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Article

World development assessment in an invariant coordinate system of energy units: The newly industrialized economies perspectives

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Abstract: The purpose of the article is to present the results of analysis of newly industrialized countries in the context of sustainable development. The study took place within the framework of the Kaldor's structural-economic model of the gross domestic product and the energy flow model, using the socio-economic systems power changes analyzing method. Within the context of the approach, an invariant coordinate system in energy units is considered, the necessary conditions for sustainable development are formulated, and the main parameters for assessing the potential for growth and development are determined. The article focuses on key issues regarding new concepts of sustainable development and methodology for assessing sustainable development using the concept of socioeconomics useful power for the countries of the newly industrialized economy a group of emerging countries that have made in short time period a qualitative transition in socio-economic development. Based on a new definition of sustainable development in energy units, development trends are formulated for the selected countries during 20 years for the period 2000–2019. Results of the study can be used to planning for the transition to sustainable development. The data of the Central Statistical Office of European Union, the World Bank and the United Nations Organization were used for calculations. Initial interpretation of the calculated data has been done for the largest newly industrialized countries Brazil, India and China in terms of the gross domestic product in the period 1990–2019. For comparison, data on USA are presented as countries with advanced economy.

Keywords: emerging economy; newly industrialized country; sustainability; development; GDP structure; energy flows; power

1. Introduction

In 2020, the International Monetary Fund (IMF) classified more than 40 countries as "emerging" based on factors such as per capita income, exports and integration into the global financial system. Most are economies with strong growth and stability that can produce high value-added goods and participate in global trade and financial market integration. Newly industrialized countries occupy a special niche in the international division of labor between emerging countries. The term "newly industrialized country" (NIC) is a socio-economic classification used by political scientists and economists to refer to about 11 of emerging countries in the world (IMF Report, 2016).

The NIC countries have rapidly growing economies and export a lot, and are undergoing a transition from an agricultural to an industrial economy, especially in the manufacturing sector. In addition, the open market economy is growing, allowing free

trade with other countries and large national corporations that operate on several continents. The largest emerging and newly industrialized economies in terms of gross domestic product (GDP) are Brazil, India, China, and Indonesia. They are members of the G20, and their combined GDP based on purchasing power parity (PPP) in 2022 was about 32.5% of the corresponding world figure (IMF Report, 2022). According to IMF experts, the growing economic and financial power of emerging countries may in the future become a new source and catalyst for growth for low-income countries (IMF report, 2022). In this regard, in today's changing world, the need to identify objective indicators of sustainable development becomes of great importance for decision-making. The problems cannot be solved by the means used (Lélé, 1991; Pogge and Sengupta, 2015) and the currently used methods for assessing the sustainability of developed and developing socio-economic systems do not provide an objective picture of regional and national development. In today's changing world, decision-making requires objective indicators of the sustainable development of the socio-economic system. All processes must be considered and measured in a coordinate system independent of external factors.

The purpose of the article is to present the results of an analysis of newly industrialized countries in the context of sustainable development.

The study took place within the framework of the Kaldor's structural economic model of GDP PPP (in dollars) and the energy flow model (in energy model), using the socio-economic systems power changes analyzing method.

Within the framework of the approach, an invariant coordinate system in energy units is considered, the conditions for sustainable development are formulated, and the main parameters for assessing the potential for growth and development are determined.

The paper focuses on key issues regarding new concepts of sustainable development and methodology for assessing sustainable development using the concept of socioeconomics useful power for the newly industrialized countries of the newly industrialized economic (NIE), a group of emerging countries that have made in short time period a qualitative transition in socio-economic development.

The proposed model was development as the next step within existing models and the framework of the concept of ecological economics (Capra and Jakobsen, 2017; Odum, 1968) and taking into account the conclusions of the energy theory of cost (Costanza, 2004), in order to formalize the tasks of sustainable development, a sustainable development management model was developed using the energy flows (power) changes analysis method in open dynamic socio-economic systems (Trusina and Jermolajeva, 2021). The basic element of the proposed model is the introduction of the useful power P(t) concept. Useful power determines the level of intellectual possibilities and technological innovation of the socioeconomical system. Non-decreasing growth of useful power is a necessary condition for ensuring sustainable development. The formulated concepts are the basis for creating the basic structure of universal indicators for determining and monitoring sustainable development using invariant coordinate system in energy units (Trusina and Jermolajeva, 2022; Abramov et al., 2023).

Authors presented the results of the newly industrialized countries study in the context of sustainable development using the proposed models for period 1990–2019.

The developed model and system of indicators shows that, during the period of industrialization until 2019, none of the NIE countries reached the United States in terms of useful power per capita (U1) as an innovative development potential.

The first part of the paper focuses on key questions concerning the concepts of development newly industrialized economy, problems and prospects for the development of newly industrialized countries at the present stage and criteria for assessing the emerging economy.

The second part focuses on the description of socioeconomic system power changes analysis method and system's economy structure changes formalization. The third part presents the research results and discussion

Data from the Central Statistical Office of the European Union, the World Bank and the United Nations were used for the calculations. The initial interpretation of the calculated data was made for the largest newly industrialized countries—Brazil, India, China—by GDP for the period from 1980 to 2019, data for the United States as a developed economy is also presented for comparison.

2. Review of literature

2.1. Literature review

2.1.1. Emerging economies and their development

The global economic recession and the frequent crises of the modern world increase economic instability, provide a higher level of economic insecurity and cause stagnation (Frankel, 2020). Despite this, our world is capable of producing more material product than any social formation in history. At the same time, the transition to a new technical and economic structure is accompanied by an increasing rate of change and economic instability. Under these conditions of high variability, the importance of sustainable development of countries and regions increases.

There are differences among the four groups of countries of the world—economies with developed industry, newly industrialized economies, other emerging economies and least developed countries (Savelyev et al., 2021).

Different observers classify emerging market countries differently. Income levels, the quality of financial systems and growth rates are all popular criteria, but the exact list of emerging market countries may change. An emerging market economy is generally considered to be an economy that is transitioning to a developed market economy. The country has experienced rapid GDP growth, rising per capita income, increased liquidity in debt and equity markets, and a well-developed financial system infrastructure (IMF Report, 2020). Classifications vary. The concept of emerging markets and the rapid development of emerging markets are not entirely new topics, but the rise of the emerging markets group since the 2008 global financial crisis has indeed generated widespread interest around the world. Emerging economies support rapid and sustainable economic development.

From a global perspective, such inclusive and sustainable development has elevated their status in the global economy.

Overall, at purchasing power parity, emerging economies account for nearly 50 percent of global GDP.

High-speed development means strong thrust. Since the onset of the global financial crisis in 2008, emerging economies have become important engines of the global economic recovery, making significant contributions to global economic growth.

Between 2008 and 2009, their contribution to world economic growth increased from 78 percent to 88 percent, and this share will exceed 92 percent future period (World Bank data, 2023).

According to the IMF report, emerging economies were not affected by the global financial crisis compared to the Western world and maintained high levels of economic growth. Collective recovery is one of the most characteristic features of emerging economies.

2.1.2. Newly industrialized countries

Newly industrialized countries occupy a special niche in the international division of labor (IMF Report, 2016). A newly industrialized country (NIC) or a newly industrialized economy (NIE) or a middle-income country is a term used to describe a country whose level of economic development falls between developing and developed countries. They reached the forefront of the world economy in the 80s. These countries have moved from agriculture-based economies to more industrialized, urban economies. This set of countries has experienced rapid grow of macroeconomic performance, which consequently has accelerated the pace of natural resource consumption. Again, in these groups of countries, economic growth optimization has been considered the primary strategy over concerns of ecological performance (Bogan et al., 2023).

The modernization of the NIE countries was carried out dynamically since the late 70s under the management of the world's leading economies, primarily the USA, in accordance with the following directions:

- effectively organized influx of foreign capital;
- an effectively organized channel for the transfer of technologies and scientific and technical specialists from countries that are leaders in global technological progress;
- export expansion with a growing share of exports of high-tech products;
- formation of scientific and technical personnel;
- creation of scientific and technical infrastructure.

Experts include the "newly industrialized countries" of the "first wave" or "first generation" NIC are South Korea, Taiwan, the city-states of Singapore and Hong Kong, as well as the NIC of Latin America—Argentina, Brazil, Mexico. Following them are the newly industrialized countries of the "second generation" are the Philippines, Thailand, Malaysia, and Indonesia. The "third generation" includes China and India in 2002 (Savelyev et al., 2021). The sharp change in GDP per capita for each NIC during the transformation process can be observed in the **Figure 1**.

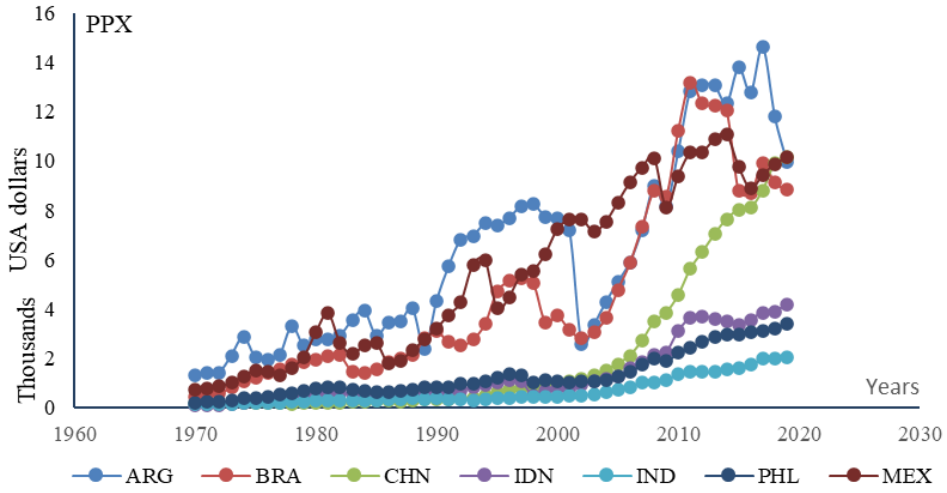

Figure 1. Dynamic of gross domestic products by purchasing power parity per capita PPX(t) changes of the China (CH), Argentina (ARG), Brazil (BRA), Indonesia (IDN), India (IND), Philippine (PHL), Mexico (MEX), period 1970–2019

Source: authors' construction based on world bank data.

There are two models for the development of newly industrialized countries (Gereffi, 2008): the Asian and Latin American models. The essential differences between these models are shown in **Table 1**.

Table 1. A newly industrialized models' description.

Asian model of NIC	**Latin American model of NIC**
Combining import substitution and export-oriented policies	The policy assumes protectionism, lack of competition from foreign companies, and cheap loans.
Entrepreneurial capital is directed mainly to manufacturing and primary industries	Entrepreneurial capital is directed into trade, services, and manufacturing
Wide range of funding sources	Powerful economic potential
Development of labor-intensive enterprises for the production of mass consumer products	Development of material-intensive and capital-intensive industries in manufacturing and mining industries
Excess of exports over imports	Excess of imports over exports
Small share of state ownership in the economy	Large share of state ownership in the economy
High power of the state in decision-making in the economic sphere	Insignificant power of the state to make decisions in the economic sphere

Source: Gereffi (2008) and authors' construction.

An analysis of **Table 1** allows us to understand that Asian NIC models are focused on external sources and markets and are more open to the world community than Latin American NIC models, which are focused primarily on internal sources of self-development. This partly reflects the high level of natural resource endowment that characterizes this group of countries. In his works, M. Porter argued that national prosperity does not arise in itself from the country's natural resources, available labor force, prevailing interest rates or the purchasing power of the national currency. In a situation of increasing global competition, the role of the state especially increases as

the competitive basis shifts towards the acquisition and assimilation of new knowledge (Porter, 2005).

2.1.3. Problems and prospects for the development of NIC at the present stage

The newly industrialized economy (NIE) was launched as a project of targeted change in each individual socio-economic system with clearly defined goals, results, defined risks, framework for spending funds and resources and special requirements for the institutional structure. The domestic institutional environment was reinforced by the creation of international global institutions, for example the creation of an International Trade Organization (1995). The average duration of newly industrialization process was about 25–27 years.

During the implementation of the project, depending on the level of development achieved in each NIC, various problems could be identified. In general, the NIC is characterized by problems, primarily related to the lack of stable domestic savings, significant interdependence between countries, as well as high external debt. The most serious task facing the NIC is determining further development in the long term. In the process of active industrialization and rapid GDP growth averaging 5%–7% per annum, two main problematic trends emerged.

On the one hand, the countries of the last wave of industrialization are characterized by the secondary nature of the development and development of high-tech industries, when the invention of innovative products and processes is not at the center of technological development. The focus is on acquiring the capabilities needed for efficient production and investment, as well as the need to find relatively strong niches in relevant global markets. Some countries have overestimated their desire for technological self-sufficiency and paid a high price in the form of insufficient productivity. Increased competitiveness had to be ensured by improving the education system. (Dahlman et al., 1987; Nayyar, 2021).

On the other hand, the newly industrialized countries of the first wave, after initial high rates of economic growth, joined the general trend of developed countries, which have been characterized by a slowdown in development rates since 2000 At the moment, the main goal of most NIC is to increase the opportunities for independent innovative development and build an innovative economy (Freeman, 2023). In this detection, three priorities can be formulated:

- reducing dependence on foreign technologies.
- increasing investment in R&D.
- increasing the contribution of knowledge-intensive industries to the economic development of countries.

Additional, NIC economies must implement environmental plans that amalgamate economic decisions and environmental concerns. Another thrust of emphasis is on the need to encourage the energy security and environmental welfare (Bogan et al., 2023).

2.1.4. Criteria for assessing the emerging economy

There is no official definition of an emerging market. The International Monetary Fund (IMF Report, 2020) classifies 39 countries as “developed” based on factors such as high per capita income, exports of diversified goods and services, and greater integration into the global financial system. The rest of the countries are classified as

emerging market and developing countries. Of these, 40 are considered "middle-income emerging market economies" in the IMF Fiscal Monitor based on their higher incomes. Income is not the only characteristic of an emerging market. Most of these are countries with strong growth and stability that can produce higher value-added goods and are more like advanced economies, not only in terms of income, but also in terms of participation in global trade and integration of financial markets.

According to the main theories and methods of development economics for the study of emerging market countries can be analyzed based on the following parameters (Hu et al., 2021): the size of the socio-economic system (state); the economic growth; socio-economic structural changes; momentum of development; institutional environment.

The IMF uses the following main criteria to classify countries as emerging economies (IMF Report, 2020):

1) Gross domestic product at purchasing power parity (GDP PPP) and annual growth changes (d GDP) (World Bank data, 2023).
2) Population (M) and annual growth changes of population (dM) (World Bank data, 2023).
3) Gross domestic product at purchasing power parity per capita (PPX) and annual growth changes (d PPX), which sums up all goods and services produced in a country in one year and divides this number by its population (World Bank data, 2023).
4) The volume of international trade of countries (EXP) — s an indicator of integration into the global financial system (World Bank data, 2023).
5) The Human Development Index (HDI), which quantifies the levels of education, literacy and health in a country in a single figure, as a quick way to classify an advanced economy (Human Development Report, 2019).

Additionally, the following indicators are considered as parameters:

6) GINI index (GINI) as a summary measure of income inequality (World Bank data, 2023).
7) Adjusted net savings per capita (ANS)—Adjusted net savings are equal to net national savings plus education expenditure Human Development Report and minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide and particulate emissions damage (World Bank data, 2023).
8) Index of sustainable development (SGD)—the index of sustainable development is determined in accordance with the data of the Sustainable Development Report, which is the first global study and which assesses the position of each country in relation to the achievement of the Sustainable Development Goals (Sustainable Development Report, 2021).

The above indicators for the NIE countries, as biggest emerging economy- China, Brazil, India, and the USA with advanced economy are presented in **Table 2**. NIE countries are ranked in descending order of gross domestic product at purchasing power parity per capita (PPX) in 2019.

Table 2. Socio-economic indicators of the USA, Brazil, India and China in 2019.

	M	**dM**	**GDP PPP**	**d GDP**	**PPX**	**d PPX**	**EXP**	**HDI**	**GINI**	**ANS**	**SDG**
	*	%	**	%	***	%	%	x	x	$	x
	1	x	2	x	3	x	4	5	6	7	8
China	1410	0.3	23	6	16	6	18	768	38	1617	72
Brazil	212	0.8	3	1	15	0	14	766	53	− 431	74
India	1380	1.0	10	4	7	3	19	645	36	340	63
USA	328	0.5	21	2	65	2	12	911	41	4520	76

Source: world bank data, sustainable development report and human development report information.
*- $x10^6$ capita
**- x 10^{12} $ (USA dollars)
***- $x10^3$ $ (USA dollars) per capita

The data in **Table 2** show differences in the parameters of the emerging NIE countries. India and China have closer values of indicators, at the same time, the indicators of Brazil differ significantly from them. According to World Bank and International Monetary Fund forecasts, emerging economies are expected to achieve eight percent or more economic growth in the coming years, while developed countries will be below two percent.

2.1.5. Economy sectoral structure changes analysis methods

The object of this study is the newly industrialized countries of the NIE, a group of emerging countries that have made a qualitative transition in their socio-economic development in recent years and past decades. In a short period of time, the economies of these countries transformed from a backward, low-income economy typical of emerging countries, into a highly developed industrialized economy. First of all, this was due to serious structural changes and transformation of the economy as a whole and by industry.

In modern economic science, the issues of structural changes in the economy, the structure of the economy, as well as the influence of the structure of the economy on indicators of economic growth. The key element in the manifestation of structural changes is the division of the economy into sectors. There are many criteria for formalizing the division of the economy into different sectors or industries. The most common of these is the division into three broad sectors: 1. the agricultural sector; 2. industrial sector; 3. the service sector (Kongsamut et al., 2001). The term “structural change” reflects changes in the structure of sectors of the economy and, in fact, structural change is the most indicative fact of economic growth. The clearest examples of such changes are industrialization or the transition to a service economy. It is well known that structural changes have a key role in the economy and society, especially in terms of economic growth. Although structural change has been known for a long time, the theoretical foundations of this area have not been fully developed, especially in terms of the theory of economic growth. Structural change is a well-known phenomenon that has been studied since the 1930s.

According to the statements and rules of Kaldor and Baumol (Kaldor, 1967; Baumol, 1967), the weakening of the economic dynamism is determined by the change in the sectoral composition of modern capitalism, and this is primarily due to the lack

of a solid industrial base. For Kaldor, manufacturing not only has the inherent properties of stimulating economic growth, but more broadly represents a fundamental 'growth engine' as productivity growth spreads to the rest of the economy, boosting aggregate productivity and GDP growth (Kaldor, 1996). Manufacturing has the potential to generate important spillovers for the rest of the economy, spurring growth in other sectors and driving technological innovation. Nicholas Kaldor noted in his works a high correlation between the standard of living and the number of resources allocated to production activities. Kaldor's Laws of Growth (Thirlwall, 2003) are a series of three laws concerning the causes of economic growth:

1) GDP growth is positively associated with the growth of the manufacturing sector.
2) Productivity of the manufacturing sector is positively related to growth in the size of the manufacturing sector.
3) The productivity of the non-manufacturing sector is positively related to the growth of the manufacturing sector.

Therefore, structural changes have an impact on real GDP (Baumol, 1967; Abramov et al., 2016).

Baumol, in his model of an unbalanced economy (Baumol, 1967), confirms the unfavorable nature of the service sector for economic growth. Differences in productivity between the two sectors stimulate an industry shift of resources towards less dynamic sectors, since high productivity activities require less labor to meet existing demand (Aaronson et al., 2004; Barro et al., 2004).

While services have historically resisted mechanization, they should not be considered consistently immune to productivity breakthroughs. Recent decades have seen the development of technologies that could potentially overcome some of Baumol's limitations on services, increasing their commercial value and productivity. Digitalization lowers transaction costs and facilitates the provision of services remotely, increasingly exposing them to increased productivity in international trade (Sorbe et al., 2018).

2.1.6. Different point of view and indicators of sustainable development

In the conditions of modern society in developed and developing countries, the concept of sustainable development of countries and regions is becoming increasingly important. Zero-loss transformation and nature management, investment-led growth and innovation, an inclusive approach to using human talent to manage insecurity, and a process of international cooperation aimed at achieving common goals — this will be the story of economic growth in the 21st century.

The current official methodology used to construct sustainable development indicators is based on heterogeneous and disproportionate measurements using a normalization procedure, but the resulting indicators are also heterogeneous as they are supported by heterogeneous values expressed in disparate units, which generates erroneous estimates and, as a result, ineffective control. The ongoing changes force the development of new methods for analyzing economic relations. Taking into account the interdependence of socio-economic systems and the natural environment, it must be borne in mind that the coordinate system and units of measurement used in the analysis of the stability of economic systems must be independent of various

external factors and be constant in time and space. Therefore, it can be said that the use of an economic structure in which money is the basic unit of analysis of the stability of economic relations seems to be incomplete, since the currencies themselves change over time.

3. Methodology

3.1. Socioeconomic system power changes analysis method

Within the framework of the concepts and definitions of the natural sciences, all living systems—nature and society—are open, stable, unbalanced and dynamic systems. Therefore, it is natural to use the laws of living systems to create technologies for sustainable development. In nature, there is no closed living system in which there would be no inflow and outflow of energy with zero power (energy flow) (Podolinsky, 2004; Vernadsky, 2006). According to E. S. Bauer, a feature of living systems is that they work against the expected equilibrium using free energy (Bauer, 2002). The main characteristic of energy flows circulating in living systems is their ability to perform external useful work or create external useful power (Trusina and Jermolajeva, 2022). Human activity can be described in terms of flows of energy and matter, and since the 1980s and 1990s, some systems ecologists and economists have begun to pay more attention to economic issues (Costanza, 2004; Georgescu-Roegen, 1986). The human economy exchanges materials and energy with the larger Earth system. Only energy flows have no boundaries, and these continuous flows provide and support the processes of the Earth system (Odum, 1968).

According to Costanza's theory, free or available energy is defined as the ability to do work and has characteristics that satisfy the criteria of a primary input to a system or a major contribution to the production process. On the other hand, the ability to do work is related to the degree of organization or order in a system relative to its environment. As an example, complex manufactured goods have the ability to perform work, which is not related to their raw energy content, but may be related to the degree of their organization in relation to the environment. To maintain organized structures (such as the economy), it is necessary to constantly add organized low-entropy energy from outside the system, which is essentially the mission of human activity.

As the next step in the development of these models and within the framework of the concept of ecological economics (Capra and Jakobsen, 2017) and taking into account the conclusions of the energy theory of cost (Costanza, 2004), in order to formalize the tasks of sustainable development, a sustainable development management model was developed using the energy flows (power) changes analysis method in open dynamic socio-economic systems (Trusina and Jermolajeva, 2021).

The analysis of socio-economic systems is based on the law of conservation of the power (Kuznetsov, 2015) in time, that necessary for the development and provision of the all-kind processes in the socio-economic system. The law defines, that energy flow (power) N(t) entering to the system over the period Δ t is equal to the sum of the output flow or useful power P(t), as results of transformation during the activities, and power losses G(t) as impact on environment (Equation (1)):

$$N(t) = P(t) + G(t) \quad (1)$$

The basic element of the proposed model is the introduction of the useful power P(t) concept as a function of the level of technological development of the system and the structure of energy consumption. Useful power determines the level of intellectual possibilities and technological innovation of the socioeconomical system. The formulated concepts are the basis for creating the basic structure of universal indicators for determining and monitoring sustainable regional development (Trusina and Jermolajeva, 2022; Abramov et al., 2023).

The model includes follow main provisions:

(1) In the context of the model, sustainable development is a continuous process of increasing the opportunities of the existing socio-economic system in terms of energy units, to meet current needs, as well as the needs of future generations, while increasing the level of the system useful power, reducing power losses and without increasing the level of consumption power in the face of negative external and internal influences (Bolshakov, 2019).

(2) The introduction of the term "power" into the formulation of sustainable development makes it possible to create an invariant system of coordinates in energy units.

(3) The socioeconomic systems power changes analyzing methods.

Within the framework of the model, the energy flows of the socio-economic system are analyzed as the final consumer and converter of incoming energy flows as a result of its activities. The final consumed energy flow or the full power N(t) of system includes all types of energy resources that necessary to ensure life, production, technological and other processes. This sum of all consumption flows determines the needs or potential of society, volume of economy (Podolinsky, 2004; Bauer, 2002; Shamaeva, 2019). In accordance with the law of conservation of living systems power (Kuznetsov, 2015), the main goal of the socio-economic systems development is the increasing of the amount of useful power P(t), as a result of activity, and reduce losses G(t). The development of the socio-economic systems, or changes of state, must be supported by new ideas, projects, technologies or intellectual opportunities, which can be defined as innovations. The formalized concept of innovation lies in the fact that during implementation, the efficiency of using the full power of the system changes (increases or decreases). Intellectual capability is the ability of the system to change the net power by changing the generalized coefficient of technology perfection—f (t) and the quality of planning. The coefficient of technological excellence is determined by Equation (2):

$$P(t) = f(t) \times N(t) \quad (2)$$

According to the model (Trusina and Jermolajeva, 2022), the management of development we can characterized by expansion into a series of changes in useful power P (t), and represented by Equation (3):

$$\Delta P(t) = P - P_0 = a\frac{dP}{dt}\Delta t + b\frac{d^2P}{dt^2}\Delta t^2 + c\frac{d^3P}{dt^3}\Delta t^3 \quad (3)$$

The first derivative of useful power is responsible for the growth of the systems power, and the second derivative is responsible for the development, third derivative is the condition of sustainable development. The basic step for analysis is 3 years for country or region. The growth of the socioeconomic system is considered for a period of at least 6 years (two steps), development - for a period of at least 9 (six steps) years,

sustainable development—for a period of at least 27 years (nine steps, approximately one generation). Based on certain parameters, it is possible to formulate various directions for the development of socioeconomic and natural systems (**Table 3**) and can be used as important indicators for assessing internal changes and external influences.

Table 3. Development trends of socio-economic systems depending on the useful power (energy flow) changes.

N	Trend of the system	Minimal period	Trends cod	dP(t)	$d^2P(t)$	$d^3P(t)$
1	Growth Zero	9	S	≈0	≈0	x
2	Growth	3	G	>0	≈0	x
3	Development	9	D	>0	>0	x
4	Sustainable development	27	SD	>0	>0	>0
5	Decline	3	DC	<0	≈0	x
6	Degradation	9	DG	<0	<0	x

Source: authors' construction.

Useful power P(t) is a function of the level of technological development of the system and the structure of energy consumption. Useful power determines the level of intellectual possibilities and technological innovation of the socioeconomical system. The formulated concepts are the basis for creating the basic structure of universal indicators for determining and monitoring sustainable regional development.

(4) Quality of life in energy units (QoLE).

The quality of life as an objective function in energy units in the concept of this model is defined as the power per capita necessary to fulfil human needs in order to realize ever-increasing opportunities, taking into account the quality of the environment and the level of technological development. The higher the quality of life, the higher the potential to ensure the development of the socio-economic system through the use of innovations and tools of the digital economy in order to improve the quality of living space for present and future generations. (Trusina and Jermolajeva, 2021).

(5) The main universal indicators of sustainable development model, full power N(t) as volume or needs of system, useful power P(t) as a possibility of system, innovation level and losses power G(t) are calculated out according the systems power changes analysis model (Trusina, Jermolajeva and Sloka, 2022). Model parameters such as quality of life (QoLE), technological excellence (f) and standard of living U(t) (useful power per capita), productivity as a production of useful power by one employee (PHP), calculated according formulae from **Table 4**.

Table 4. Sustainable development parameters definition and formulae.

Definition	design	unit	Formulae
Full (final) consumption per capita	D	W	D(t) = N(t) / M(t)
Standard of life	U	W	U(t) = P(t) / M(t)
Technological efficiency	f	%	f (t)=P(t) / N(t) ×100

Table 4. (*Continued*).

Definition	design	unit	Formulae
Productivity	PHPE	W	PHP = P(t) / LM(t) × M(t)
Quality of environment	q	x	q(t)= G (t − 1) / G(t)
Quality of life	QoLE	W	QoL(t) = U(t) × q(t) × TAN(t)

Source: created by the authors.
Basic designations in **Table 4**:
TAN(t) = (life expectancy) /100 — normalized life expectancy;
LM (t)—employment to population ratio (%) as the proportion of a country's population that is employed.

3.2. The formalization of economic system sectoral structure changes

In view of the above and in order to formalize the approach to studying structural changes in the economy, was determined indicators showing the structure and changes in GDP in various sectors

The sectoral structure of GDP is represented by the following indicators:

1) STINA is ratio of non-manufacturing share to manufacturing sectors share of GDP by formulae 4:

$$STINA = (100 - AG - IN) / (AG + IN) \quad (4)$$

where:

AG is value added (%) in GDP of agriculture, forestry, and fishing;

IN is value added (%) in GDP of industry (including construction);

ST = 100 − AG − IN is value added (%) in GDP of all kind of services and transports (tertiary and quaternary sectors).

2) I-STINA is ratio of agriculture, forestry, and fishing sectors value added to industry (including construction) value added sector of GDP by formulae 5:

$$I\text{-}STINA = IN / AG \quad (5)$$

The structural indicators are calculated out according the above description and presented in **Table 5,** where AD is advanced countries according the IMF classification, EM is emerging countries (including NIC) according the IMF classification. The countries are ranking according value of coefficient STINA.

Table 5. The sectoral structure indicators in 2019.

	2019	PPX	AG	IN	ST	STINA	I-STINA	IMF classification	Author classification
N	countries	$/10^3	%	%	%	x	x	x	x
1	USA	65	1	18	81	4.3	22	AD	A
2	France	50	2	17	81	4.3	11	AD	A
3	Italy	46	2	22	76	3.3	11	AD	B
4	Brazil	15	4	19	77	3.4	5	EM	B
5	Germany	57	1	27	72	2.6	35	AD	C
6	Japan	42	1	29	70	2.3	28	AD	C
7	Korea	43	2	33	65	1.9	16	AD	D
8	Mexico	20	3	31	66	1.9	9	EM	D
9	Philippines	9	9	30	61	1.5	3	EM	D
10	Thailand	19	8	34	58	1.4	4	EM	D

Table 5. (*Continued*).

	2019	PPX	AG	IN	ST	STINA	I-STINA	IMF classification	Author classification
11	India	7	17	25	58	1.4	2	EM	D
12	China	16	7	38	55	1.2	5	EM	D
13	Malaysia	29	7	38	55	1.2	5	EM	D

Source: World Bank data and authors' calculations.

The data in the **Table 5** show that the largest advanced economies (G7) have a STINA coefficient value of more than 2, and for the leading countries more than 4. Countries that are classified by the IMF as countries with emerging economies have a STINA coefficient of less than 2. In accordance with the value of STINA, four levels of economic structure are distinguished—A, B, C, D (**Table 6**).

Table 6. The sectoral structure indicators classification with standard description of society and economy and IMF classification.

Author classification	STINA interval for classification	Description of economy
A	4.0 and more	Post-industrial economy. Information society. High level of GDP per capita
B	3.0–3.9	Transition economy
C	2.0–2.9	High-tech production and services
D	1.0–1.9	Industrial economy
E	<1	Industrial and agrarian economy

Source: created by the authors.

Group "A" countries with a STINA value more than 4 have entered a post-industrial period in which the economy no longer relies on heavy industry and manufacturing, but instead on the supply of services. The main parameter in this stage is a high level of GDP per capita. This group is represented in the table by the USA and France.

A STINA indicator of less than 2 indicates the stage of industrial development of the economy ("D"). An industrial society is a society based on industry with flexible dynamic structures, which is characterized by: division of labor and growth of its productivity, a high level of competition. This group represents countries with newly industrialized economies, including the largest economies—India and China. Group C countries represent a high-tech production and service economy. Group B countries have a high level of deindustrialization, but the level of services provided is still not high enough. This group of countries includes the country of the first wave of industrialization according to the Latin American model—Brazil. According to the IMF, this country is classified as emerging.

4. Findings and discussion (also called results)

Within the framework of the proposed model of socio-economic system's power changes analyzing and Kaldor's model, calculations were carried out, and the data obtained were presented in the form of tables and graphs. The data of the Central

Statistical Office of the EU (Eurostat data), the World Bank (World Bank data) and the United Nations Organization (UNDATA) were used for calculations.

Calculations and initial interpretation of the calculated data of the largest NIE countries with emerging economies—Brazil, India, China, were carried out with comparison of the United States for the period 1990–2019.

The growth of the GDP PPP for the period 1995–2019 is linear tendency for USA and China for period 2000–2019 with rather high coefficients of determination with values about $R^2 = 0.99$ and more (see **Figure 2**). During the period 2000–2019, China's growth rate was twice that of America, and China's excess point was in 2016–2017.

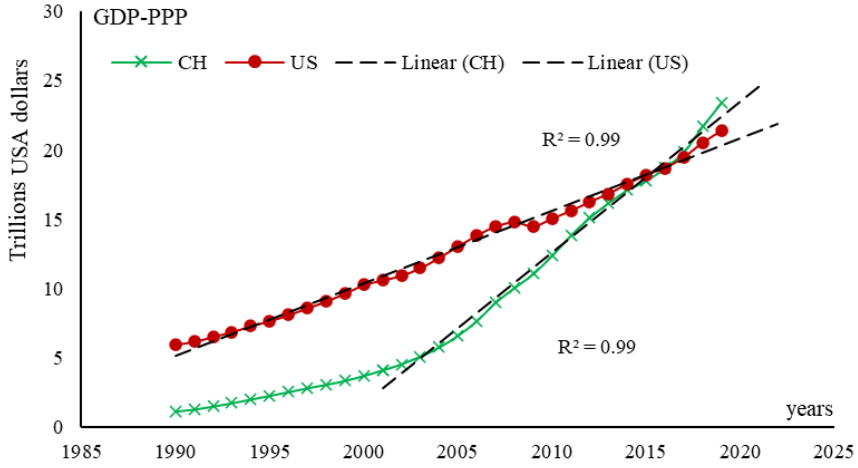

Figure 2. Dynamic of gross domestic product by purchasing power priority GDP PPP(t) changes of the USA (US) and China (CH), period 1990–2019.
Source: world bank data and authors' calculations.

The **Figure 3** present the development of the USA and China in the period 1995–2019 in the new invariant coordinate system and energy units of measurement.

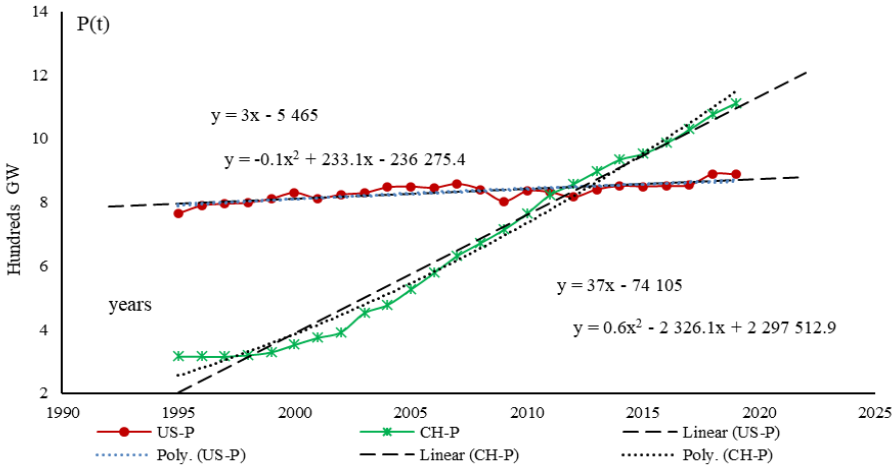

Figure 3. Dynamic of useful power P(t) changes of the USA (US) and China (CH), period 1995–2019.
Source: World Bank data and authors' calculations.

During the period 2000–2019 in the new coordinates, China has a significant growth rate of the useful capacity of the economy—more than 30 times. During the

same period, US power growth was near zero. China's excess point was in 2011, which 5 years earlier.

The **Figure 4** presents the dynamic of the GDP PPP changes for the NIE countries India and Brazil in the period 1995–2019. During the entire period, the countries represented had linear growth with a higher or lower growth rate. Growth rate of India is about 3 times higher than of that of Brazil for this period.

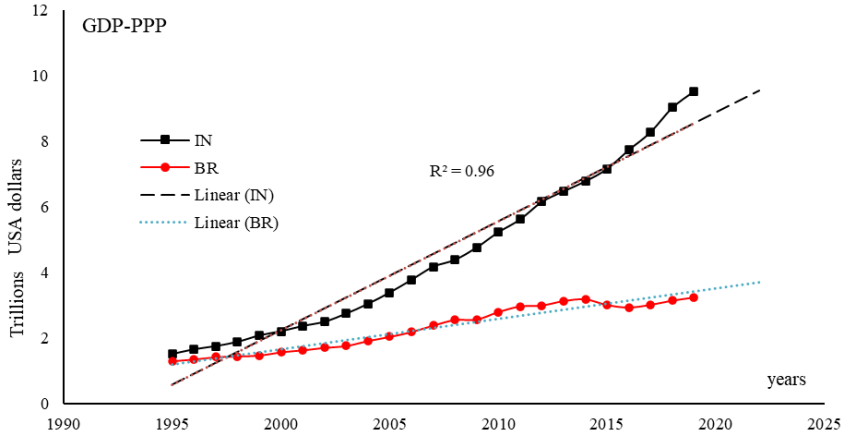

Figure 4. Dynamic of gross domestic product by purchasing power priority GDP PPP(t) changes of India (IN) and Brazil (BR), period 1995–2019.
Source: world bank data and authors' calculations.

The **Figure 5** present the dynamic of the useful power P(t) changes for the NIE countries India and Brazil in the period 1995–2019 in the new invariant coordinate system and energy units of measurement. The figure data shows a strong linear growth in India's development possibilities (useful power P(t)) over the past 20 years (2000–2019) and a weaker damped growth for Brazil for the same period.

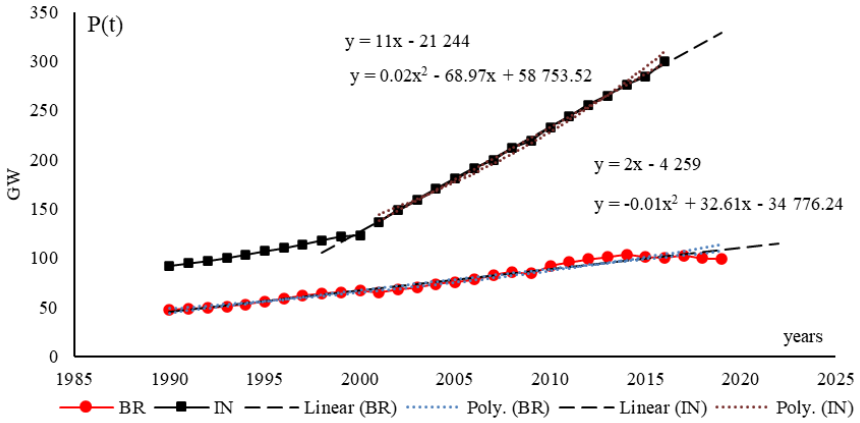

Figure 5. Dynamic of useful power P(t) changes for India (IN) and Brazil (BR), period 1990–2019.
Source: world bank data and authors' calculations.

According to the presented data on **Figures 3** and **5** and based on **Table 3** conditions, authors formulated various directions of the socio-economic development (**Table 7**) for the NIC countries and the US. Using trend data in **Figures 3** and **5**, parameters "a" and "b" were determined as:

- "a" is the average rate of change of the useful power P(t) in the period 2000–2019. g.
- "b" is average acceleration of the useful power P(t) in the period 2000–2019. g.

Table 7. Development trends for the USA (US), India (IN), China (CH) and Brazil (BR) in period 2000–2019.

	Trend of the system	**period**	**Duration, years**	**Trends cod**	**dP**	**d^2P**	**a**	**b**
CH	Growth	2000–2019	20	G	>0	> 0	37	0.60
IN	Growth	2000–2019	20	G	>0	≈ 0	11	0.02
BR	Growth, almost zero	2000–2019	20	S	≈0	≈ 0	2	−0.01
US	Growth, almost zero, with a tendency to slow down	2000–2019	20	S	≈0	< 0	3	−0.10

Source: authors' calculations.

The Brazil has been on a "Growth, almost zero" trend for the past 20 years same as for USA and a decrease in useful power produced per capita. That country has a declining potential for advanced development without changes of the development and the energy paradigm, and the technological level. China and India are, respectively, in the stage of Growth, subject to advanced development, have great potential.

The trend of the previous period and the state of the system in 2019 is the initial information for designing the further development of the socio-economic system and the formation of conditions for the transition to sustainable development.

In accordance with the methodology and **Table 4**, the main indicators were calculated for the NIC countries and the USA. Countries were ranked according to STINA (see **Table 8**).

Table 8. Sustainable development model parameters for the USA (US), India (IN), China (CH) and Brazil (BR) in 2019.

		PPX	**P1**	**U1**	**QoLE**	**PHPE**	**STINA**	**I-STINA**	**Trend and economy description**	
		$/10^3	GWt	kWt	kWt	kWt	x	x	x	x
1	CH	16	1113	0.8	0.6	1.4	1.2	5	G	industrial
2	IN	7	300	0.2	0.2	0.4	1.3	2	G	industrial
3	BR	15	110	0.5	0.4	1.0	3.4	5	S	transition
4	US	65	769	2.3	1.8	4.9	4.3	18	S	post-industrial

Source: world bank data and authors' calculations.

The high rates of scientific and technological progress and the technological dynamism of the developed USA economy before 2000 g. allowed the formation of significant technological potential (QoLE and PHPE), the use of which in the context of globalization has become a necessary condition for the modernization of the NIC of states.

In 2019, none of the NIC countries reached the level of the United States in terms of quality of life (QoLE) as a potential for innovative development. The internal structure of the socio-economic system of China and their potential as a quality of life

(QoLE) and productivity (PHPE) have been on the rise for the last ten years. The system in this state can more easily and quickly move to the stage of advanced development. The economies of China and India at the stage of "industrial" development will increase the level of all indicators. India's low quality of life (QoLE) is associated with a high share of agriculture (I-STINA). The high level of deindustrialization in Brazil (STINA) in 2019 does not provide an opportunity to increase the potential for the transition to sustainable innovative development (QoLE and PHPE). All relevant parameters in 2019 are lower than those of China.

5. Conclusion

Authors present the results of the newly 'industrialized countries' analysis in the context of sustainable development using the system's power (energy flows) changes analyzing methods and Kaldor's GDP structural model for period 1990–2019.

Within the framework of the proposed concept and in order to formalize the tasks of sustainable development, a sustainable development monitoring model was developed using the method of energy flows and power changes analyzing in the open dynamic socio-economic systems. The basic element of the proposed model is the introduction of the concept useful power P(t) as function of the level of technological development of the system, the level of intellectual possibilities and possibility for innovation sustainable development.

In the frame of research, using the invariant coordinate system in energy units and the main provisions of the Kaldor's model, a basic system of indicators of socio-economic systems and structural changes' coefficient was developed. Indicators were calculated and interpreted for the NIE countries—Brazil, India, China and in comparison, with the USA data as country with advanced economic.

Based on a new definition of sustainable development in energy units, development trends are formulated for the selected countries during 20 years for the period 2000–2019.

The developed model and invariant coordinate system with indicators in energy units show that China and India during the period of industrialization until 2019 had accelerated growth in terms of the level of useful power per capita (U1) as a potential for innovative sustainable development. The China and India internal structure of the socio-economic system (STINA), as well as the quality of life (QoLE) and productivity (PHPE) potential, have been in a growth phase over the past ten years. If the conditions for moving from the project stage to ensuring a continuous process of accelerated growth of useful power are met, countries in this state will be able to move more easily and quickly to an advanced stage of sustainable development. This transition requires additional research and analysis.

Based on the results of the analysis of the developed indicators, it can be noted, that India needs to focus its attention on strengthening and expanding the industrial sector, which will increase the growth rate of the useful power of the system and the economy as a whole.

The developed indicators of Brazil confirm the statements of experts about the beginning of a development trend similar to that of developed post-industrial countries.

The post-industrial nature of the US economy in the invariant coordinates system

of useful power was displayed in the form of a long period from 2000 to 2019 without growth. This is not so clearly expressed in monetary units.

The proposed methodology and formalization results allow us to obtain an additional amount of information and parameter values about different periods of the country's development and changing trends. The results of the study can be used for further design of sustainable development in developing and developed countries.

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