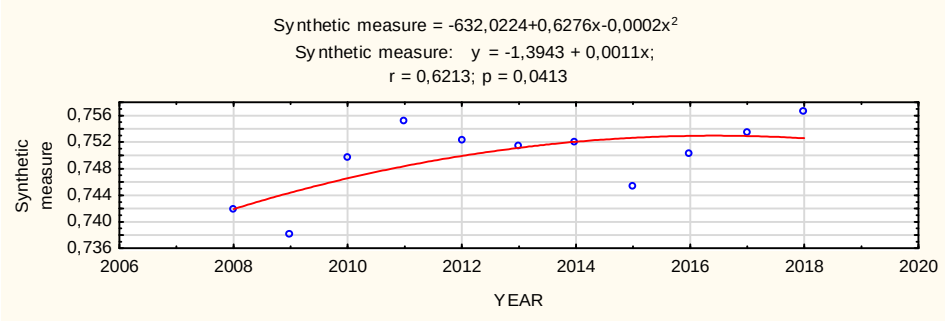

Fig. 46. Values of the synthetic measure for Finland for the years 2008-2018
(*Source: author's calculations*)

For Finland (fig. 46), the values of the socio-economic development measure decreased after the crisis in 2008 and then increased until 2011. From 2011, they decreased again until 2015. Since 2015, Finland has achieved a continuous increase in the value of the development measure.

For Denmark (fig. 47), in recent years, starting from 2015, the value of the socio-economic development measure has been reduced. However, it is a country that, according to the ranking, ranks third in 2018 among the countries of the Economic Community.

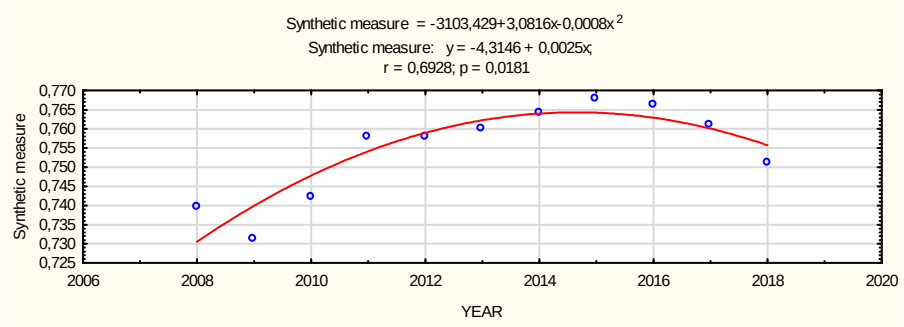

Fig. 47. Values of the synthetic measure for Denmark for the years 2008-2018
(*Source: author's calculations*)

Austria (fig. 48) belongs to the group of countries with a high level of socio-economic development. In this country, the impact of the financial crisis of 2008 has not been observed. The pace of economic growth washigh at the turn of the period of 2008-2018. Among the countries of the European Union, Austria ranks 4th in the ranking created for 2018.

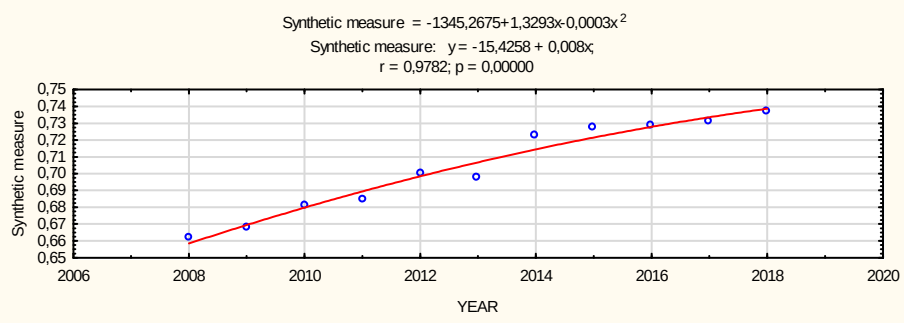

Fig. 48. Values of the synthetic measure for Austria for the years 2008-2018
(*Source: author's calculations*)

For Ireland (fig. 49), only two years saw a decline in the measure of socio-economic development. The first was in 2009, when the world was in a financial crisis. On the other hand, since 2012, a continuous increase in the value of the synthetic measure can be observed. The pace of economic growth for this country remains high.

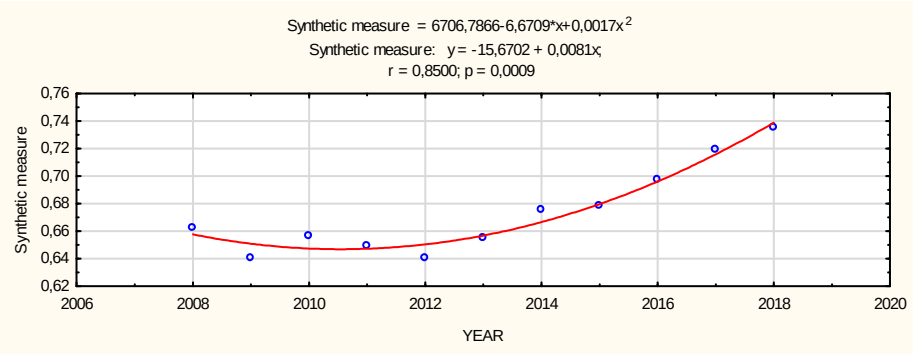

Fig. 49. Values of the synthetic measure for Ireland for the years 2008-2018
(*Source: author's calculations*)

In the case of the Netherlands (fig. 50), an increase in the value of the measure of socio-economic development can be noticed in the period analyzed, except for 2009 and 2013.

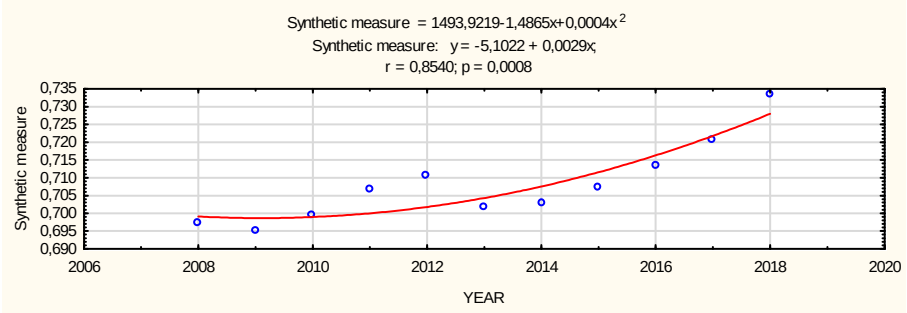

Fig. 50. Values of the synthetic measure for the Netherlands for the years 2008-2018
(*Source: author's calculations*)

In the development model for Luxembourg (fig. 51), the maximum value of 0.75 reached in 2014 can be observed. Since then, the values of the socio-economic development measure have shown a rather downward trend from 2014. There were no lower values for this country due to the 2008 crisis.

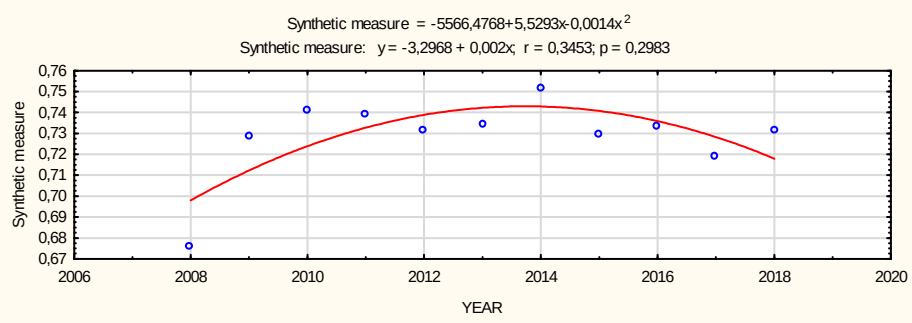

Fig. 51. Values of the synthetic measure for Luxembourg for the years 2008-2018
(*Source: author's calculations*)

Germany (fig. 52), similarly to other Western European countries, achieves high values of the synthetic measure of socio-economic development, which oscillate around 0.72. The dynamics of economic growth for this country is a high index of socio-economic development for the entire Economic Community.

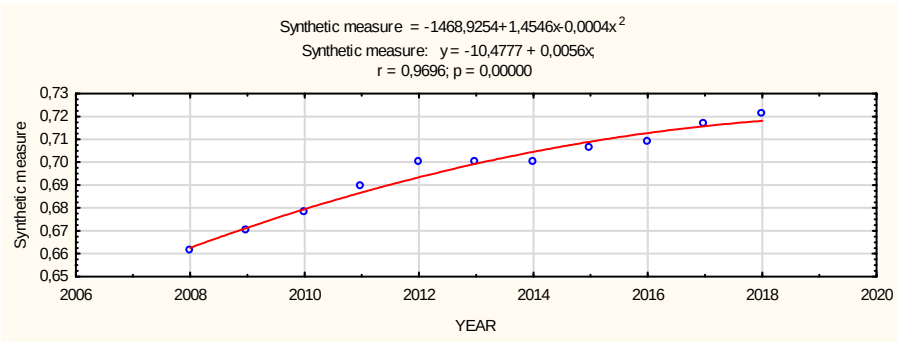

Fig. 52. Values of the synthetic measure for Germany for the years 2008-2018
(*Source: author's calculations*)

As in the case of Germany, the situation of Belgium (fig. 53) is one of the higher values of the measure of socio-economic development for the entire Economic Community. The pace of economic growth for Belgium is similar to the pace of economic development in Germany and oscillates around 0.72.

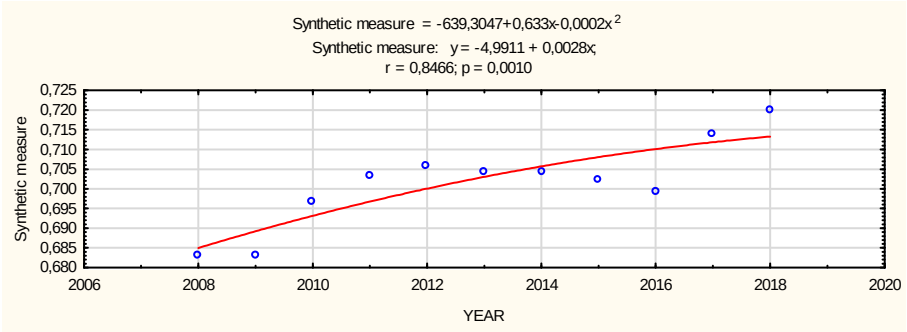

Fig. 53. Values of the synthetic measure for Belgium for the years 2008-2018
(*Source: author's calculations*)

The values of the measure of socio-economic development obtained by the United Kingdom (fig. 54) are lower than those obtained by Belgium. However, when analyzing the slope of the obtained linear model, the dynamics of economic growth for this country is higher.

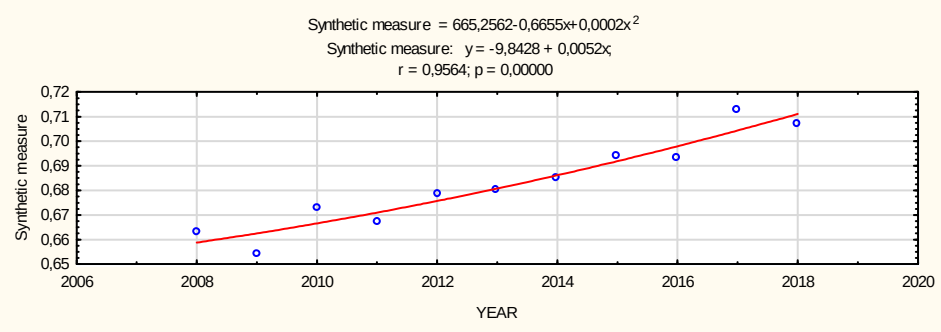

Fig. 54. Values of the synthetic measure for the United Kingdom for the years 2008-2018
(*Source: author's calculations*)

The values of the measure of socio-economic development that France (fig. 55) obtained in 2018 indicate that development in this country is also starting to slow down compared to the countries by which the Union enlarged in the following years. Problems with strikes that occur in this country are indicated and are associated with high costs of living, to which the French do not agree.

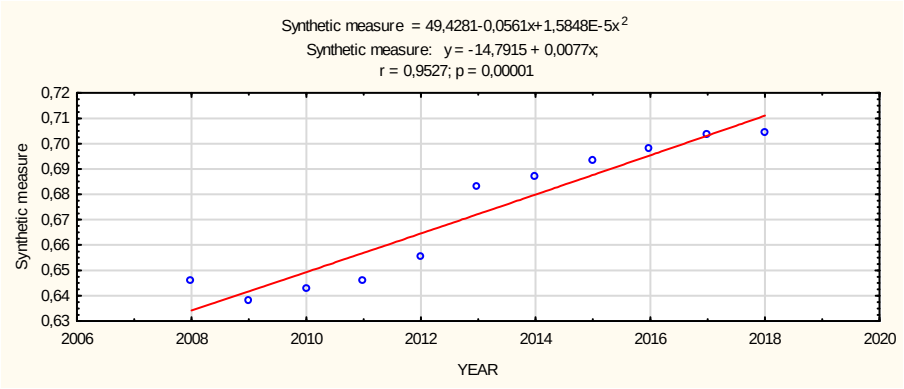

Fig. 55. Values of the synthetic measure for France for the years 2008-2018
(*Source: author's calculations*)

The following chart presents the values of the socio-economic development measure for Slovenia (fig. 56). The values that Slovenia obtains indicate the country's continued development with minimal decreases in the socio-economic development measure in 2009, 2012 and 2014.

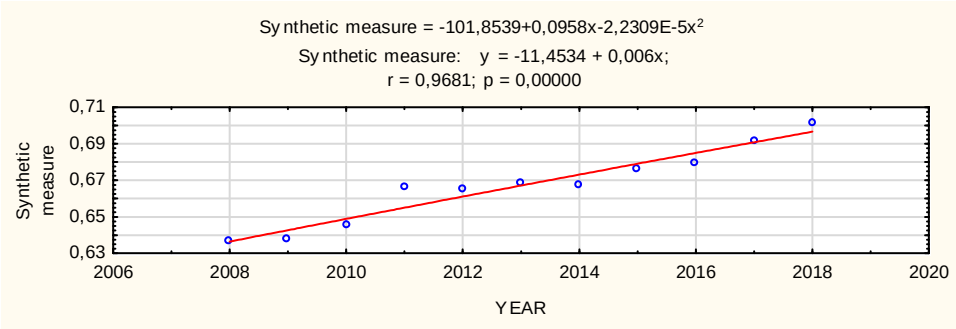

Fig. 56. Values of the synthetic measure for Slovenia for the years 2008-2018
(*Source: author's calculations*)

For the Czech Republic (fig. 57), a continuous increase in the value of the measure of socio-economic development can be observed. Together with Slovenia, it is a country that is gaining a very high pace of economic development. It is similar to that obtained by the countries of Western Europe. The values of the measure decreased only for 2009. Starting from 2010, their systematic increase can be observed (except for 2013, when they minimally decreased).

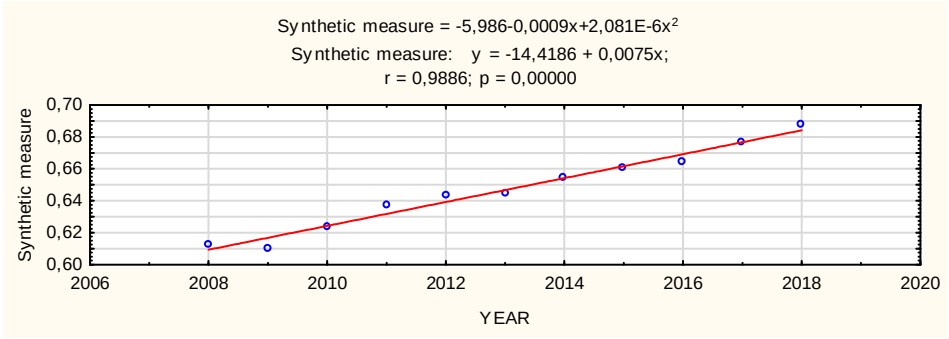

Fig. 57. Values of the synthetic measure for the Czech Republic for the years 2008-2018
(*Source: author's calculations*)

The following chart shows the economic development model for Malta (fig. 58). For this country, an increase in the value of the measure of socio--economic development can be noticed starting from 2010. The following years confirm its further economic growth in Malta.

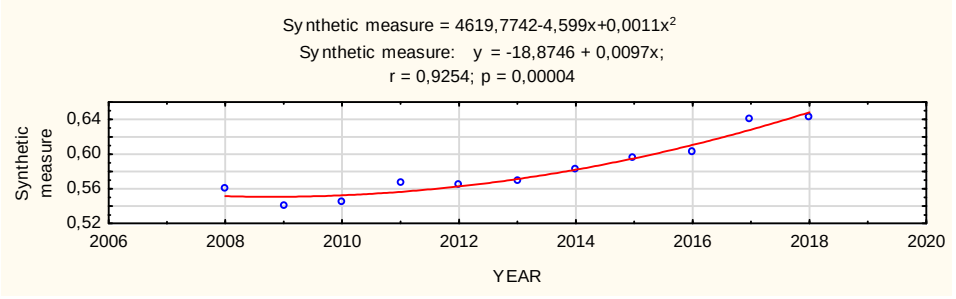

Fig. 58. Values of the synthetic measure for Malta for the years 2008-2018
(*Source: author's calculations*)

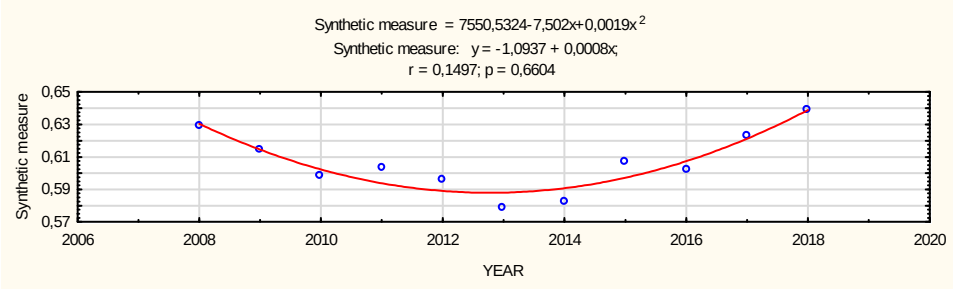

Fig. 59. Values of the synthetic measure for Cyprus for the years 2008-2018
(*Source: author's calculations*)

In the case of Cyprus (fig. 59), a decrease in the value of the socio-economic development measure for 2008-2010 and 2011-2013 can be noticed. Only starting from 2014, this country obtains a growing tendency in the case of the values of the socio-economic development measure.

From the Baltic states, Estonia (fig. 60) obtains the highest values of the synthetic measure of socio-economic development. All three Baltic countries are characterized by an increase in the value of the measure of socio-economic development. This increase is higher than in the countries of Southern Europe. So one can see the horizontal division of Europe into the rich north and the poor south.

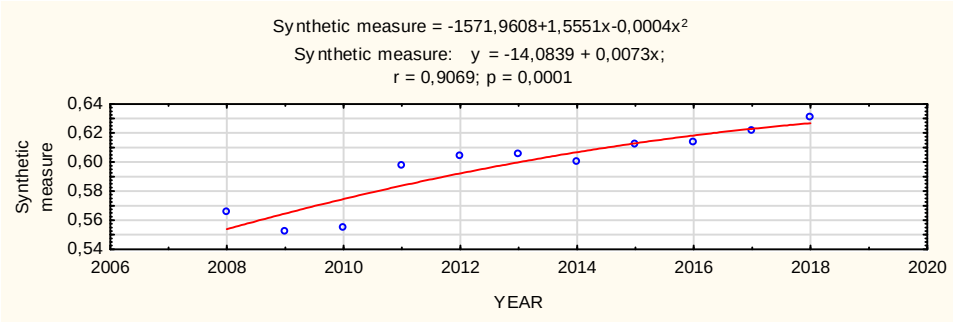

Fig. 60. Values of the synthetic measure for Estonia for the years 2008-2018
(*Source: author's calculations*)

For Hungary (fig. 61.), a decrease in the value of the socio-economic development measure can be noticed from 2008 to 2012. Only starting from 2013, this country achieved a growing trend in the values of the socio-economic development measure.

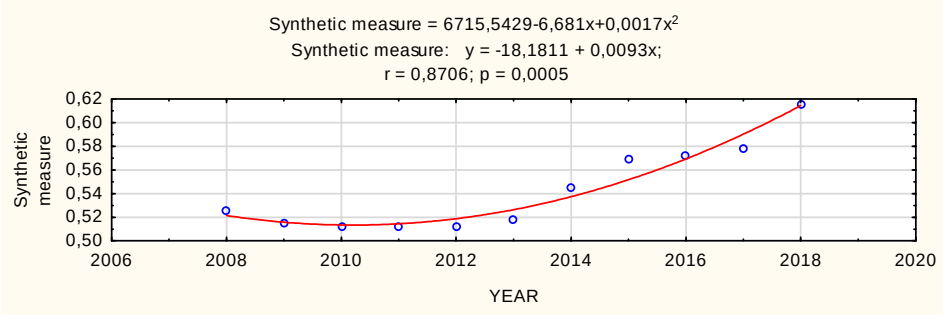

Fig. 61. Values of the synthetic measure for Hungary for the years 2008-2018
(*Source: author's calculations*)

As far as the model of social and economic development in Slovakia (fig. 62) is concerned, a decrease in the value of the measure caused by the crisis in 2008 can be observed, while from 2010, a growth in the value of the measure of socio-economic development for this country can be observed.

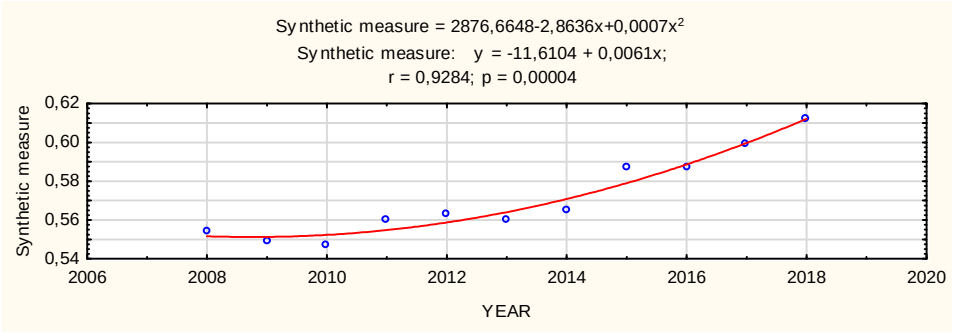

Fig. 62. Values of the synthetic measure for Slovakia for the years 2008-2018
(*Source: author's calculations*)

Poland (fig. 63) belongs to the group of countries that have achieved a satisfactory level of growth in socio-economic development compared to other European Union countries. There is a continuous increase in the value of the measure of socio-economic development for this country. Ireland obtained a similar slope for the linear function. The 500+ program, which covered families with children, certainly contributed to the improvement of the Poles' lives.

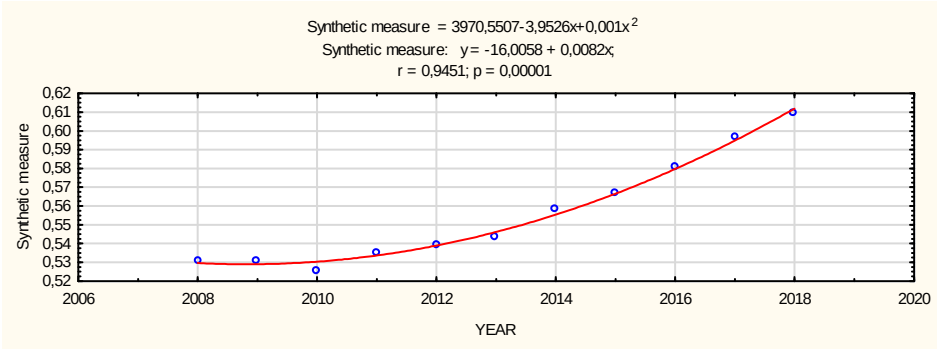

Fig. 63. Values of the synthetic measure for Poland for the years 2008-2018
(*Source: author's calculations*)

In the case of the model of socio-economic development in Spain (fig. 64), a decrease in the value of the measure caused by the crisis in 2008 can be observed, while from 2009 on, an increase in the value of the measure of socio-economic development for this country can be noticed. In the years 2012-2013, the values of the measure decreased again. Since 2014, a new increase in the value of the synthetic measure can be observed.

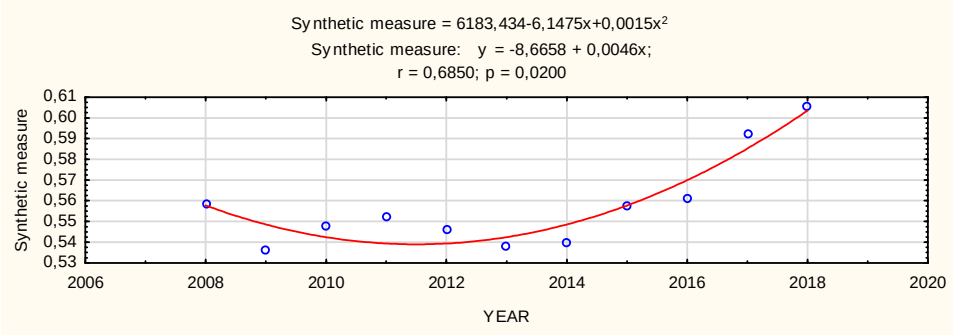

Fig. 64. Values of the synthetic measure for Spain for the years 2008-2018
(*Source: author's calculations*)

In terms of the Lithuanian (fig. 65) socio-economic development model, a decrease in the value of the measure caused by the crisis in 2008 can be observed, while from 2010 on, a growth in the value of the socio-economic development measure for this country can be observed.

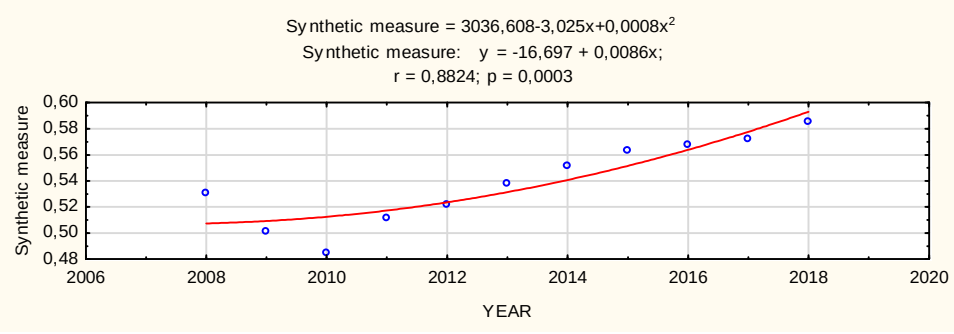

Fig. 65. Values of the synthetic measure for Lithuania for the years 2008-2018
(*Source: author's calculations*)

For Portugal (fig. 66), the values of the socio-economic development measure are not high (the country ranks 22nd in the 2018 ranking). However, it is worth noting that the pace of economic growth in this country is impressive.

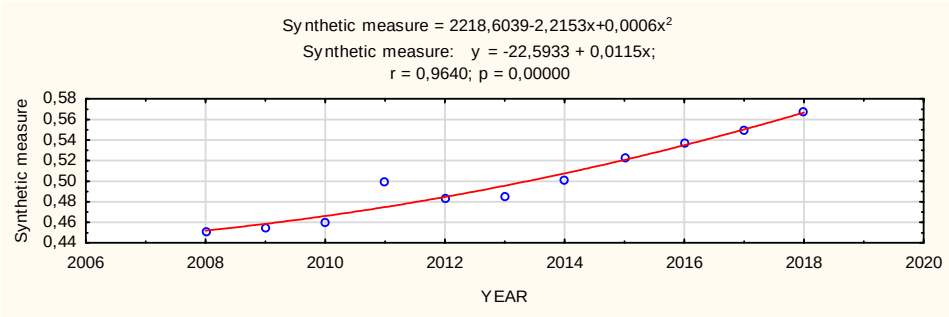

Fig. 66. Values of the synthetic measure for Portugal for the years 2008-2018
(*Source: author's calculations*)

The measure values obtained for Croatia (fig. 67) are similar to those obtained for Portugal. These values are not high compared to other European countries, but when analyzing the values achieved by the countries of Southern Europe, Croatia performs well on this scale. It should also be noted that, starting from 2013, they have been systematically increasing.

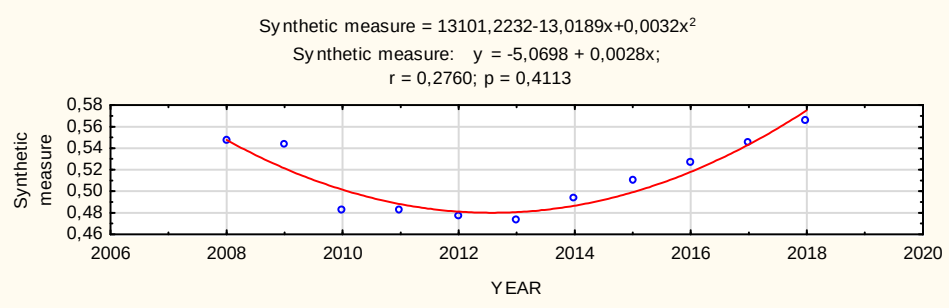

Fig. 67. Values of the synthetic measure for Croatia for the years 2008-2018
(*Source: author's calculations*)

Italy (fig. 68) belongs to the group of countries characterized by one of the lowest values of the synthetic measure of socio-economic development. This is due to the public debt that slows down the country's economic growth. This country achieved low values until 2016, and from 2017 an increase in these values can be noticed.

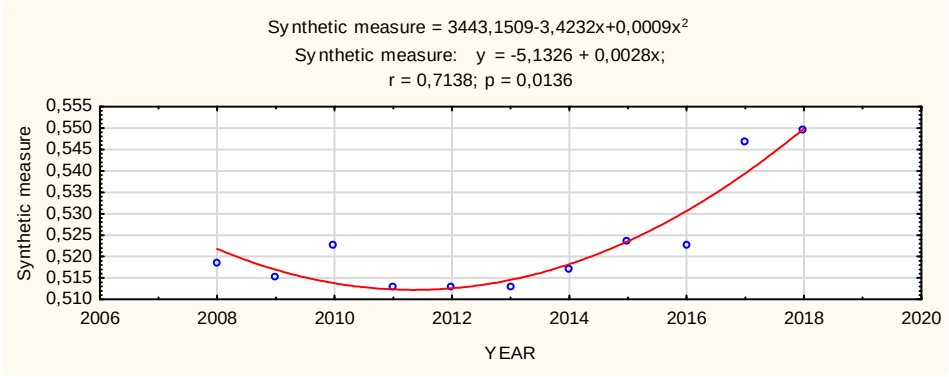

Fig. 68. Values of the synthetic measure for Italy for the years 2008-2018
(*Source: author's calculations*)

The figure 69 presents the values of the measure of socio-economic development obtained by Latvia. Latvia is also one of the EU countries with the lowest values of the measure of socio-economic development. For Latvia, the crisis of 2009 was reflected in the decline in the value of the socio-economic development measure. In subsequent years, their re-growth is visible.

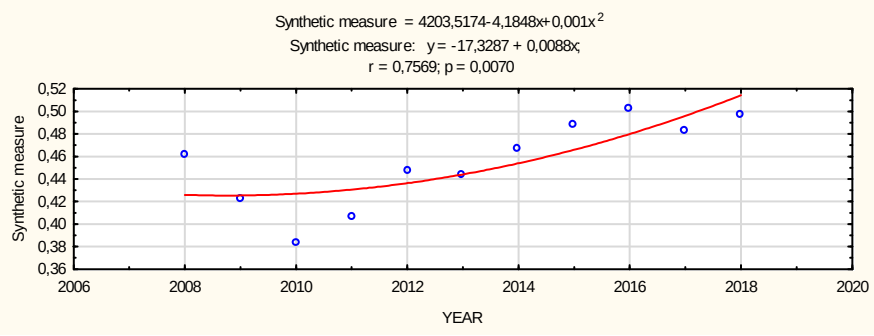

Fig. 69. Values of the synthetic measure for Latvia for the years 2008-2018
(*Source: author's calculations*)

Bulgaria (fig. 70) obtains one of the lowest values of the synthetic measure of socio-economic development in the European Union. However, it can be observed that since 2011 there has been an increase in the value of the synthetic measure.

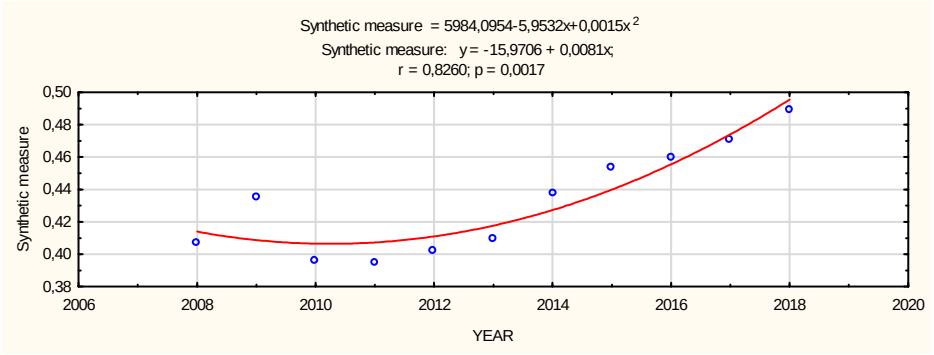

Fig. 70. Values of the synthetic measure for Bulgaria for the years 2008-2018
(*Source: author's calculations*)

Romania (fig. 71) is one of the countries with the lowest value of the synthetic measure of socio-economic development. However, in the period analyzed it can be noticed that despite the fact that it obtains low values of the socio-economic development measure, since 2012 the values of the measure have been increasing for this country.

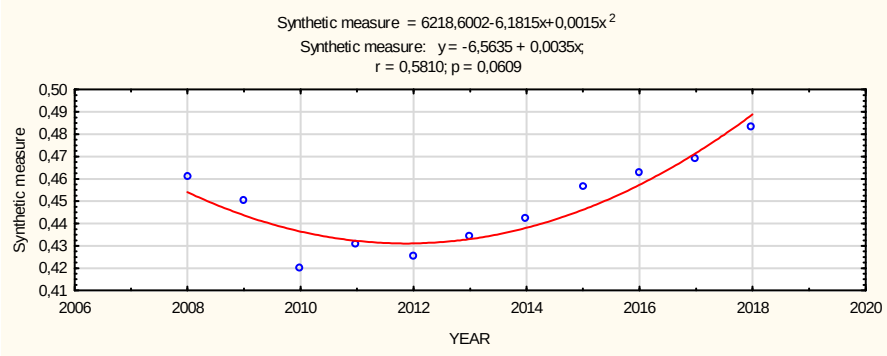

Fig. 71. Values of the synthetic measure for Romania for the years 2008-2018
(*Source: author's calculations*)

Greece (fig. 72) is a country whose main problem is the influx of refugees. The Greeks expect more help from the European Union in this regard. Another aspect of the bad economic situation is the fact that the Greeks live on credit. It is a country that lives off tourism, but it is seen as a cheap country, and therefore the income from this source is not high enough. In addition, the extensive bureaucracy in this country means that some of the initiatives that could be launched in this country are not implemented.

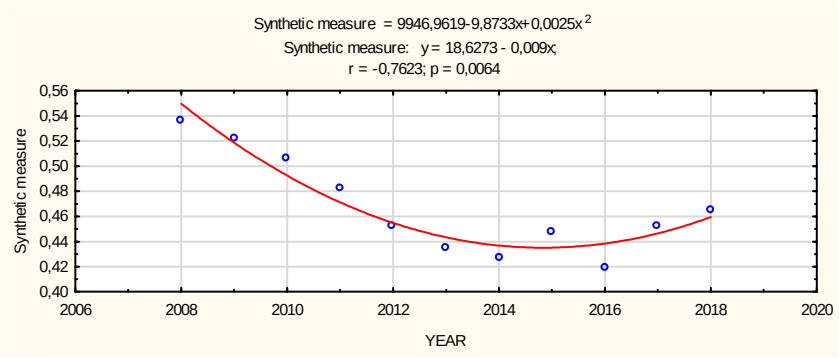

Fig. 72. Values of the synthetic measure for Greece for the years 2008-2018
(*Source: author's calculations*)

Most of the European Union countries felt the effects of the economic crisis of 2008. This can be seen in the individual charts presented in this subsection of the book. Some EU countries coped faster with the crisis, others it took longer. It can also be observed that some of the richer countries of the European Union, namely Denmark and Luxembourg, achieved a minimal decrease in the value of the measure of socio-economic development in the last years of the period analyzed.

4.6. Poland against other European Union countries in the context of socio-economic development

Poland was admitted to the European Union in 2004 and it can be seen that since then a lot has changed in this country. The graphs show the level of Poland's socio-economic development compared to other European Union countries. The individual variables and the value achieved by Poland in the analyzed period compared to other EU countries are presented.

For the variable expenditure on R&D, an increase can be noticed for Poland, although this value still does not even reach the median value obtained for all European Union countries.

For the human resources in science variable, a definite increase can be observed for Poland. For 2018, however, the value of this variable did not exceed the value of the second quartile, i.e. the median of the value obtained for all EU countries (fig. 73).

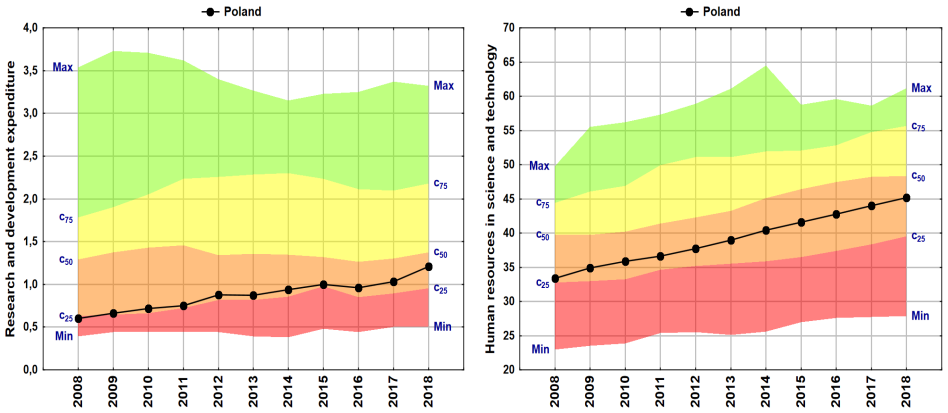

Fig. 73. Research and development expenditure (left), human resources in Science and Technology (right) (*Source: author's calculations*)

For the variable employment in the high- and medium-high technology sector, manufacturing sectors and knowledge-intensive service sectors, the value for Poland oscillates around the third quartile. Since 2008, this value has slightly decreased, which was most certainly caused by the financial crisis in 2008, but since 2010, an increase in this value can be observed. The government's total revenues for Poland oscillate around the second quartile. After 2008, this value decreased, but only until 2009. Starting from 2009, the value of this variable was increasing (fig. 74).

At that time, the unemployment rate dropped significantly for Poland, although an increase in the value of this variable can be noticed from 2008 to 2013. This fact can be explained by the crisis that took place in 2008 and had a negative impact on the situation on the labor market throughout the European Union.

The value of GDP per capita for Poland increased in that period, however, it can be seen in the chart that it is a value oscillating on the border of the first quartile. For this variable, Poland is in the group of the weakest countries of the European Union (fig. 75).

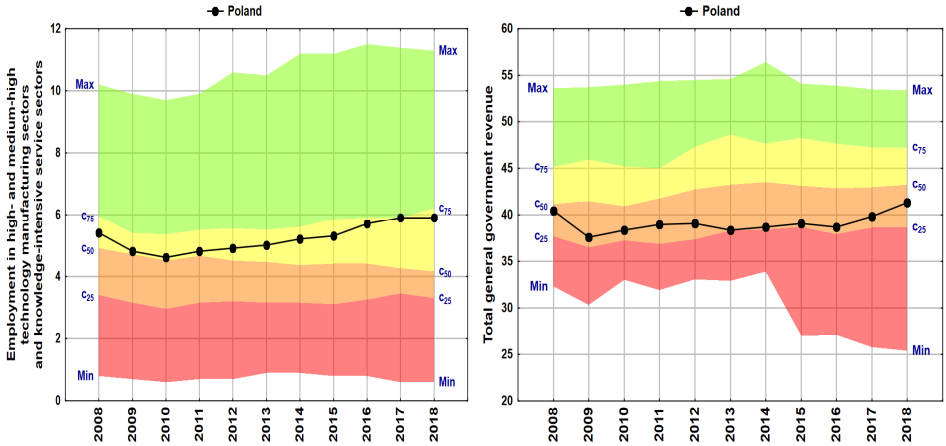

Fig. 74. Employment in high- and medium-high technology manufacturing sectors and knowledge-intensive service sectors (left), total general government revenue (right) (*Source: author's calculations*)

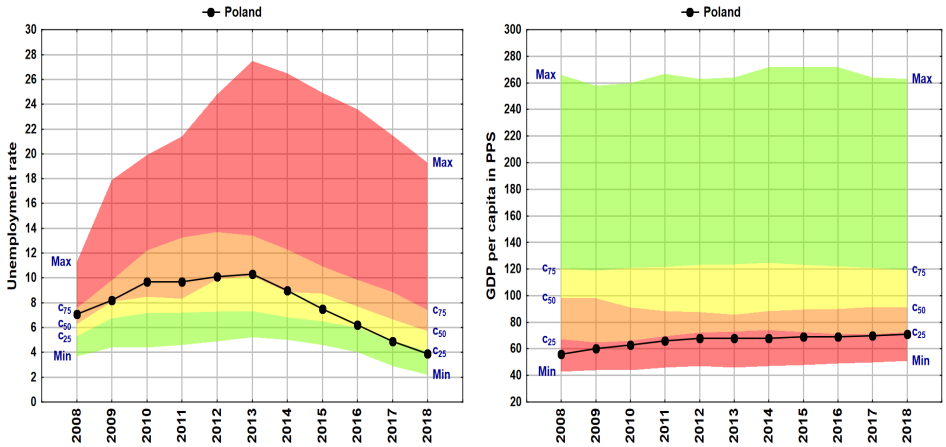

Fig. 75. Unemployment rate (left), GDP per capita in PPS (right) (*Source: author's calculations*)

The value of the life expectancy variable for Poland was increasing since 2008, however, it was at the level of the first quartile for the entire analyzed period of 2008-2018 for Poland. Self-reported unmet needs for medical examination is an indicator for which Poland achieved values at the level of the third quartile in the entire period from 2008 to 2018 (fig. 76).

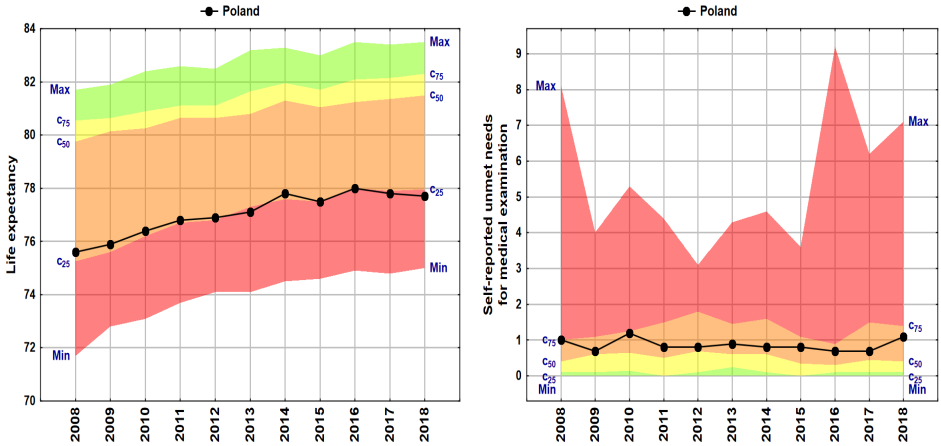

Fig. 76. Life expectancy (left), self-reported unmet needs for medical examination (right)
(*Source: author's calculations*)

The value of self-perceived health for Poland reached the value of the first quartile throughout the analyzed period from 2008 to 2018. The value for the percentage of people gaining or with higher education aged 15-64 indicator continued to grow in the period analyzed, starting from 2008 (fig. 77).

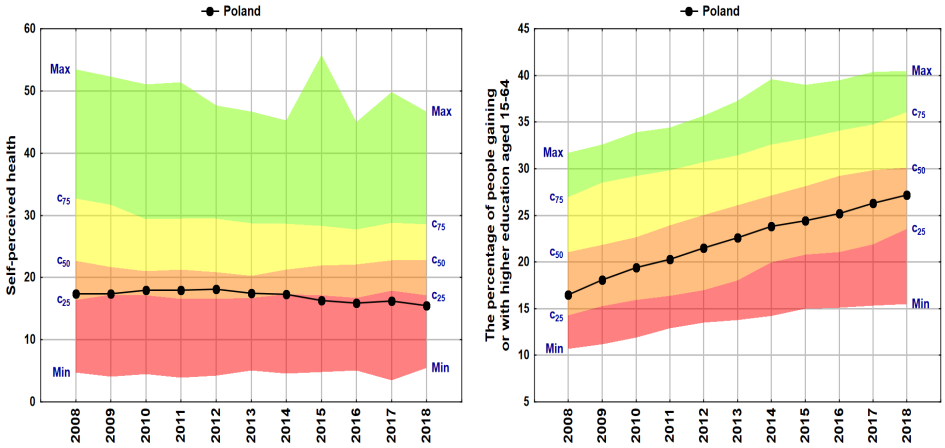

Fig. 77. Self-perceived health (left), the percentage of people gaining
or with higher education aged 15-64 (right)
(*Source: author's calculations*)

As for the next indicator related to participation rate in education and training, one can observe a decrease in the value of this indicator for Poland, which may be due to the lack of interest in acquiring another education. For the early leavers from education and training variable, the values for Poland oscillate around the minimum value, which proves this indicator positively. It can also be seen in the figure that the maximum value obtained for the European Union has decreased significantly (fig. 78).

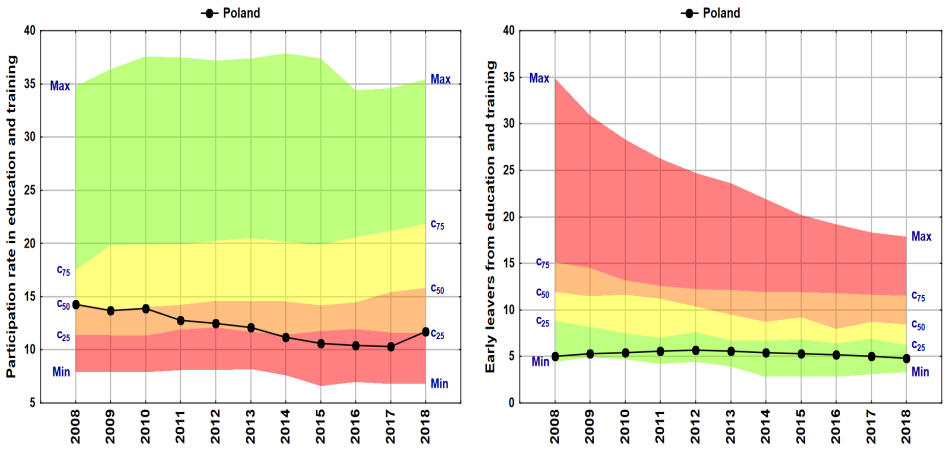

Fig. 78. Participation rate in education and training (left),
early leavers from education and training (right)
(*Source: author's calculations*)

For the Share of people living in under-occupied dwellings variable, Poland reaches the value of the first quartile, which means that the Poles live in crowded apartments compared to other EU countries. The values for the variable – Inability to make ends meet decrease from 2008 (from almost the third quartile) to the level of the second quartile. This means that the life situation of Poles is improving (fig. 79).

The value of variable people at risk of poverty variable in 2009 decreased compared to 2008, then increased in 2010, while from 2010 its values decreased until 2018. For Poland, the values fluctuate around the second quartile compared to other EU countries (fig. 80).

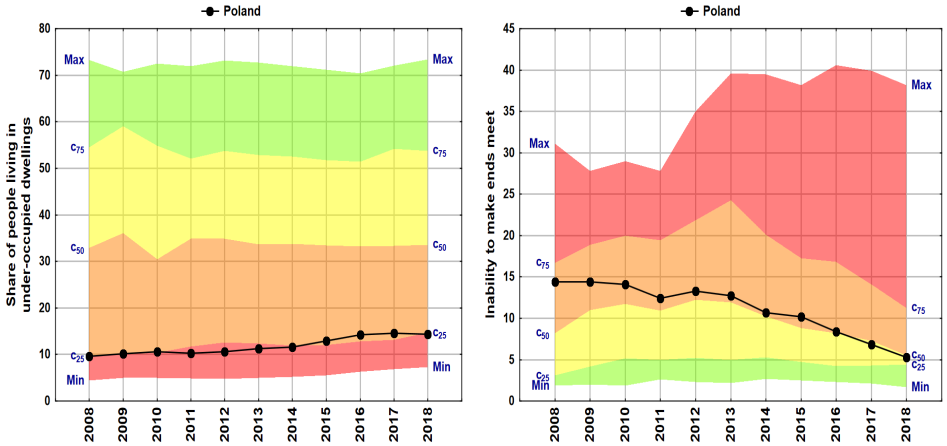

Fig. 79. Share of people living in under-occupied dwellings (left), inability to make ends meet (right)
(*Source: author's calculations*)

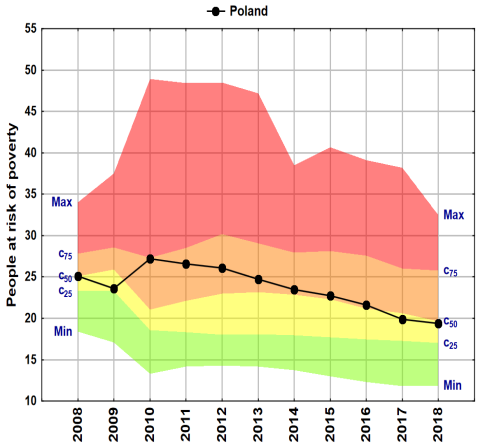

Fig. 80. People at risk of poverty
(*Source: author's calculations*)

Measures designated for determinants of socio-economic development

The figures below present the values for the determinants of socio-economic development in the European Union countries.

For a determinant Science and Technology values increase. Poland currently oscillates at the level of the second quartile in terms of scientific and technological development. The values for the determinant Economy and finance also increase in the period analyzed from the first quartile to the median value (fig. 81).

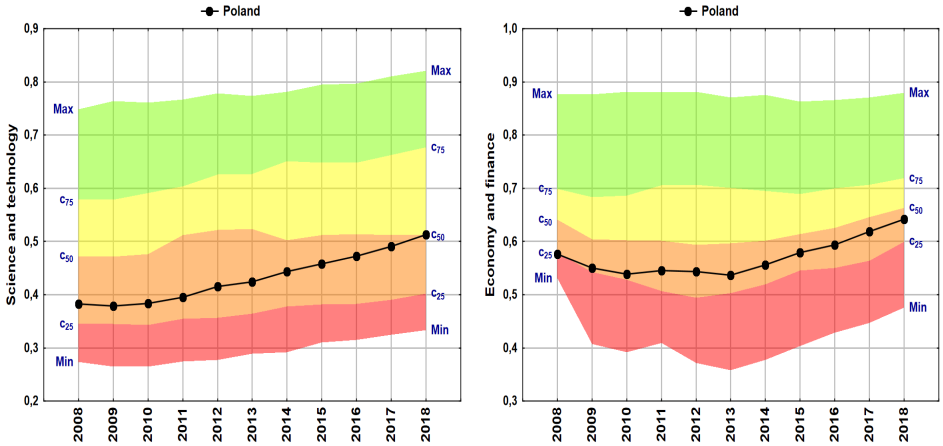

Fig. 81. Science and Technology (left), Economy and Finance (right)
(*Source: author's calculations*)

In terms of Health, Poland does not achieve the best results. For this determinant, it reached the level of the first quartile throughout the entire period under examination. It definitely requires some changes and allocating more funds to improve health among the Poles. In the case of education, a decrease in the position of the indicator for Poland below the value of the second quartile can be observed (fig. 82).

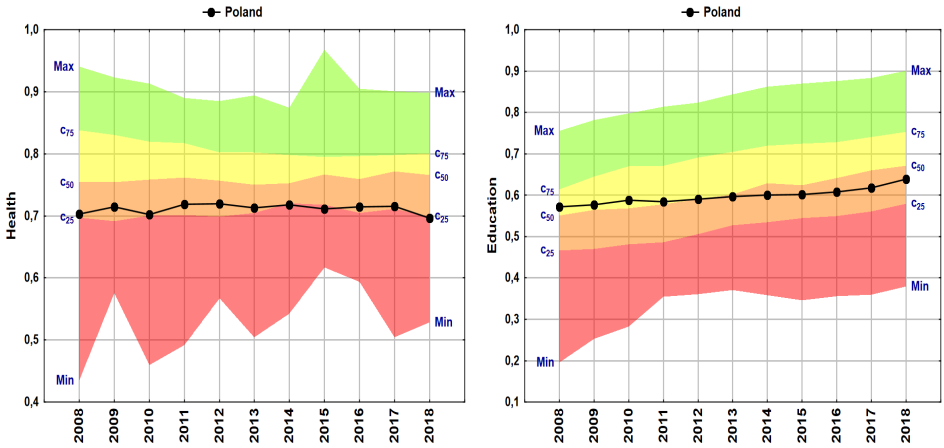

Fig. 82. Health (left), Education (right)
(*Source: author's calculations*)

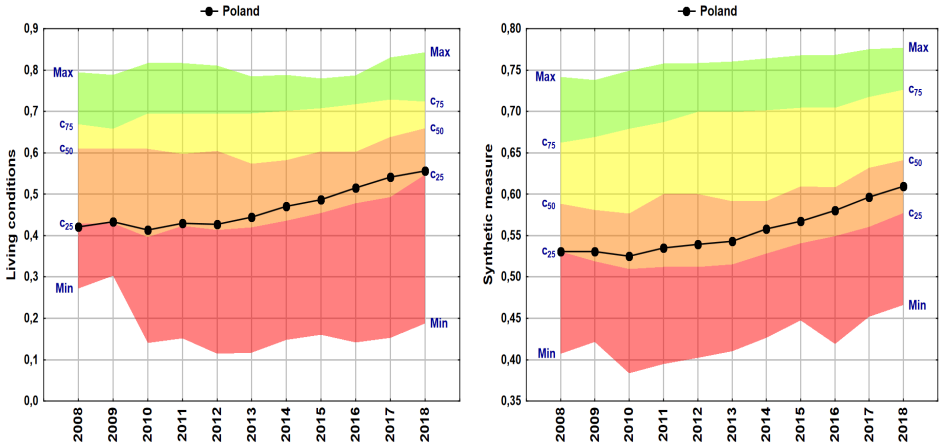

Fig. 83. Living Conditions (left), Synthetic measure (right)
(*Source: author's calculations*)

For the Living Conditions determinant, the value increased, although it remained at the level of the first quartile throughout the entire period under study. The next figure shows an increase in the value of the synthetic measure for Poland in the analyzed period. In 2018, the values obtained are in the range between the first and the second quartile. In 2008, the value was exactly on the level of the first quartile (fig. 83).

Chapter 5. Comparison of the results of research approaches in the analysis of socio-economic development – conclusions

5.1. The comparison of the results of research approaches in the analysis of the socio-economic development

The Human Development Index (HDI) was created in 1990, as an acknowledgment that income levels are not enough to capture the concept of human development. Under that premise, the HDI operationalized the broad concept of human development by combining health, education and income into a composite index (Aguña&Kovacevic, 2011).

According to the literature review, the set of dimensions and the mathematical approach used by UNDP are not solid enough to give a realistic view related to development of countries.

Booysen (2002) also affirms that composite indices are in general of a cardinal nature, but remains ordinal in so far as differences in index values cannot be interpreted meaningfully. The author also affirms that the multidimensionality of these indices represents one of their main advantages, however the comparative application of indices of development over space and time remains problematic (Monteiro, Pereira&Costa, 2018).

Further, human development index as it is being presently constructed is not compre hensive as it does not include the two important indicators such as poverty and unemployment since reduction in them are important indicators of development. However, UNDP which constructs human development index separately calculates 'human poverty index' (HPI) which has now been replaced by 'multi-dimensioned poverty index'. But the existence of unemployment, which is an important aspect of human development, still remains excluded. Thus in the view of researchers, the chief drawback of human development index (HDI) is that it obscures many dimensions of the concept of development. The concept of development is so much wider, deeper and richer that a single composite measure like HDI cannot adequately measure it. Therefore, it is better to judge and assess the development performance of different countries by a number of indicators that reflect different aspects of development rather to judge it by a single composite index of HDI.

As regards the evaluation of the methodology for calculating the HDI index, it should be noted that it is certainly adequate to the study of global development, while for the study of the socio-economic development of the European Union

countries, this measure does not show an appropriate differentiation of the values of individual countries, and therefore it is proposed to use the measure based on more determinants.

Regarding the high development countries, the main driver is income, while for the medium development group the main driver is education but health has the highest interaction effects, what seems natural given that this block has the highest differentiation in life expectancy of all groups. Concerning the low development group, the interaction of life expectancy plays a major role.

According to the research conducted in the book, the following determinants have the greatest impact on the socio-economic development in the European Union countries: living conditions, economics and finance, as well as science and technology. Two of the determinants specified that have the greatest impact on socio-economic development, i.e. science and technology, as well as living conditions, have been added in the methodology of constructing the measure of socio-economic development, and this definitely constitutes the novel aspect of the book. Health has the least impact on the socio-economic development in the European Union countries.

In addition, it is a substantive conclusion - HDI is characterized by very low sensitivity for changes in conditions of life. Partial indicators included in the HDI: GDP, life expectancy and indicators related to the level of education show high stability over time. This is confirmed by the fact that the measure of socio-economic development should be enriched with additional determinants, especially in the aspect of researching socio-economic development in the European Union countries.

In successive treaties of the European Union, it is possible to notice more and more emphasis on maintaining the balance between economic and social development, while maintaining the values of the natural environment and cultural heritage. In 1992, ”improving the quality of life of residents” was listed as one of the many objectives of the Mastricht Treaty, and the Lisbon Treaty of 2007 identifies the increase in ”quality of life” as one of the main lines of EU action. Increasing the quality of life and social cohesion was also one of the important goals of the EU's Europe 2020 strategy. Improving the quality of life of Europeans by ensuring stable and high economic growth is one of the objectives of the 2030 Agenda for Sustainable Development.

Sustainable Development Goals Agenda 2030:

Goal 1. End poverty in all its forms worldwide

Goal 2. End hunger, achieve food security and better nutrition, and promote sustainable agriculture

Goal 3. Ensure healthy life for all people of all ages and promote well-being

Goal 4. Provide quality education for all and promote lifelong learning

Goal 5. Achieve gender equality and empower women and girls

Goal 6. Provide all people with access to water and sanitation through the sustainable management of water resources

Goal 7. Ensure access for all to stable, sustainable and modern energy at affordable prices

Goal 8. Prmote stable, sustainable and inclusive economic growth, full and productive employment and decent work for all people

Objective 9. Build resilient infrastructure, promote sustainable industrialization and foster innovation

Goal 10. Reduce inequalities within and between countries

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12. Ensure patterns of sustainable consumption and production

Objective 13. Take urgent action to combat climate change and its consequences

Goal 14. Protect the oceans, seas and marine resources and use them in a sustainable manner

Goal 15. Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainable forest management, combat desertification, halt and reverse soil degradation, and halt biodiversity loss

Goal 16. Promote peaceful and inclusive societies, ensure access to justice for all, and build effective, responsible and inclusive institutions at all levels

Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

Regarding the proposal of new dimensions to calculate the indicators, Salas-Bourgoin (2014) developed a study proposing two new dimensions to the HDI: Employment Index (including employment-to-population ratio) and Democracy Index (as a way of gauging freedom). The author concludes that the modified HDI reveals that the weaknesses in countries with high overall HDI scores relate mainly to employment, while developing countries lag behind in the quality of employment.

Martinez (2013) proposes an alternative index, the Human Wellbeing Composite Index (WCI) to rank 42 countries in Europe, North Africa and the Middle East. The following dimensions compose the index: income per capita, environmental burden of disease, income inequality, gender gap, education, life expectancy at birth and government effectiveness. According to the author, the results highlight the distance still separates the Southern Mediterranean countries from the benchmark levels established by some European countries.

5.2. Conclusions

The main goal of the work was to examine the socio-economic development in the European Union countries in the years 2008-2018 in individual aspects regarding the standard of living of the inhabitants of the European Union, namely

Economy and Finance, Science and Technology, Health, Education and Living Conditions.

The analysis of the spatial diversity of socio-economic development began with the presentation of ways of defining socio-economic development and the indication and description of factors determining socio-economic development in the European Union countries.

In the empirical part of the work, the countries were organized and grouped in accordance with the level of socio-economic development of the population living in the European Union. In the next part of the study, the occurrence of social convergence was tested and development modelling for each of the European Union countries separately using a nonlinear model – a second-degree polynomial.

Analyzing the values obtained by means of linear ordering, it should be concluded that there is still a division into old European Union countries and new ones that joined the Economic Community at a later time. However, the division of Europe into a richer north and a poorer south is visible (this applies especially to the determinants of living conditions). When it comes to determining the Economy and Finance, there is a division into the north-west and south-eastern European Union.

The synthetic variable turned out to be a good tool for quantifying social and economic development and building on this basis rankings and groups of similar objects due to the level of life achieved. On this basis, we can observe the changes that have taken place in the EU countries after the financial crisis in 2008. Summing up the above considerations, it should be stated that lower values for the synthetic standard of living standard were obtained by the countries of Southern and Eastern Europe, higher ones in Northern and Western Europe (the exception is Spain and Portugal).

However, it should be stressed that a greater variation in living standards in EU countries is evident when a synthetic measure of living standards is used compared to Human Development Index. This means that this indicator more fully describes the real situation of the standard of living of the inhabitants of the European Union countries.

The paper conducted an analysis of convergence at the level of synthetic group measures. The results of the sigma social convergence study allowed to conclude that in the case of determinants of Economy and Finance, as well as Living Conditions, there is a divergence in the countries of the European Union. For the other determinants distinguished in the study, sigma convergence was obtained, which means that for the above-mentioned determinants, countries with an initially lower value of the synthetic measure of socio-economic development developed faster than countries with an initially higher value of these measures, which thus led to a decrease in diversity in the studied areas.

However, in the case of determinants Economy and Finance and Living Conditions, a large variation in these areas in European Union countries can still

be observed. Therefore, it is precisely these areas that require the greatest funding from the authorities of the Economic Community in order to compensate for disparities in the living conditions of its inhabitants, which is one of the sustainable development goals.

The calculated Moran's spatial autocorrelation indices indicate a moderate spatial relationship. A greater dependence can be observed for the countries of Western and Northern Europe, and less for the countries of Southeastern Europe.

The table 26 presents the values of of Pearson's linear correlation coefficients between individual determinants and the synthetic measure. The study found that the following determinants: Economy and Finance, Science and technology, and Living conditions are most correlated with the synthetic measure. It should be noted that the determinants which the measure of socio-economic development was supplemented with, in comparison with the Human Development Index, are among the most correlated with the synthetic measure. Therefore it seems justified to construct the measure of socio-economic development on the basis of a larger number of indices.

Table 26. Correlation coefficients between determinants and the synthetic measure of socio-economic development in the European Union countries

	Synthetic measure of socio-economic development	ECO-NOMY AND FINANCE	SCIENCE AND TECHNO-LOGY	HEALTH	EDU-CA-TION	LIVING CON-DITIONS
Synthetic measure of socio-economic development	1.00	0.81	0.80	0.61	0.77	0.88
ECONOMY AND FINANCE	0.81	1.00	0.61	0.39	0.49	0.69
SCIENCE AND TECHNOLOGY	0.80	0.61	1.00	0.31	0.54	0.57
HEALTH	0.61	0.39	0.31	1.00	0.38	0.54
EDUCATION	0.77	0.49	0.54	0.38	1.00	0.56
LIVING CONDITIONS	0.88	0.69	0.57	0.54	0.56	1.00

(*Source: author's calculations based on Eurostat databases*)

The analysis shows that GDP per capita has a strong, statistically significant effect on the synthetic measure of socio-economic development. This is demonstrated by the value of the Pearson linear correlation coefficient (r = 0.7). To a positive, moderate degree (r = 0.52) the indicator of socio-economic development is affected by the indicator of total general government revenue. In the case of unemployment rate it was noticed that this variable had a moderate, negative impact on the synthetic measure of socio-economic development (r = -0.5).

The inability to make ends meet and the synthetic indicator of the percentage of people at risk of poverty have the greatest negative impact on the synthetic measure of socio-economic development. In the case of the first analyzed variable the Pearson's linear correlation coefficient was obtained at the level of r = -0.81, for the second variable the Pearson's linear correlation coefficient was obtained at the level of r = -0.76. Only the indicator of share of people living in under-occupied dwellings has a positive, moderate influence on the synthetic measure of socio-economic development (r = 0.62).

The highest value of the Pearson linear correlation coefficient (r = 0.83) was obtained in the case of human resources in science and technology. High value of the Pearson linear correlation coefficient (r = 0.79) was received for the variable connected with the research and development expenditures. It means that the most important for the socio-economic development are variables describing the Economy and Finance, Science and Technology and Living Conditions.

The relative importance of the determinants on the dependent index could be calculated with a multiple regression, i.e., where all determinants are included as independent variables in the standardized form (so that they are all measured on the same scale).

By comparing the results, which confirm that of the growth factors considered that characterise human resources in science and technology and educational attainment, the former plays a greater role in shaping the convergence processes for the European Union.

It is a variable that is characterized by higher flexibility, which means that an increase in the logarithm value of the variable human resources in science and technology by 1 percentage point is associated with a relatively higher increase in the logarithm of GDP than the corresponding increase in the logarithm of the variable level of education. In addition, among the models that take into account human capital, a faster rate of convergence suggests models that take into account the size of human resources in science and technology [Bal-Domańska, 2009].

Theory of beta convergence shows that the poorest countries of European Union are achieving faster economic development that the developed countries. However according to the research results it can be observed that there is currently a division in the European Union due to socio-economic development between the rich North and the poorer South. Based on the available data, it should be

stated that membership of the Euro area had a positive impact on the pace of convergence.

When analyzing the socio-economic development in the European Union countries with the use of the synthetic measure of socio-economic development, it should be stated that the first place in the ranking for 2018 was taken by Sweden. The next two positions were taken by Finland and Denmark. The last three positions in the ranking were taken by Bulgaria, Romania and Greece. This is confirmed by the division of Europe into North and South, and not as before into a rich West and a less developed East.

When analyzing the Economy and Finance determinant, it can be observed that Luxembourg was the leader in 2018 in the European Union. The next two positions were taken by Denmark and Austria. The last three positions in the ranking were taken by Romania, Spain and Greece. In 2018, the countries that achieved the highest positions in the ranking for the Science and Technology determinant were Germany, Sweden and Austria. The last three positions in the ranking were taken by Greece, Cyprus and Latvia. In 2018, the countries that achieved the highest positions in the ranking for the determinant of Health were Ireland, Cyprus and Austria. The last three positions in the ranking were taken by Portugal, Lithuania and Latvia. In 2018, the countries that achieved the highest positions in the ranking for the determinant Education were Sweden, Finland and Luxembourg. The last three positions in the ranking were taken by Bulgaria, Italy and Romania. When analyzing the Living Conditions determinant, it was observed that Malta was the leader in 2018 in the European Union. Ireland and the Netherlands followed. The lowest values were obtained by Romania, Bulgaria and Greece.

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MODELING OF SOCIO-ECONOMIC DEVELOPMENT
IN EUROPEAN UNION COUNTRIES

Summary

The main goal of the work was to examine the socio-economic development in the European Union countries in the years 2008-2018 in individual aspects regarding the standard of living of the inhabitants of the European Union, namely Economics and Finance, Science and Technology, Health, Education and Living Conditions. The synthetic measure of socio-economic development was created using data obtained from the European Statistical Office – Eurostat.

The synthetic measure turned out to be a good tool for quantifying social and economic development and building on this basis rankings and groups of similar objects due to the level of life achieved. On this basis, we can observe the changes that have taken place in the European Union countries after the financial crisis in 2008. Summing up the above considerations, it should be stated that lower values for the synthetic measure of living standard were obtained by the countries of Southern and Eastern Europe, higher ones in Northern and Western Europe (the exception is Spain and Portugal).

The following research methods were used in the book:

1. The linear ordering in order to create rankings of European Union countries according to the synthetic measure of socio-economic development in the selected years 2008, 2013 and 2018,
2. The Moran's spatial autocorrelation indices,
3. The convergence methods to explore the convergence of socio-economic development in European Union countries,
4. The cluster analysis to receive the classification of European Union countries,
5. The nonlinear models of socio-economic development for individual countries of the European Union to study the pace of development.

MODELOWANIE ROZWOJU SPOŁECZNO-GOSPODARCZEGO
W KRAJACH UNII EUROPEJSKIEJ

Streszczenie

Głównym celem pracy była analiza rozwoju społeczno-gospodarczego w krajach Unii Europejskiej w latach 2008-2018 w poszczególnych aspektach dotyczących poziomu życia mieszkańców Unii Europejskiej, tj. Ekonomii i Finansów, Nauki i Technologii, Zdrowia, Edukacji i Warunków Życia. Syntetyczny miernik rozwoju społeczno-gospodarczego został utworzony na podstawie danych uzyskanych z Europejskiego Urzędu Statystycznego – Eurostatu.

Miara syntetyczna okazała się dobrym narzędziem do kwantyfikacji rozwoju społeczno-gospodarczego i budowania na tej podstawie rankingów i grup podobnych obiektów ze względu na osiągnięty poziom życia. Na tej podstawie możemy obserwować zmiany, jakie zaszły w krajach Unii Europejskiej po kryzysie finansowym w 2008 roku. Podsumowując powyższe rozważania, należy stwierdzić, że niższe wartości syntetycznego miernika rozwoju społeczno-gospodarczego uzyskały kraje Europy Południowej i Wschodniej, wyższe zanotowano dla krajów Europy Północnej i Zachodniej (wyjątkiem jest Hiszpania i Portugalia).

W pracy wykorzystano następujące metody badawcze:

1. Porządkowanie liniowe w celu utworzenia rankingów krajów Unii Europejskiej według syntetycznej miary rozwoju społeczno-gospodarczego w wybranych latach 2008, 2013 i 2018,
2. Wskaźniki autokorelacji przestrzennej Morana,
3. Metody konwergencji w celu zbadania zbieżności rozwoju społeczno-gospodarczego w krajach Unii Europejskiej,
4. Analizę skupień w celu otrzymania klasyfikacji krajów Unii Europejskiej,
5. Nieliniowe modele rozwoju społeczno-gospodarczego dla poszczególnych krajów Unii Europejskiej do badania tempa rozwoju.