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The barycentric model of determining the sustainable growth determinants

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Abstract

The authors investigate the issue of modelling the balance of sustainable growth determinants based on determining the center of mass. They have identified the most relevant factors that characterize countries' social, economic, and political spheres, digital capability, and cybersecurity to determine sustainable development and growth. The research has been carried out based on empirical values of the selected 17 indicators for 127 world countries in 2018. As a result, the four–pole barycentric models were built as quadrangles, the vertices of which are composite targets formed by the determinants of the four spheres. The models' calculations were carried out taking into account three components: the values of the composite targets (as a geometric mean), the level of pairs balance (as the sum of opposite pairs of quadrilateral angles), and all four targets (as the distance between the actual and standard value of the center of mass). According to the analysis result of the first component, developed countries have the most effective targets (top five – Switzerland, Denmark, Norway, Finland, and the Netherlands). Research of the results of the second component has revealed an imbalance in target pairs for most countries. Determinants of socio–political development are the most effective for developed countries. The economic sphere is most unbalanced for the least developed countries. Various determinants can cause an imbalance for developing and new industrial countries. The analysis of the center of mass distances revealed that not only developed countries could be balanced, but also developing, new industrial and the least developed, which indicates a balanced development of their determinants, which is pretty slow. New Zealand, Mauritius, South Africa and Mali were the most balanced in each country's sustainable growth group.

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Keywords: Barycentric model, Center of mass, Cybersecurity, Digital capability, Economic determinants, Social determinants, Sustainable growth, Political determinants

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1. Introduction

Today, the dynamic processes in society lead to the fact that some areas of its life are not developing evenly enough. It can be seen through the rapid development of information technology, which has led to the transformation of many processes in the economic, political and social spheres over the past decade. In this context, its consequences are more favorable for society and the country since they lead to the construction of new IT companies, creation of new jobs, human empowerment through the latest developments. As for other aspects that also affect the country's development, their impact can be both positive and negative. Accordingly, this problem needs to be studied and improved in identifying the determinants that affect the country's sustainable development and growth, balancing the needs of society and protecting the future generations' interests, and the balanced development of all social spheres. It should be in line with the United Nations Sustainable Development Goals announced at the UN Summit on 25 September 2015 and the development strategies of countries being developed in line with their priorities. That is why this study aimed to determine the level of balance of social, economic, political determinants and determinants of digital capability and cybersecurity, as composite targets, typical for any country in the world. The formation of an appropriate model will identify the targets that affect the imbalance of the country's sustainable development and growth, as well as outline the relevant areas of government policy to develop effective strategies that set priorities for improving the population welfare, quality of social and living standards, overcoming political and military conflicts, solving environmental problems in terms of those challenges to a society that generate global problems.

2. Problem formulation

The country's balanced development assumes that its changes are systemic and have an equal impact on all areas. It can be ensured by several determinants, among which the most influential are economic [1]. Significant imbalances in countries' economies are caused by an imperfect legal framework and the presence of a corruption component, the impact of which violates macroeconomic stability [2]. [3] empirically proved that the financial sector's crisis of confidence also destabilizes the economy. [4] have investigated the dependence of macroeconomic stability on fiscal decentralization and focused on expenditure decentralization, revenue decentralization and expenditure decentralization simultaneously. The formation of a sustainable growth financing system is one of the main strategic priorities, which should consider the specifics of the functioning of the corporate sector [5]–[6]. [7] prove that money is not only an instrument of payment but also acts as a tool for propaganda and laundering of illegal income, which leads to the development of the shadow sector of economics. In turn, it affects the innovative potential [8]. The formation of a favorable investment climate in the country is one of the ways to improve the welfare of the country's population, which is mathematically proven by [9]. The optimal distribution of the portion of private and public investment was modelled in the context of economic development by [10].

The country's sustainable growth significantly affects the conditions for ensuring public welfare and the formation of stable paradigms for its improvement, which leads to qualitative changes in social relations. However, social determinants form the corresponding model of social life, the consequences of which are the driver of sustainable development [11]. For this aspect, it is crucial to ensure precisely social security when there are minimal risks to the life of the population in the country [12]. The formation of a better social climate in the country is one of the primary sources of attracting investment [13]. The features of the insurance system construction create the preconditions for its formation [14]. Besides, quality education [15] and the healthcare system [16] form a model of a prosperous society. The triad of the influence of economic, social, and political determinants was analyzed by [17] to ensure the countries' national security growth. As a result, a forecast of the level of innovative changes was constructed using the exponential smoothing method. [18] have proved using the 2SLS method that political instability negatively affects the country's economic security.

In addition to economic, political and social determinants, environmental factors can also affect the sustainable development and growth of a country. [19] investigated this issue and determined a link between gross domestic

product per capita and indicators of the ecological system (greenhouse gas emissions, renewable energy consumption, green investments), which positively affect the development of certain spheres of life. Similar findings were obtained by [20]. [21] studied the relationship between economic, social, and environmental aspects of development and built an environmental Kuznets curve for Ukraine and the EU. The synergistic effect of the interaction of green investments and institutional determinants manifests itself in the national economy. It leads to a decrease in its energy efficiency [22]. The convergence between tax and ecological systems has been proven based on the beta and sigma convergence by [23]. It also should consider that world crises and global phenomena also directly impact the balanced development of countries. The negative consequences confirm that most countries in the world have suffered due to the COVID–19 pandemic [24]–[25].

The consequences of the fourth industrial revolution contributed to the digitalization of many processes. First of all, it has affected the dynamism of the country's economic development and increased the level of its national security [26]. [27] has proved, based on bibliometric analysis of research, that the balanced development of a country depends to a greater extent on its social, economic and information security. Informatization processes are also relevant for the economy's financial sector, where there is the greatest need to digitalize financial services [28]. With the growth of information flows, the confidentiality of big data must be ensured [29]. In parallel, the risks of financial losses also increase due to the implementation of massive cyberattacks, which destabilize processes and systems and inhibit their development [30]. Although most countries are trying to solve this problem using artificial intelligence technologies [31], unfortunately, preventing cyberattacks is essential for ensuring the countries' national security. Therefore, when determining the determinants, one should consider not only the factors characterizing the development of the IT industry but also the direction of information security [32]–[35]. The relationship between them was investigated by [36] based on correlation and cluster analyses.

A wide range of mathematical methods is used for modelling economic, political, social, and informational development. Scientists have solved these problems by building optimization models [37], structural modelling [38], gravity modelling [39], using data mining methods [40], fuzzy sets [41], regression analysis [42]–[43], probabilistic methods [44], econometric tools [45], statistical analysis [46], methods for implementing integer arithmetic operations [47], pseudo–random sequence [48]. It is necessary to use a more specific method, such as determining the center of mass, to model sustainable growth. This method will determine the level of balance based on the development determinants. For the study, it has been chosen a triad of economic, political and social determinants, as well as determinants that characterize the development of information technology and cybersecurity, a group of which will be referred to as digital capability and cybersecurity. Since environmental factors have a narrower impact on the country's development, in this paper, they will not be taken into account to build a model.

3. Data and methodology

3.1. Economic, social, political determinants and determinants of digital capability and cybersecurity

Various determinants can influence the balance of countries' growth, which either increase or decrease its level. The scientific knowledge methods, which allowed to determine the most relevant indicators for each composite target, were used to substantiate their choice. Thus, the digital capability and cybersecurity are evaluated under the influence of trends in the development of the IT industry and its components, the level of digital development and the security component. Since there are no uniform approaches to defining this dimension, this group includes five key indicators that characterize: countries' cybersecurity weaknesses and opportunities by developing a cybersecurity strategy and relevant standards (The Global Cybersecurity Index); countries' readiness to counter cyber threats and control cyber incidents (The National Cyber Security Index), the level of information and communication technology development in the country (ICT Development Index), the country's technological readiness degree to use the latest information and communication technologies in various spheres of life Readiness Index), the country's digitalization compliance degree with its cybersecurity

level to form recommendations for adjusting cybersecurity programs (Digital Development Level). Since the value of these indicators positively affects the integrated value of evaluating digital capability and cybersecurity, i.e., with the increase of their value increases its level, we consider them as indicators–stimulators. It is believed that the country with a high value of the composite target of digital capability and cybersecurity has a strong development of information technology and is considered the country with the highest level of information security.

Factors of the country's economic development form a key component in achieving its balance. They enable to assess the citizens' welfare level (The Global Competitiveness Index), the conditions of running the business in the country and protection of property rights (Ease of Doing Business), the impact of financial systems on growth, stability, and inequality of different economies (Financial Development Index), ethnic, racial, regional, educational inequality that forms the economic difference between these groups. It ultimately affects the country's economic development (Uneven Economic Development Index), human ability to control their work and property, the level of own consumption and investment (Economic Freedom Index). The higher the country's economic development, the more opportunities for it to be a leader in world markets and ensure a high living standard for its population. Among the selected indicators, only the Uneven Economic Development Index is a disincentive indicator, with the increase of which the integrated level of the economic development target grows. Other indicators are stimulants in nature.

The social dimension is aimed at determining the country's ability to provide the population with a high living standard, which is to create favorable conditions for the population to receive such social benefits as education, quality health services, "environmental footprint", ensuring and maintaining peace within the country. Indicators measuring the quality of the citizens' current life (Happiness Index), the level of basic human needs provision, their welfare and opportunities for progress (Social Progress Index) and such basic features of human potential as living standards, literacy, education and longevity (Human Development Index) were selected to analyze this composite target. The selected determinants are stimulant indicators, so the high–integrated level of social dimension will indicate a top level of living standards in the country.

The political development of any country is an integral part of its overall sustainable development and growth, as it describes the political life dynamics of the country, its ability to interact with other countries in the foreign policy space to establish a dialogue between the state and the population. The political fluctuations can destabilize the social mood of the population and slow down economic development, so its evaluation is extremely important to find the level of the country's balanced development. Therefore, to determine its integral level, the following indicators were chosen that measure: the probability that the government can be destabilized or destroyed through unconstitutional and violent nature (Political Stability Index), the democracy quality in the country based on assessments of the electoral process, civil freedom, functioning of the government, political culture (Democracy Index), quality of government activities based on an assessment of the quality of public services and bodies, quality of formation and implementation of political measures, independence degree on political pressure, etc. (Government Effectiveness Index), corruption level in the public sector (Corruption Perceptions Index). High values of the selected determinants affect the growth of the composite target level that indicates the political stability in the country and its high political development.

3.2. Research methodology

The balance of any system is its state, which provides the optimal ratio of its components. It enables to be in balance and be stable in the event of external factors. Accordingly, the country's balanced development shows the uniform or balanced development of its components, which ensures its sustainability for a long time. For its modeling, the most optimal models are those based on certain centers of mass. It means that, depending on the number of components that participate in evaluating the development balance, a geometric figure is built, the vertices of which are their composite values, which are formed under the influence of various determinants. This study observed four main areas – economic, political, social, and digital capability and cybersecurity, the most influential components or targets for any country's development. Thus, their formation is carried out based

on the chosen determinants which most characterize their development. Accordingly, this article formed a barycentric model.

[49] popularized the approach of determining the center of mass for the economic sciences. The authors developed a triangle model to determine the stability of the insurance and reinsurance market, focusing on the calculation and analysis of the circumscribed circle radius. The methodology of building a barycentric model for the analysis of business activity of companies was proposed by [50], which did not provide a graphical interpretation of the model and there were no practical calculations. [51] continued its development to determine the development balance level of the national economy.

The method is based on the definition and analysis of three components of the barycentric model: the composite measurements, the balance of target pairs and the balance of all four targets. It is necessary to normalize the influencing determinants to find the values of composite targets. This procedure is required because the selected factors are different and differ in their absolute values. Normalization will reduce the values of all factors in the range from 0 to 1. Accordingly, it will simplify the data convolution to determine the composite value of economic, social, political and digital capability and cybersecurity, which will also range from 0 to 1. If the composite target approaches 1, it will indicate a strong development and growth of the relevant sphere of life in the country. Otherwise, if it is closer to 0, it is the development slowdown indicator.

There are different types of data normalization, but this paper will use linear normalization for stimulators (1) and Savage normalization for destimulators (2), because the study data are spatial:

$$\widetilde{x_{ik}} = \frac{x_{ik} - x_{min_i}}{x_{max_i} - x_{min_i}}, \quad (1)$$

$$\widetilde{x_{ik}} = \frac{x_{max_i} - x_{ik}}{x_{max_i} - x_{min_i}}, \quad (2)$$

where $\widetilde{x_{ik}}$ is the normalized value of *i*– determinant of the economic, social, political dimensions, digital capability and cybersecurity dimension for *k*–country; x_{ik} is the input value of the *i*–determinant of economic, social, political dimensions, digital capability and cybersecurity dimension for *k*–country; x_{min_i} and x_{max_i} are the minimum and maximum value of the *i*–determinant of economic, social, political dimensions and the digital capability and cybersecurity dimension among the observations, i.e., countries.

The calculation of the composite target for economic, social, political dimensions and the dimension of digital capability and cybersecurity is based on the geometric mean function (3). Its choice is due to the fact that, as a result, we obtain an average proportional value of the target for each country:

$$G_m = \left(\prod_{i=1}^{n} \widetilde{x_{ik}}\right)^{1/n}, \quad (3)$$

where G_m is the geometric mean value of composite targets, which were formed by the normalized determinants of economic, social, political dimensions and digital capability and cybersecurity dimension, defined for *k*–country; m is the number of composite targets ($m = 4$); *n* is the number of determinants that form the corresponding composite target ($n = 5$ – for the target of digital capability and cybersecurity, $n = 5$ – for the target of economic determinants, $n = 3$ – the target of social determinants, $n = 4$ – for the target of political determinants).

When determining the geometric mean value of those factors the normalized values of which are equal to 0, there is a significant shift in the value of the composite target towards 0. Then, you can use Minkowski formula to eliminate this factor for such values (4):

$$R(x_{ik}) = 1 - \sqrt{\sum_{i=1}^{n} \omega_{ik} \left|1 - \frac{x_{ik}}{x_{max_i}}\right|^2 + \sum_{i=1}^{n} \omega_{ik} \left|1 - \frac{x_{min_i}}{x_{ik}}\right|^2}, \quad (4)$$

where $R(x_{ik})$ is the composite target of economic, social, political and digital capability and cybersecurity dimensions; ω_{ik} is the weight of each determinant in the formation of the composite target $\sum_{i=1}^{n} \omega_{ik} = 1$. One can conduct a canonical analysis, build a standardized regression equation, or consider their uniform influence on the formation of the target, to determine them.

Building a four–pole barycentric model is necessary to determine the balance of pairs of targets and all four targets. It is carried out as a construction of a quadrangle and determining its main features. This process involves setting four points on the coordinate area, the coordinates of which correspond to composite targets. It is reasonable to build a standard model and the actual data model to understand how balanced the country's development is. The four–pole barycentric model is a square, the vertex coordinates of which are equal to the maximum value of the target, i.e., 1. It is a point with coordinates (1; 1) to measure digital capability and cybersecurity, for the social dimension – (1; –1), economic – (–1; –1), political – (–1; 1). The points are connected by lines that form the sides of the square. The intersection of its diagonals is called the "Center of Mass", which coincides with the starting point of the coordinate axes and has coordinates (0; 0). The standard model was built using GeoGebra software and is shown in Figure 1.

It is quite difficult for empirical data to build a barycentric model in the form of a square. Under such conditions, the country has the same economic, social, political, and information security levels. In practice, different quadrangles can be obtained for different countries, with different side lengths and angles. Therefore, it is also essential to draw a circle around the quadrangle. It is possible if the sum of its opposite angles is 180°. Otherwise, this fact will indicate the imbalance between the pairs of dimensions.

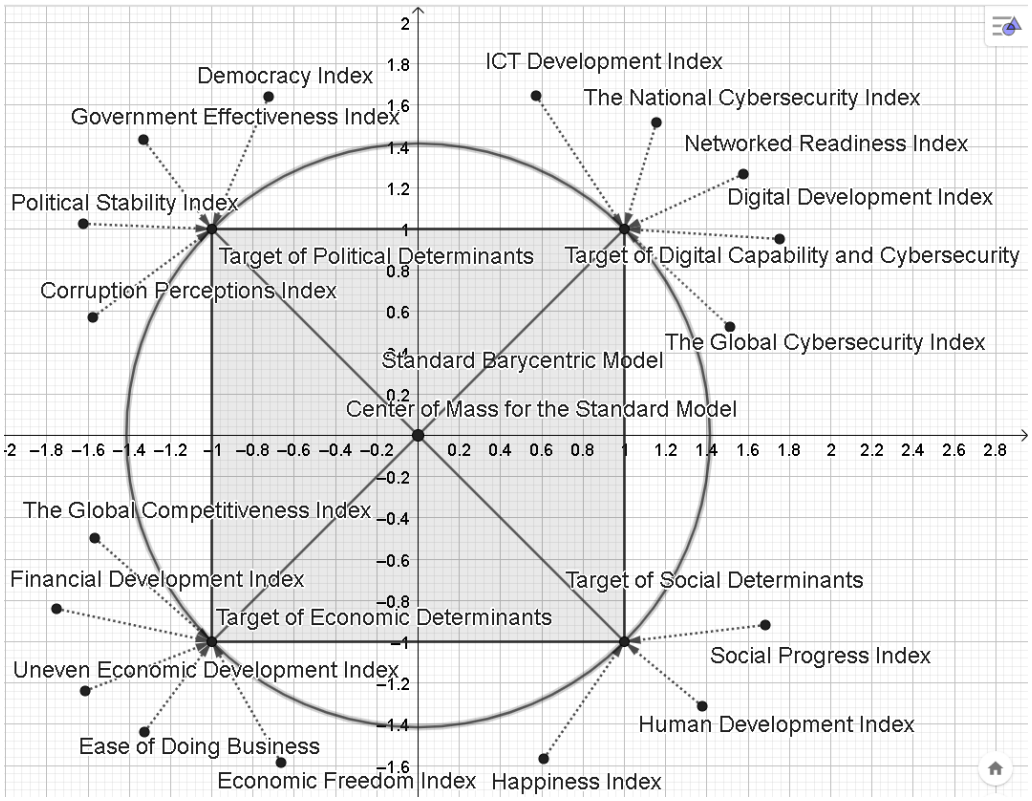

Figure 1. Standard four–pole barycentric model of country's balanced development. *Source*: [51]

It is necessary to divide the quadrangle into two triangles and calculate their side lengths as the length of segments to find the degree of angles in a quadrangle and check the possibility of constructing a circle around it, by the following formula (5):

$$AB = \sqrt{(x_b - x_a)^2 + (y_b - y_a)^2}, \quad (5)$$

where *AB* is the length of the segment between two dots A (for example, target of economic determinants) and B (for example, target of political determinants), which are the vertices of one of the two triangles (for example, ABC); $(x_a; y_a)$ and $(x_b; y_b)$ are accordingly the coordinates of dots A and B related to composite targets of economic, social, political determinants or determinants of digital capability and cybersecurity.

Similarly, there are other sides of the triangle ABC and the sides of the second triangle, which together form a quadrangle.

The found sides of the triangles allow us to calculate the cosines of their angles by formula (6):

$$\cos\alpha = \frac{AC^2 + AB^2 - BC^2}{2 \cdot AC \cdot AB}, \quad (6)$$

where α is the angle between two sides AC and AB of the triangle ABC; *AB, BC, AC* are values of the lengths of the three sides in the triangle ABC. Similarly, cosines are found for all angles of both triangles according to formula (6).

The obtained values are converted into degrees using special tables or calculators. In this article, the calculations were performed using MS Excel software, which uses the appropriate functions.

We sum the degrees of two angles at the base of one triangle with degrees of the other angles to obtain the values of the two opposite angles in the quadrangle. First, we check whether the sum of the four angles is 360°. Then we check the balance of two pairs of dimensions by determining the sum of pairs of opposite angles in the quadrangle. If their sums are equal to 180°, we conclude that a circle can be described around this quadrangle, i.e., the pairs of dimensions are balanced.

The third component of the barycentric model (balance of four targets) is identified through defining the centroid of the quadrangle. It involves the calculation of its coordinates by formulas (7) – (8):

$$O_x = \frac{1}{6A}\sum_{i=0}^{n-1}((x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i)), \quad (7)$$

$$O_y = \frac{1}{6A}\sum_{i=0}^{n-1}((y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i)), \quad (8)$$

where *Ox* and *Oy* are the coordinates of the centroid quadrangle; $(x_i; y_i)$, $(x_{i+1}; y_{i+1})$ are the coordinates of the quadrangle vertices, where the vertex with coordinates $(x_n; y_n)$ matches with the vertex with the coordinates $(x_0; y_0)$; *A* is the quadrangle area, calculated by formula (9):

$$\mathrm{A} = \frac{1}{2}\sum_{i=0}^{n-1}(x_i y_{i+1} - x_{i+1} y_i). \quad (9)$$

The balance of four targets is determined by obtaining the difference between the center of mass, which corresponds to the data of a particular country, and the center of mass of the standard model. For this reason, we calculate this distance as the segment length according to formula (5). The closer the obtained value to 0, the closer the center of mass of the country's barycentric model to the standard value, which indicates a balanced development of the country based on its four composite targets.

4. Results

Authors took the data of selected determinants for 127 countries for 2018 for the study and calculations from the sources of such organizations as The World Bank, The International Monetary Fund, The World Economic Forum, the independent Swedish foundation "Gapminder", the global nonprofit "The Social Progress Imperative". This period was chosen because most determinants do not have actual values after it, especially indicators of measuring digital capability and cybersecurity. We will group countries by economic development according to the classification of the International Monetary Fund, to analyze the results. Thus, they are divided into developed, developing and least developed. We will also single out among them a group of countries that are considered to be newly industrial due to their high rates of technological development, which acts as a driver of their economic development. These include Argentina, Brazil, Mexico, India, Malaysia, Thailand, Chile, Indonesia, Turkey, China, Iran, the Philippines [52], and promising industrial countries from the Group of Eleven (Nigeria, Egypt, Pakistan, Bangladesh, Vietnam) [53]. All calculations were performed using MS Excel software.

4.1. Analysis of the results of the composite targets

Figure 2 presents the results of the calculated composite targets of economic, social, political, and digital capability and cybersecurity for twenty developed countries or countries with a high economic level, the list of which was determined following the International Monetary Fund [54]. The top ten countries have the highest total value of targets, the second ten – the lowest among the group of developed countries.

A comparison of the composite targets with the standard level (Figure 1) shows that for most developed countries, their values go to 1 but do not reach it. In practice, this is impossible for any country, so the closer the estimated values go to 1, the higher the level of dimension development in the country. One should note that Switzerland demonstrates the best result. Its total value of economic, social, political, and digital capability and cybersecurity dimensions is the highest (3.735).

Such countries as Denmark, Finland, Norway, the Netherlands, Singapore, Sweden, New Zealand, Australia, and Canada are among the top ten countries with the highest values of composite targets. It indicates a relatively high level of their sustainable development and growth. Portugal, Lithuania, Israel, Malta, Italy, Slovenia, Latvia, Slovakia, Cyprus, and Greece show the lowest values among the analyzed group of developed countries. The social dimension demonstrates the highest level of growth, indicating the effective social policy of these countries' governments in relation to their population. The political and digital development and cybersecurity dimensions for most countries prevail over the economic target values.

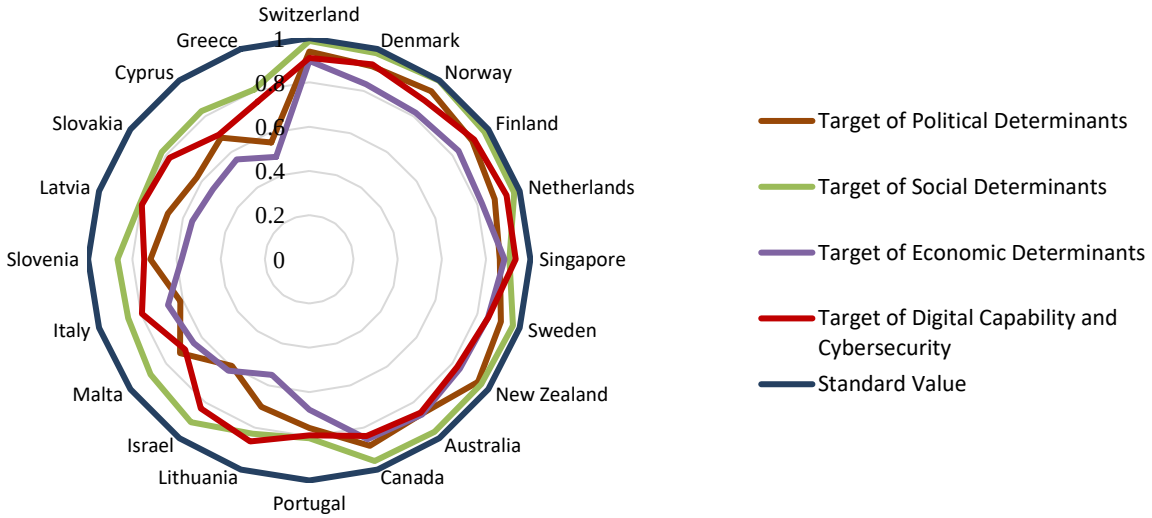

Figure 2. The values of composite targets of economic, social, political and digital capability and cybersecurity dimensions for developed countries. *Source:* Authors' calculations

It proves that the economic potential of these countries has given impetus to accelerate the growth of other targets, which will further contribute to stronger economic growth in these countries.

Figure 3 presents the calculated values of composite targets of economic, social, political, and digital capability and cybersecurity dimensions for developing countries according to the list of the International Monetary Fund [54]. Ten countries with the highest values and ten with the lowest values were issued. Poland, the United Arab Emirates, Mauritius, Uruguay, Croatia, Hungary, Qatar, Bulgaria, Costa Rica and Romania are leading countries. The least developed countries are Kyrgyzstan, Bolivia, Kenya, Algeria, Nicaragua, Honduras, Suriname, Côte d'Ivoire, Tajikistan and Cameroon.

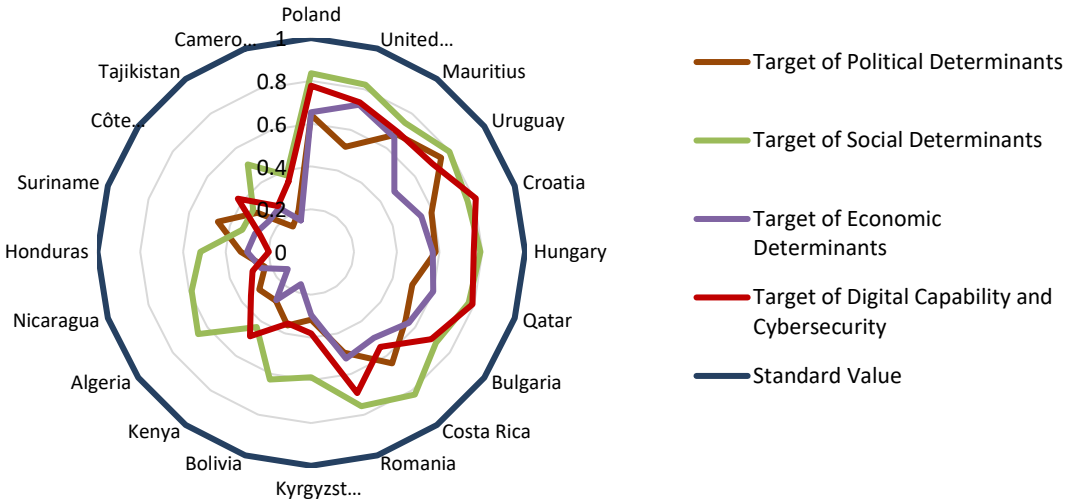

Figure 3. The value of composite targets for economic, social, political, digital capability and cybersecurity dimensions for developing countries. *Source:* Authors' calculations

Compared to the data obtained for developed countries, a significant imbalance arises between the social dimension and the cybersecurity, economic and political dimensions. The differences are quite significant. For example, for Poland the social dimension target is 0.8357, digital capability and cybersecurity – 0.7773, economic – 0.6533, political – 0.6410, and for Algeria – respectively 0.6542, 0.3486, 0.1365, 0.3002. The development of the economic and political spheres is quite critical for developing countries. It is due either to the unstable political situation in them (for example, Ukraine, Honduras, Guatemala), or the ineffectiveness of the government and its political laws and decisions. The economic development instability of such countries is a direct consequence of the crisis in their political sphere, which leads to a slowdown in their development as a whole. In other words, it is important for developing countries, first of all, to strengthen the political dimension by transforming legislation, combating corruption, making more effective decisions by the government aimed at economic development and reform, etc. The calculated results of composite targets for the newly industrialized countries are presented in Figure 4.

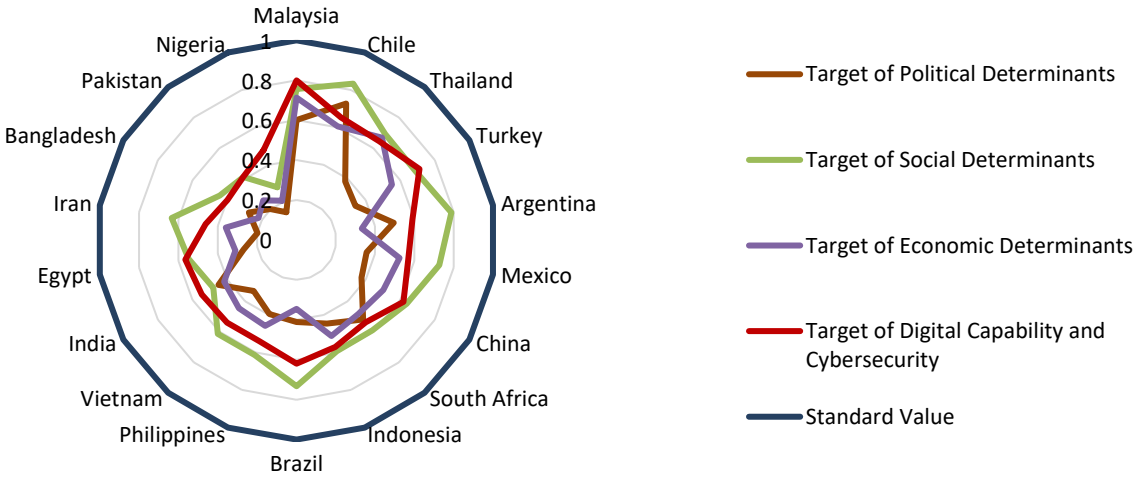

Figure 4. The values of composite targets of economic, social, political and digital capability and cybersecurity dimensions for newly industrialized countries. *Source:* [51]

There is also an imbalance in the development of newly industrialized countries (Figure 4), with the same direction of development in the social, economic, and political dimensions and the digital capability and cybersecurity dimensions. However, in contrast to the values of the composite targets presented in Figure 3, most of these countries, except Chile, Argentina, and Brazil, are characterized by a more uniform development of selected areas, which does not contain abnormal differences. Malaysia, Chile, Thailand, Turkey, and Argentina have the highest targets. Iran, Bangladesh, Pakistan, and Nigeria have the worst results. Since the represented countries are considered to have already passed certain stages of socio–economic growth and achieved success or have all the chances for an industrial leap, we can say that for most of them, namely Turkey, Thailand, Argentina, Nigeria, Pakistan, Chile, Brazil, Bangladesh, Mexico and Iran, attention should be paid to the political and economic dimensions to ensure the social sphere development and the digital capability sphere.

Figure 5 shows the composite targets of economic, social, political and digital capability and cybersecurity dimensions for the least developed countries, the list of which is defined by the United Nations [55]. Ten countries with the highest and lowest values of indicators were distinguished among their group of countries. Almost all countries except Botswana and Bhutan have low values of the four targets (Figure 5). At the same time, you can see the uneven development of all dimensions, mainly economic. The obtained results prove the existence of actual problems of economic, social, political nature and insufficient level of information technology development, which needs help from global and international organizations.

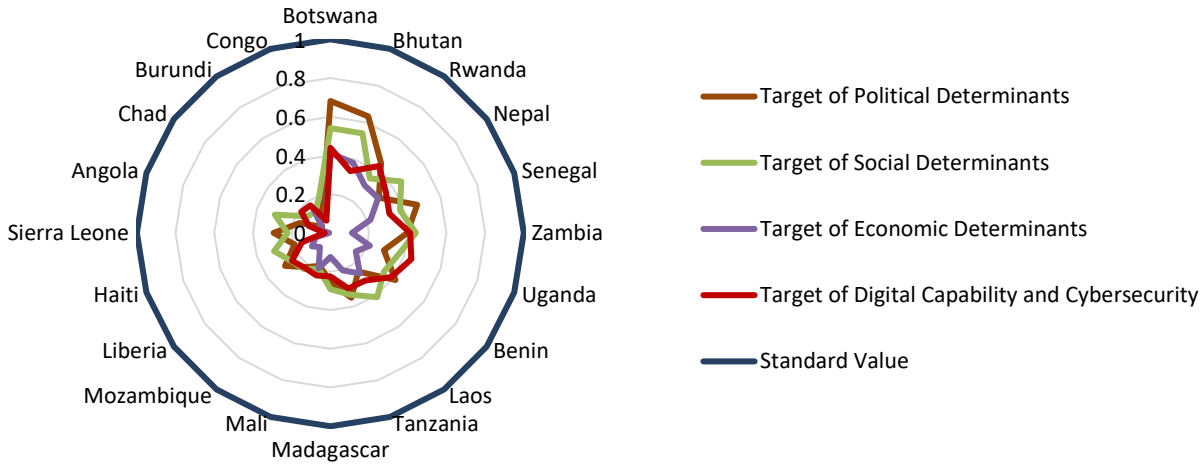

Figure 5. The values of composite targets for economic, social, political, digital capability and cybersecurity dimensions for the least developed countries. *Source:* Authors' calculations

4.2. Analysis of the results of the target pairs balance

The degree of angles of quadrangle for 127 countries was determined and their pairs were formed to analyze the balance of target pairs. They were selected based on the following considerations. Today, the greatest impetus in the economy is provided by the development of information technology, transforming it into digital technology. On the other hand, the country's economic development stimulates scientific and technological progress, the consequence of which is the IT–sphere development in the country. These considerations were also supported by calculating a linear correlation coefficient between the four composite targets values. It turned out that there is the closest correlation between the integrated values of the economic dimension and the dimension of digital capability and cybersecurity (0.9144). This relationship is also close between the pair of social and political dimensions (0.8343). We visualize the obtained calculations, which in percent show the ratio of the sums of opposite angles of the quadrangle. It enables us to conclude that the balance or imbalance of the dimension pairs development – socio–political and economic–digital (to reduce the name of digital capability and cybersecurity dimension, we use "informational"). It means that if the value goes to 50% (for a pair of social and political dimensions) and 100% (for a pair of economic dimensions and dimension of digital capability and cybersecurity), the sum of the pair of angles is 180°; otherwise, it will be either greater or less than 180°. Thus,

Figure 6 presents the results of calculations for developed countries, where ten countries are with the highest values, and ten is with the lowest values.

Analyzing the data in Figure 6, we can conclude that countries like Italy, Japan, France, and Israel have the most balanced pairs of targets because the sums of pairs of opposite angles go up to 180°.

When constructing their barycentric model, you can draw a circle around their quadrangle. For Spain, Singapore, Estonia, the United Kingdom, Germany and the United States, the sum of the angles has a slight deviation of 180°, but for other countries, the discrepancy is growing.

At the same time, it can be seen that the socio–political dimension value is lower for the vast majority of countries, which indicates the greater importance of this pair for balanced development of economically developed countries, as well as their rapid growth compared to a pair of economic and digital capability.

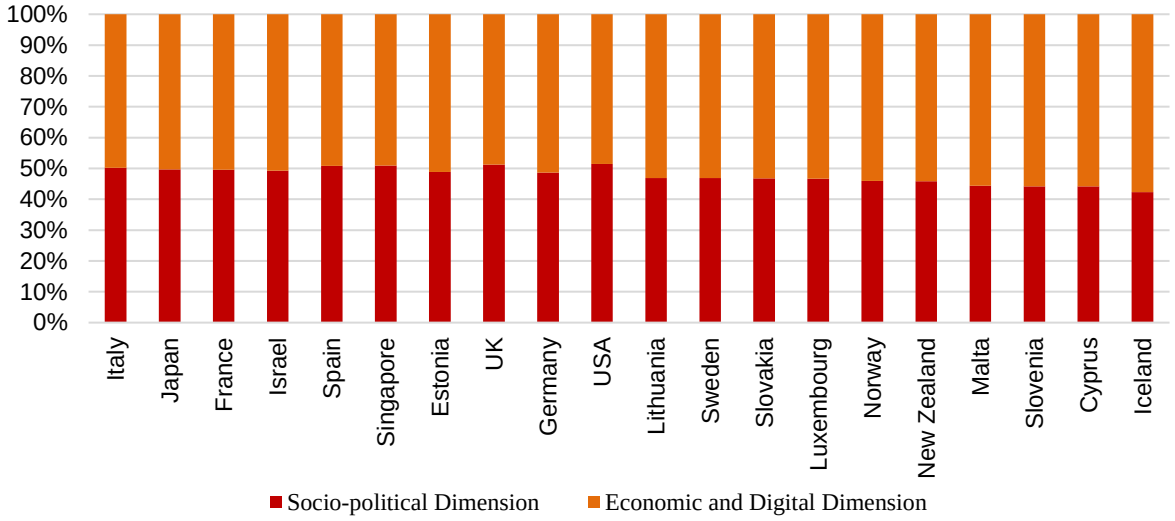

Figure 6. Balancing composite target pairs of economic, social, political, and digital capability and cyber security dimensions for developed countries. *Source:* Authors' calculations

The results of calculating the sums of opposite angles to build a barycentric model of developing countries are presented in Figure 7, where ten countries are with the highest values, and ten is with the lowest values.

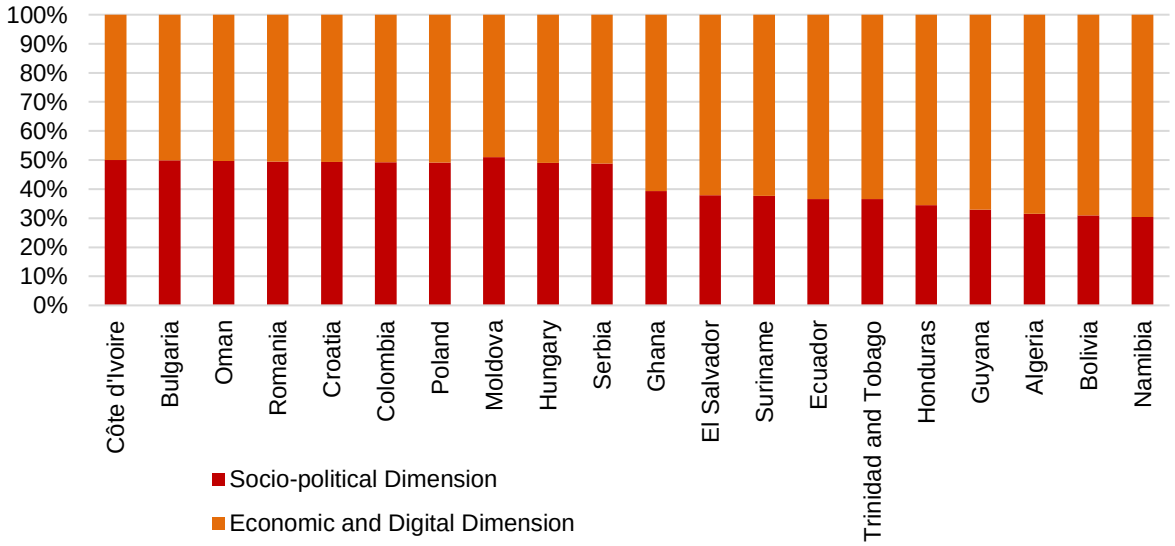

Figure 7. Balancing composite target pairs of economic, social, political, and digital capability and cyber security dimensions for developing countries. *Source:* Authors' calculations

We can see that Côte d'Ivoire, Bulgaria, Oman and Romania have values close to 180°. For other countries, the discrepancy is growing, which indicates that it is impossible to describe a circle around the quadrangle of the model. The results show that for some countries, the predominant pair is the socio–political dimension. For Moldova, Georgia, Kenya, Armenia, Qatar, the United Arab Emirates, Ukraine, Bahrain, Kazakhstan, Saudi Arabia, Azerbaijan and the Russian Federation (some of them are not presented in Figure 7), the dimension of economic development and digital capability and cybersecurity prevails. Analysis of this pair of dimensions for these countries showed that they have the most powerful development in the IT, and economic development lags far behind. Therefore, in the case of these countries, an economic breakthrough is possible due to the strong potential of the IT sector.

Figure 8 demonstrates the values of opposite angles for the newly industrialized countries, where it can be seen that only the model of the Philippines and India have the sums of quadrangle angles, approximately equal to 180°. Other countries have unbalanced pairs of dimensions, and some are characterized by the prevalence of economic–digital dimension (India, Indonesia, Mexico, Egypt, Vietnam, Malaysia, Pakistan, Iran, China, Thailand, Turkey, Nigeria), for others – socially –political (South Africa, Argentina, Bangladesh, Brazil, Chile). The analysis of individual indicators showed that China, India, Egypt have a strong development of the IT industry and cybersecurity. Mexico and Malaysia have the same level of economic development and IT. Brazil, Chile and Argentina have the destabilizing political target, which is a consequence of the political instability of these countries. It means that the group of newly industrialized countries has different directions of development that must be considered by the government for development strategy.

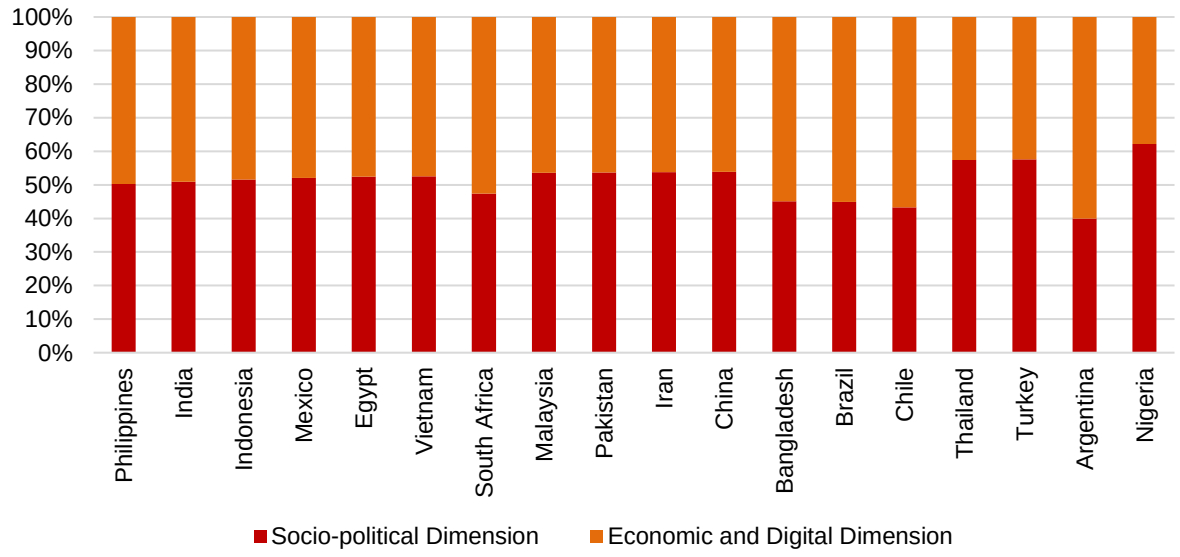

Figure 8. Balancing composite target pairs of economic, social, political and digital capability and cyber security dimensions for newly industrialized countries. *Source:* [51]

Figure 9 demonstrates ten countries with the highest and ten with the lowest values. Only for Cambodia, the values of the sums of opposite angles of a quadrangle are 180°, and for Ethiopia these values are close. Other countries have imbalance of dimension pairs, and the vast majority of them are characterized by the prevalence of socio–political dimension and economic–digital imbalance. It is vice versa for Chad, Mali and Burundi. Although the values of their targets are low, some countries have a balanced development of targets for dimension pairs.

For example, Bhutan (0.5400 – social target, 0.6322 – political, 0.3800 – economic, 0.3356 – digital capability and cybersecurity), which has the same socio–political and economic–digital development, but there is a significant difference between these pairs, which indicates the insufficient potential of the economic and digital sphere. Other countries in this group may have other development scenarios where only one of the targets will dominate due to their historical, cultural, political and other features of existence and development.

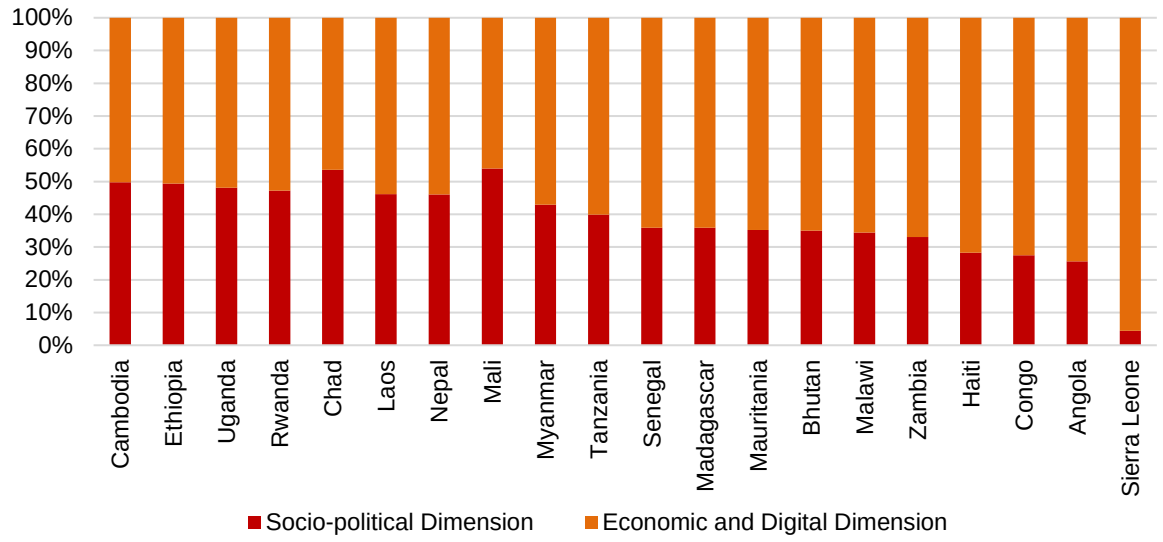

Figure 9. Balancing composite targets of economic, social, political and digital capability and cybersecurity dimensions for the least developed countries. *Source:* Authors' calculations

4.3. Analysis of the results regarding the balance of the four targets

Figure 10 demonstrates the distances between the centers of mass for all countries, which represent the deviation of their natural values from the standard one.

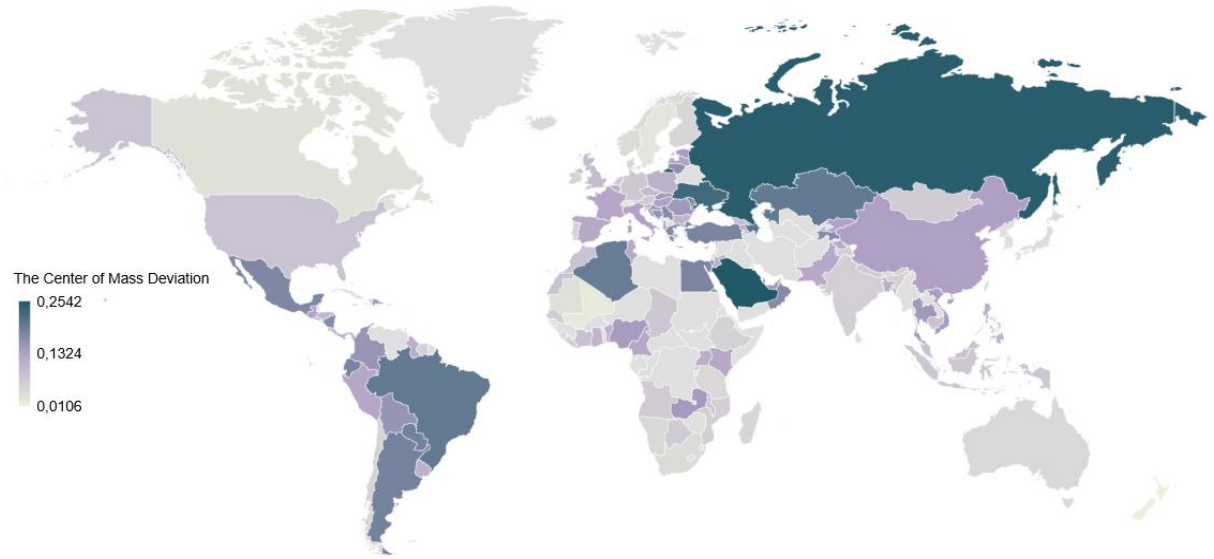

Figure 10. The level of countries' development balance is based on the deviation of the centers of mass in their barycentric models. *Source:* Authors' calculations

Thus, New Zealand (0.0106), Mali (0.0196), Burundi (0.0214), Switzerland (0.0236), Sweden (0.0272), Singapore (0.0312), Mauritius (0.0340), Canada (0.0350), Mauritania (0.0357) are the most balanced countries. It means that the developed, developing, and the least developed states are the most balanced countries. This factor proves that regardless of the values of targets, the balance level of their pairs, any country can have an effective combination of four targets. For example, Mali has low target values, but their combination is balanced, which in the future can serve as a driver for their more rapid and dynamic development. Paraguay (0.1860), Algeria (0.1946), Brazil (0.1990), Kazakhstan (0.1998), Azerbaijan (0.2063), Bahrain (0.2093), Iran (0.2113), Ukraine (0.2269), the Russian Federation (0.2467), and Saudi Arabia (0.2542) were the least balanced countries. This result suggests that these countries have an imbalance due to the prevalence of mainly one (for

example, in Ukraine, the digital capability and cybersecurity target) or two targets over others, which indicates their development inconsistency and the need to transform their strategies based on data.

4.4. Barycentric models of the most balanced countries in each group level of their economic development

We construct four–pole barycentric models of the countries' balanced development from each of the four groups with the smallest distance of the calculated center of their masses from the standard value. For this purpose, GeoGebra software was used. New Zealand (0.0106) is a representative for developed countries; Mauritius (0.0340) – for developing countries; South Africa (0.0428) – for newly industrialized countries; Mali (0.0196) – for the least developed. Figure 11 shows the barycentric model of New Zealand.

The barycentric model (Figure 11) shows the development of New Zealand, considering the balance of four composite targets – economic, social, political and digital capability and cybersecurity. Their values are quite high and close to 1, which indicates a high level of economic development, social standards, political stability, and significant potential of IT and cybersecurity. Figure 11 shows the center of mass of a quadrangle, the coordinates of which are almost equal to the coordinates of the standard center of mass. It indicates a complete balance of the four targets. It is impossible to describe a circle around a given quadrangle, because the sum of pairs of opposite angles is not equal to 180°. It is because the dimension of the digital capability and cybersecurity and the economic dimension are much lower than the social and political. According to this model, the following conclusion can be made: the country's development is sustainable because the distance between the centers of mass is insignificant. The relationship between the pairs of dimensions (economic–digital and socio–political) is unbalanced, but another can offset the development of one area. The composite targets of economic and digital dimensions are weaker, so the country needs to shift the emphasis in this direction of development, especially in terms of digitization and automation of various activities of economic agents. At the same time, political and social dimensions can act as a driver of development.

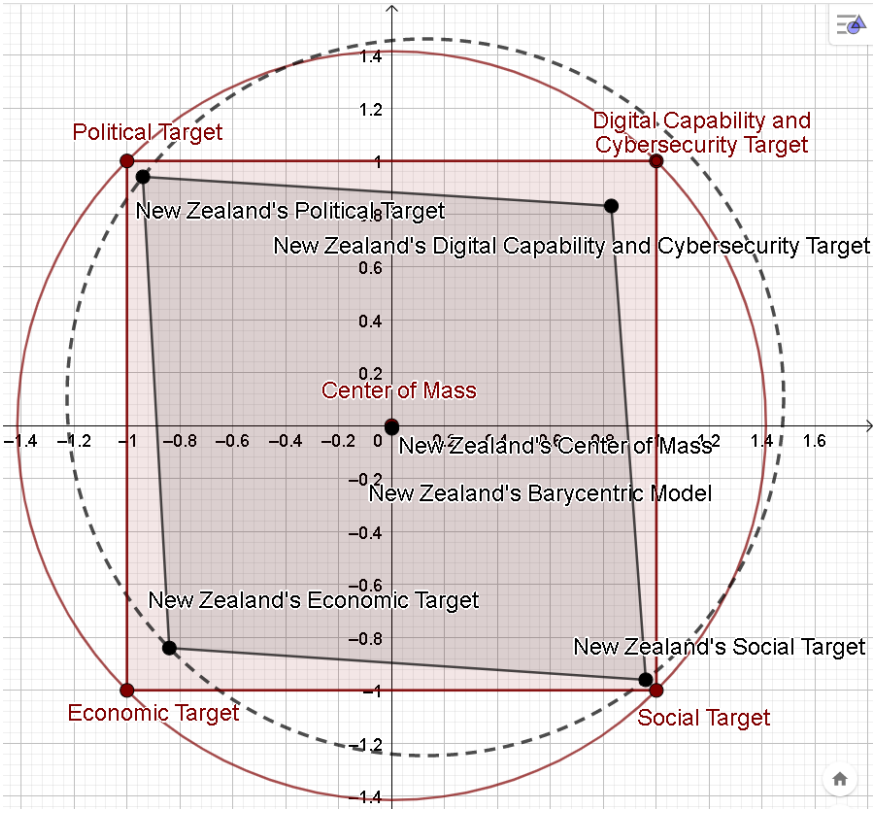

Figure 11. Four–pole barycentric model of balanced development of New Zealand. *Source:* Authors' calculations

The four–pole barycentric model of balanced development of Mauritius is presented in Figure 12.

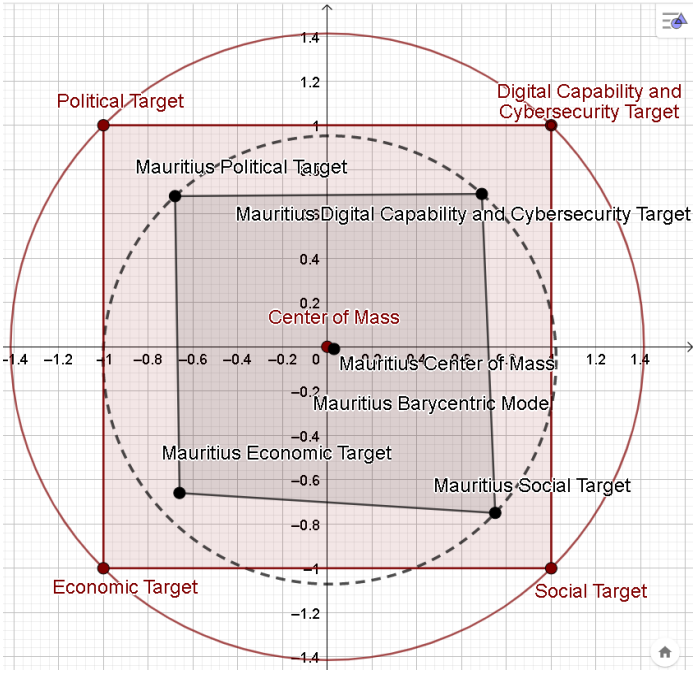

Figure 12. The four–pole barycentric model of balanced development of Mauritius. *Source:* Authors' calculations

The obtained model allows us to draw the following conclusions: the country's development is relatively stable because the distance between the centers of mass is 0.0340, bringing it closer to the minimum value among the distances. The ratio between the dimension pairs (economic–digital and socio–political) is imbalanced because the sums of the opposite angles are not equal to 180°. The imbalance is the largest for economic–digital dimensions. The least effective in this pair is the target of digital capability and cybersecurity, which indicates that the development of information technology and cybersecurity measures lag behind others. It means that Mauritius is an island nation, which focuses on the tourism industry development. This target needs to increase the national cybersecurity level. Compared to other data, its value is low, indicating possible problems in the state cyber defense system. The value of targets is above average, among which the most effective is the social development target, which can be a suitable driver for economic development and its digitalization.

We will build a four–pole barycentric model of balanced development of one newly industrialized country, namely the Republic of South Africa, the result of which is presented in Figure 13.

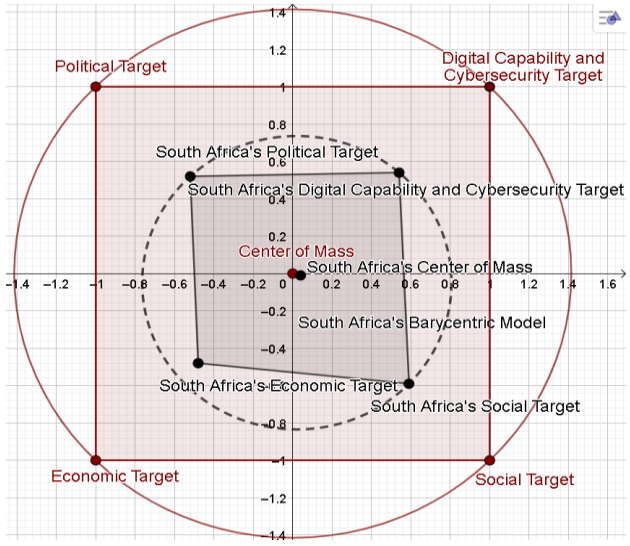

Figure 13. Four–pole barycentric model of balanced development of South Africa. *Source:* Authors' calculations

According to the results of the model (Figure 13), the following conclusions can be drawn: the country's development is stable, because the distance between the centers of mass is close to 0 and equal to 0.0428. The ratio between the pairs of dimensions (economic–digital and socio–political) is unbalanced because the sums of opposite angles are not equal to 180°, and the imbalance is greater for the economic–digital dimension than for socio–political. The values of targets fluctuate around the average level, but the economic sphere target is the most inefficient, which hinders the country's development and makes it impossible to develop comprehensively. The four–pole barycentric model of the development balance of Mali is presented in Figure 14.

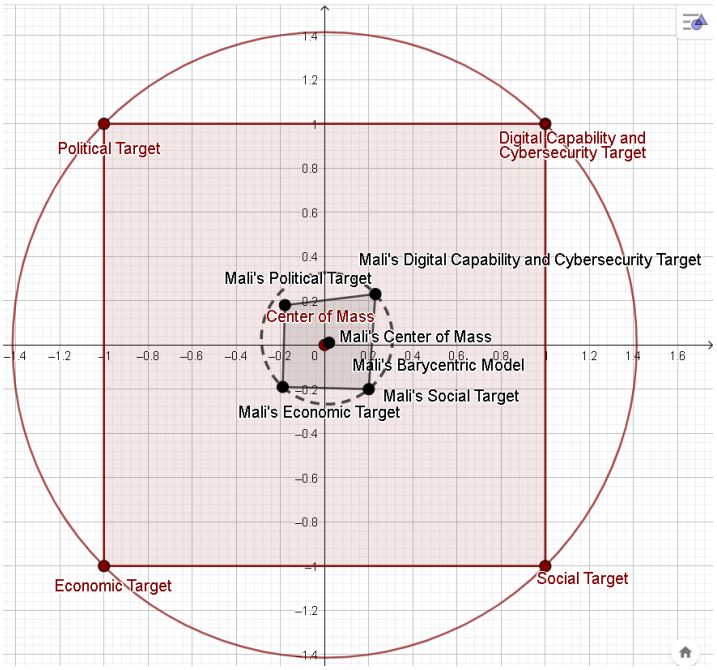

Figure 14. Four–pole barycentric model of balanced development of Mali. *Source:* Authors' calculations

According to the results of the model (Figure 14), the following conclusions can be drawn: the country's development is balanced because the distance between the centers of mass is 0.0196. Since the target values are quite low (0.2323 – for digital capability and cybersecurity dimensions; 0.1940 – for economic; 0.1954 – for the social; 0.1791 – for the political) and approach 0, it indicates a rather weak pace of development of all spheres in Mali. The ratio between the pairs of dimensions is unbalanced, because the sum of the opposite angles is not equal to 180°. Under the condition of effective political decisions, financial assistance of international organizations, the transformation of strategies, balanced conditions can contribute to a more dynamic further development of the country.

5. Conclusion

In terms of dynamic changes in various spheres of society, it is essential to identify critical determinants that ensure the balanced development and sustainable growth of economic, political, and social spheres and the sphere of information technology and cybersecurity. Accordingly, it is necessary to consider what factor causes the imbalance and how critical it can be. The authors of this study used the approach of determining the center of mass of a geometric figure to model the countries' development balance based on economic, social, political, information technology and cybersecurity development factors. It is a four–pole barycentric model with composite targets created under the influence of the outlined determinants. The list of factors and targets was selected using literature analysis and scientific knowledge methods. The study is based on observations of 127 countries set for 2018. The construction of the barycentric model considered its three components: the composite targets, the balance of target pairs and the balance of all four targets, i.e., determining the center of mass of the quadrangle. While analyzing the obtained values, it was revealed that developed countries have aggregated values of four composite targets higher than for groups of developing, new industrial and least developed

countries. It indicates a high level of welfare in these countries, social protection of their population, political stability, development of the IT sphere, and sustainable growth. The calculated values of the sums of opposite angles for most countries are not equal to 180°. It proved an unbalanced level of their development, which can slow their sustainable growth. For developed countries, the most effective is a pair of socio–political development, which is a consequence of the high rate of economic development. This pair of dimensions can also serve as a driver to accelerate the growth of the economic targets and digital capability, and cybersecurity targets. For developing and newly industrialized countries, various determinants can cause imbalances. For most of them, digital capability and cybersecurity are such targets. These include Côte d'Ivoire, Croatia, Georgia, Kenya, Moldova, Qatar, the Russian Federation, Saudi Arabia, Serbia, Ukraine, Egypt, India, Malaysia, Pakistan, and Turkey. This fact can contribute to developing the Quaternary economy sector in these countries and lead to its gradual transformation into the digital plane. For most of the least developed countries, a pair of economic–digital targets are unbalanced, where the economic target is critical for the country's further development. The obtained conclusions for the analysis of the distance of the calculated center of mass from the standard value showed that countries are characterized by balanced development based on all four composite targets. At the same time, it turned out that not only developed countries can be balanced, but also those that are developing and the least developed, such as Mali and Burundi. But despite this fact, the level of their target development corresponds to their classification group, which allowed us to conclude about the possibility of further dynamic development and sustainable growth of such countries while maintaining the effectiveness of social, political, economic, and digital capability and cybersecurity. For those countries, the development of which is the most unbalanced, for example, Saudi Arabia, Ukraine, the construction of a barycentric model enables us to identify the direction or that lead to this. Political fluctuations, military conflicts, and low quality of the social sphere can cause it. The relevant government agencies responsible for a particular area of the country's development should consider the results of this study to find more effective strategies for their sustainable growth.

Declaration of competing interest

The authors declare that they have no known financial or non–financial competing interests in any material discussed in this paper.

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