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A measurement instrument of cognitive economics in the BRICS countries

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Abstract

The paper envisages the key features of the cognitive economics in the BRICS countries. Due to their substantial impact on the development of the world economics, it is necessary to investigate the cognitive processes in these countries. The distinctive feature of the current world economy is the quality transformation of its technological basis that forms global challenges for the future world economic development. The essence of this transformation is to strengthen cognitive processes: emergence of robots, commercial spread of artificial intelligence technologies, changes in labor skills, etc. These quality changes lead to the formation of a new stage of economics — cognitive economics. As a sphere of scientific research, cognitive economics includes three main domains: intellectual systems, knowledge management, and cognitive technologies. Despite the fact that all these phenomena are present in the economy of each country there is no suitable instrument that can measure cognitive processes at the country level.

The purpose of this paper is to elaborate a measurement tool for evaluating the level of cognitivization in the BRICS countries. Taking into account this goal, the authors developed an aggregated index based on a generalized principal component analysis. As a result, the main parameters that make the greatest contribution to the cognitive index were identified. Comparison at the country level shows that the first sub-index has more weight connected with the human capital of the countries. As for R&D and ICT infrastructure — the second and third sub-indices — the situation in the BRICS countries is almost the same. The obvious conclusions of the monitoring are that cognitive economics in the BRICS countries has a chance to intensify their economic development and slash the backlog with the developed countries.

Keywords: the BRICS countries, cognitive economics, cognitive processes, measurement instrument, generalized principal component analysis.

JEL: O11, O15, O33, C43.

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Introduction

The relevance of the problems under investigation is determined by the global influence of the BRICS countries in the modern world. Possessing substantial economic potential, the BRICS countries have a significant impact on both world economic development and regional civilizations. However, despite the vast area, resources, and population, economic growth in the BRICS countries has slowed markedly. And currently, the tendency of slowing economic growth is deepening (Ignatov, 2020).

A distinctive feature of the current development of the world economy is qualitative transformation of its technological base, which forms global challenges for the future of world development (Khad'kova, 2017). In the developed countries, there is a movement towards a new socio-economic paradigm — industrial transformation on a principally new technological base. The essence of this transformation is that knowledge becomes the leading factor of the progress, not material things. The qualitative change in material manufacturing leads to the formation of a new quality of the economy and society, new ways of economic activities and the emergence of cognitive economics.

Cognitive economics is one of the modern directions of economic development (Walliser, 2008). The subject of cognitive economics is the study of human decision-making and explanation of social institutions and organizations in the context of structural uncertainty. Structurally, methodologically and technologically, cognitive economics is related to the methods of artificial intelligence and knowledge management, i.e., technologies that determine the modern technological basis (Abdikeev, 2017). Cognitive economics as a field of research and human activity includes three main domains: intellectual systems, knowledge management, and cognitive technologies in economics. However, while theoretical research in cognitive economics has been expanded since the early 2000s, applied and practical research has been presented only partially. Currently, there is no indicator that can evaluate the socio-economic phenomena describing the effects of cognitive economics.

It is evident that the problem of any qualitative shift is complicated by the uncertainty of its consequences. In this regard, the level of expansion of the ongoing qualitative changes in economics is up to date. Thus, cognitive economics provides not only new opportunities, but also new challenges: it deepens "digital gaps," increases the requirements for the qualification of the workforce and for the provision of technological self-reliance (Barkhatov et al., 2014). These challenges also cause methodological problems. There is no measurement instrument for evaluating cognitive economics.

The study of the current state of cognitive economics in the BRICS countries is relatively new. The aim of this paper is to develop a measurement tool for assessing the state of art in cognitive economics in the BRICS countries. The achievement of this aim is provided by a number of tasks: analysis of state programs aimed at cognitive processes in the economy, exploration of instruments that allow evaluating cognitive processes in the economy and development of a cognitive index, its modeling and interpretation.

The article is divided into following sections: the first section is devoted to the problem of cognitive economics in the BRICS countries and the analysis of the main state programs;

the second section deals with theoretical aspects of cognitive economics as a new scientific direction; the third section is devoted to the analysis of methodological instruments and introduces an elaborated instrument — cognitive index; the forth section is devoted to the calculation of the cognitive index of BRICS and its interpretation; and the sixth section is the conclusion.

1. The state of art in cognitive economics in the BRICS countries

Cognitive economics implies an innovative way of development based on new knowledge, technologies, competitive and effective enterprises. With an increase in the R&D intensity and introduction of modern and advanced technologies, innovation activity at the country level increases. One of the parameters of innovation activity in the national economy is R&D costs. Table 1 presents the statistics of domestic R&D costs in the BRICS countries.

Table 1. R&D costs in the BRICS countries

Country	Amount/ % of GDP	2005	2014	2016	2018
China	mln USD	86 639.80	372 326.10	453 054.80	554 327.80
	% of GDP	1.31	2.03	2.12	2.19
Russia	mln USD	18 120.50	40 330.20	39 008.60	41 505.10
	% of GDP	0.99	1.07	1.10	0.99
Brazil	mln USD	16 771.80	31 192.60	23 698.90	25 962.70
	% of GDP	0.82	1.27	1.32	1.39
India	mln USD	7336.30	14 885.60	15 570.30	16 856.10
	% of GDP	0.36	0.73	0.68	0.62
South Africa	mln USD	4619.60	5297.80	5714.50	5871.50
	% of GDP	0.86	0.76	0.81	0.78

Source: compiled by the authors based on (OECD, 2020).

Thus, analyzing the R&D costs in Russia, it can be noted that our country lags behind several fast-growing BRICS countries, namely China and Brazil. South Africa has the lowest R&D costs (5871,5 mln USD in 2018). The gap between China and South Africa is 548456,8 mln USD in absolute figures. The R&D costs in South Africa account for 1,06% of the Chinese R&D costs. We could postulate that there is a large differentiation in R&D costs among BRICS. Analyzing the share of domestic R&D costs in relation to GDP, Russia lags behind Brazil (0,99 and 1,39, respectively) and India lags behind South Africa (0,62 and 0,78, respectively).[1]

[1] http://www.statssa.gov.za; http://www.stats.gov.cn; https://www.gks.ru; https://www.ibge.gov.br; http://mospi.gov.in

Actually, the development of cognitive economics is a long-term planning priority in all BRICS countries. Table 2 presents the main state programs connected with cognitive economics.

Table 2. State programs of the BRICS countries connected with cognitive economics

Country	Programs connected with cognitive economics		
	Programs supporting human capital development	Programs supporting science development	Programs supporting digital economics
Brazil	Strategy of socio-economic development	National strategy of science, innovation, and technology development	Strategy of digital transformation
Russia	Concept of long-term socio-economic development	Strategy of scientific and technological development	Digital economics
India	Social and economic programs	Policy in the field of science and technology	Digital India
China	Five-year plan of socio-economic development	Strategy of innovative development	National strategy of cyber security
South Africa	Strategy of national development	State strategy of R&D development	National digital strategy

Source: compiled by the authors based on national state programs.

Thus, despite the differences in the elements of cognitive economics, the BRICS countries have similar goals. The main directions are the development of digital infrastructure and public access to digital services, both business and government. BRICS pays great attention to the issues of labor markets, as well as development and expansion of information skills among the population. The development of ICT also plays an important role in ensuring national security in the BRICS countries. This agenda is implemented in political and economic decisions of the BRICS countries.

2. The framework of cognitive economics research paradigm

In the modern society, intellectual resources are becoming a determining factor of social life. They exchange manual and mechanic labor for intellectual labor as a value factor. Not property, but the level of knowledge becomes the leading factor of social differentiation. The professional structure becomes more substantial for stratification than the class structure. The modern economy is more about servicing than manufacturing (Biaton & Wezner, 2018). The infrastructure of modern society is intellectual technology, not mechanics. Social organization and information technology create a symbiosis, providing

a technotronic era in society, where even social processes become programmable. Economic relations associated with factors of production are also changing. If in the industrial era, manufacturers loaded their enterprises with equipment, now the place of intellectual product in manufacturing processes is increasing, and manufacturers are faced with the problems of adopting high technologies and high speed of updating. As a consequence, the dependence on the quality of human capital is growing. The parameters that characterize the quality of human resources have a greater impact on the long-term economic development (Cassi, 2007).

The notion of cognitive economics (Fumagalli, 2007; Walliser, 2008; Vercellone, 2007) was introduced in order to point out the transformation of economy, where the cognitive component acts as a destructive element of the foundations and principles of the traditional mode of production. Cognitive factors began to play a leading role and became the main resource. Cognitive economics has the following distinctive features:

- increase of intellectual resources (staff qualifications, knowledge, increase of information flows)
- interaction of economic agents in real time, the so called time-space compression, which implies a new culture of constant change and permanent presence in the virtual space
- staff differentiation on account of the fact that people who are able to generate and commercialize innovations have become a more valuable asset, leading to organizational transformation and the emergence of network organizations instead of hierarchical ones. More competitive are those employees who can store, expand and use their professional knowledge and experience. Researchers forecast that labor skills will change dramatically by 2030 (Elwardi, 2012).

Cognitive economics has no restrictions on growth, as constant technological changes and organizational renewal create opportunities for continuous development driven by the improvement of production methods, management technologies, and producer-consumer interactions. Describing the peculiar characteristics of cognitive economics, it can be noted that cognitive abilities of a person differ greatly from material resources due to the inexhaustibility of intellectual abilities. Cognitive economics can be called anthropocentric. The main mechanisms of its development are participation and cooperation. It is these mechanisms that stimulate and motivate people to participate in the development processes.

Cognitive economics is actively elaborated as the leading concept of the modern economic development by European economic schools (Lucarelli, 2007; Ross, 2005; Rizello, 2007). Among the available works, the most fundamental is "Cognitive Economics" by Walliser (2008). It contains a structural description of the main tendencies in cognitive economics. Over the past 50 years, economics as a science has been sharply criticized for two basic concepts: rationality and collective equilibrium. On the one hand, human behavior was idealized, since it was based on the phenomenon of rationality without describing the corresponding underlying mental processes. On the other hand, collective equilibrium seems too artificial, as individuals coordinate their activities without

mentioning how they achieve this equilibrium. In response to this criticism, two research programs were developed that enrich economic models with two additional dimensions: mental and temporal.

The epistemic program focuses on a person's cognitive skills as the leading factor that explains an individual's behavior and, consequently, economic activities. Each person has his own set of knowledge, which is a specific intermediary between external information and his expectations. Collectively, all people are united in an information network that structures their permanent relations and serves as a means of the information interchange.

The evolutionary program focuses on the dynamic learning of individuals as the main component of their interactions and economic changes that result from these interactions, respectively. Each person relies on his inner beliefs that act as an intermediary between his suggestions and the actions he is going to perform. Collectively, all individuals are subjected to adaptation processes that are provided by their environment and allow them to develop together and form new structures.

Recently, due to the development of cognitive research that deeply influenced all social sciences, these two programs are combined into one called cognitive economics. The notion of "homo economicus" is replaced by the notion "homo cogitans," for whom the recurrent passage of time could alter limited cognitive abilities. The traditional state of equilibrium is replaced by self-organizing mechanisms (Kleiner, 2019).

Thus, cognitive economics could be defined as the study of persuasion principles and adaptation processes that occur to economic agents in an uncertain and dynamic environment. The combination of the epistemic and the evolutionary approaches leads to the interconnected development of both individual behavior and collective coordination.

The use of cognitive systems in economics is associated with the development of information systems, expert systems, and systems of decision-making. Knowledge economics is connected with intellectual property, information society, etc. The research field of cognitive economics comprises the intercrossing of these spheres. The research domain of cognitive economics includes business analysis, data mining, business intelligence systems together with neuromarketing and cognitive processes of decision-making (Abdikeev, 2019).

Cognitive economics is based not only on the transfer of knowledge from the producer to the consumer, but also on the influence of the producer's intelligence on the consumer's intelligence. And the level of intelligence is correlated with the cumulative parameters that accumulate and do not decrease. Thus, the connection between the producer and the consumer is formed, which does not stop after the transactions were made. In terms of cognitive economics, transactions are a responsible decision that leads to substantial changes in the entire system of relations between economic agents. Cognitive economics becomes relational economics. It can be assumed that an increase in the relationship component will ensure the influence of the consumer on the producer. Basing on cognitive economics as a research framework, let's consider methodological approaches to the elaboration of a measurement instrument.

3. Measurement instruments in cognitive economics

The expansion of digital technologies and increase of requirements to cognitive abilities hampers not only the conceptualization of cognitive economics but also the measurement of its domains. The lack of an established approach and appropriate instruments led to different evaluations and hinges the state of art in cognitive economics (Arkhipova et al., 2018). There are several methodological approaches to the analysis of digital economics, basing on which international ratings are built (Table 3), but there are not enough tools for measuring cognitive economics.

Table 3. Overview of digital economics instruments

Label of the instrument	Method of calculation	Design organization	Functional use
Going Digital Toolkit	Calculations of certain parameters of digital economics	OECD	Determining global trends in digital development for a better life
Toolkit for measuring digital economics	Aggregate data that describe digital economics	OECD	Conducting national measurements in digital economics
ICT Development Index	Rating technical parameters evaluating the level of digital technologies	ITU (International union of communication)	The state of art in the digital infrastructure of a country
Digital Adoption Index	Rating based on statistical data characterizing the level of technology development	World Bank Group	The state of art in the digital infrastructure of a country
Networked Readiness Index	Rating that combine evaluations and statistical data	World Economic Forum	Analyzing legal and business environment and the impact of digital technologies on society
I-DESI	Rating metrics	European Union	Comparing digital economics at the country level
World Digital Competitiveness Ranking	Ranking metrics	International Institute for Management Development	Analyzing legal and business environment and the impact of digital technologies on society

Source: compiled by the authors based on (Ignatov, 2020).

It is assumed that the approaches and methods of constructing an index can be substantially expanded. Considering the methodological procedures for elaborating a composite index, we can single out two main approaches: subjective and objective. The

subjective approach involves an analytical hierarchical process (Veisi et al., 2016) and the Delphi method (Garcia-Melon et al., 2012). Despite the evident benefits of information accessibility, this approach has several shortcomings, such as high qualifications requirements for experts, a sufficient number of experts, independence of expert responses, etc. The subjective approach is mainly used in the absence of available data collected and presented in official statistics.

In contrast, the objective approach lacks all these disadvantages, but needs an appropriate mathematical apparatus, such as principal component analysis (Grezebyk & Stec, 2015; Tan & Lu, 2016), factor analysis (Lee, 2013), and relevant statistical data. In order to overcome these difficulties, this paper uses a methodological procedure of the principal component analysis and official statistical data (OECD, 2019). The principal component analysis is a research technique of multivariate data analysis based on linear algebra and especially Euclidian vector spaces (Lavit & Escoufier, 1994). This technique allows to analyze the general data structure and find out differences in the analyzed period. Thus, the main advantage of the objective approach is the toolkit of standard statistical techniques that allow us to verify the obtained results.

4. Research design and data collection

Research design entails a two-stage procedure. The first stage involves conceptualization of a measurement tool covering the choice of countries and the choice of indicators. At the second stage, the developed cognitive index is subjected to a series of standard statistical procedures.

The choice of the countries was relatively simple, as all BRICS countries' economies were under analysis. According to definite indicators, three groups were singled out, each of which correlates with the main domains of cognitive economics. Thus, the first group — "human capital and information literacy" — corresponds to the development of human beings as generators of knowledge and drivers of scientific progress. The second group — "resource base of innovation" — corresponds to the conditions that each country has for its scientific development. And the third group — "infrastructure of information technologies and their availability for economic development" — reflects the state of art in information technologies common in the analyzed countries. The whole list of the selected indicators is presented in Table 4.

Table 4. List of cognitive index indicators

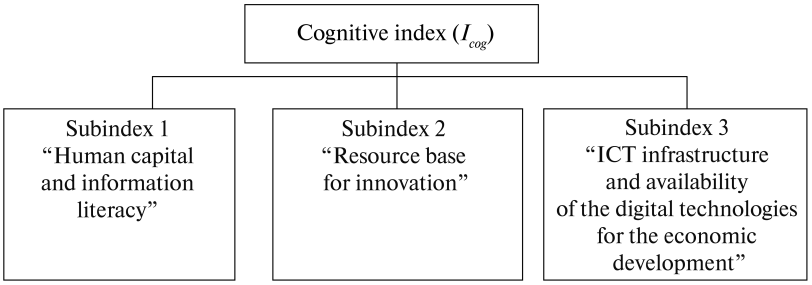
	Indicator name, unit of measurement
	Subindex 1 "Human capital and information literacy" (%)
x_1	The share of the employed population aged 25-64 years with higher education in the overall number of the employed population
x_2	The literacy rate of the adult population

Table 4. Continued

	Indicator name, unit of measurement
x_3	The share of scholars in the total population
x_4	The share of students enrolled in higher education programs (bachelor, master, specialist) in the total population
	Subindex 2 "Resource base for innovation" (%)
x_5	The share of domestic R&D costs as a percentage of GDP
x_6	The share of domestic R&D costs in the field of information technologies in the total volume of internal R&D expenditures
x_7	The share of technological innovations in the total volume of manufactured products, services, and works
x_8	The share of R&D costs aimed at economic development
x_9	The share of organizations implementing technological innovations
x_{10}	The share of innovative products, services, and works in the total volume of manufactured goods
x_{11}	The share of innovative products, services, and works in the total volume of export
x_{12}	The share of innovative technologies in the total volume of the elaborated advanced manufacturing technologies
	Subindex 3 "Infrastructure of information technologies and their availability for economic development"
x_{13}	Density of fixed-line telephone communication per 100 persons *(entity)*
x_{14}	Distribution of mobile radiotelephone communication per 100 persons *(entity)*
x_{15}	Number of collective centers with Internet access per 10 000 persons *(entity)*
x_{16}	Number of broadband Internet subscribers per 100 persons *(subscriber)*
x_{17}	Number of mobile Internet per 100 persons *(subscriber)*
x_{18}	The level of digitization of local telephone communication *(%)*
x_{19}	The share of telephonized rural entities in the total number of rural entities *(%)*
x_{20}	The rate for permanent use of the subscriber line, regardless of its type *(per month, local currency)*

Source: compiled by the authors.

The cognitive index is a combined measure of parameters in three key dimensions of the cognitivization processes: human capital and information literacy; resource base for innovation; IT infrastructure and its availability for economic development. The aggregation scheme is presented in Figure 1.



Source: compiled by the authors.

Figure 1. Structure of the cognitive index

Designing a cognitive index involves the following steps: 1) given that the data presented are measured in different units, the indicators were normalized; 2) in order to identify the most significant characteristics, a generalized principal component analysis was conducted; 3) the mean value of the three sub-indices was calculated in order to form the cognitive index; 4) to compare the processes of cognitivization, a scale from 0 to 1 was developed, where the interval from 0 to 0.3 points means that the cognitivization processes are at a low level; from 0,3 to 0,6 — at the middle level; and from 0,6 to 1 — at a high level.

5. Results

In accordance with the chosen methodology, tables of weight distributions were constructed, which could help calculate the sub-indexes weights. Table 5 presents the weights distribution in the cognitive index of the BRICS countries.

Table 5. Weights distribution for the BRICS countries

Country	Cognitive index
Russia	$I_{cog} = 0,62X_1 + 0,26X_2 + 0,12X_3$
Brazil	$I_{cog} = 0,77X_1 + 0,13X_2 + 0,10X_3$
India	$I_{cog} = 0,8X_1 + 0,11X_2 + 0,09X_3$
China	$I_{cog} = 0,84X_1 + 0,08X_2 + 0,08X_3$
South Africa	$I_{cog} = 0,72X_1 + 0,19X_2 + 0,09X_3$

Source: compiled by the authors.

Thus, the weights for sub-index 1 range from 0,62 (Russia) to 0,84 (China). The impact of sub-index 1 is higher for all BRICS countries, which confirms that cognitive processes depend on the development of human capital. The other two sub-indices have a smaller contribution, which could be considered as the overall spread of digital technologies and a resource base for innovation. The calculations of the cognitive index are presented in Table 6.

Table 6. Cognitive index for the BRICS countries' economies

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Russia	–0,05	–0,06	–0,06	0,03	0,07	0,1	0,04	0,16	0,55	0,55	0,56
Brazil	–0,04	–0,03	–0,02	0,14	0,12	0,13	0,22	0,16	0,3	0,38	0,47
India	–0,06	–0,08	–0,01	0,05	0,11	0,19	0,21	0,3	0,41	0,48	0,44
China	0,01	0,05	0,21	0,38	0,47	0,44	0,77	0,61	0,74	0,71	0,76
South Africa	–0,01	–0,03	–0,08	0,02	0,12	0,17	0,19	0,14	0,24	0,34	0,46

Source: compiled by the authors.

According to the data obtained, one could postulate that the BRICS countries are in a transition state to cognitive economies. Nevertheless, the cognitive index is growing in all BRICS countries, which confirms that the cognitive processes correspond to the development of the world economy.

6. Discussion

In this paper, an attempt is made to consider such a research gap as the elaboration of a measurement instrument for cognitive economies in the BRICS countries. On the one hand, a large number of economic studies mention cognitive processes (Rizzello, 2003; Ross, 2005; Abdikeev, 2010; Safiullin, 2012; Khadkova, 2017), but there are no attempts to measure them. On the other hand, there are many econometric studies that describe different approaches to aggregation, but there are no examples of measuring cognitive economics. In the present research, an attempt is made to combine these ideas and elaborate a measurement index for cognitive economics.

Another perspective that should be mentioned in the discussion is the evident economic slowdown in the BRICS countries. Cognitive economics provides not only opportunities, but also challenges and widens the gaps in the economic development of developed and developing countries. The growing asymmetry in high-tech sectors causes problems of national security and cybersecurity and creates social imbalances. In these conditions, cognitive economics gives the BRICS countries a chance for a qualitative transformation.

The last but not the least important perspective to be discussed is the choice of the generalized principal component method as a measurement instrument. Its ability to single out the main parameters makes is useful for various studies.

Conclusion

Nowadays, there are many transformational processes related to the spread of information technologies, improving the level of education and information literacy, and the need for innovation, which could be indicated in almost every country. In this sense, the

BRICS countries are no exception. Despite the economic slowdown, these countries are influenced by an emerging socio-economic paradigm based on intelligent technologies. In order to comprehend these processes, a measurement instrument was elaborated.

Our findings show that the human capital sub-index has a stronger impact in comparison to other sub-indices. It can be explained that cognitive processes depend mainly on human intelligence. The BRICS countries are an important force in the development of the world economy, but the economic slowdown in almost all of these countries must definitely be overcome by means of internal development factors.

This study has several theoretical implications for the development of cognitive economics. First of all, the paper presents a measurement instrument for cognitive processes in the BRICS countries. It can definitely be used in various comparative studies. Although there is an extensive literature on measurement instruments related to different aspects of digital economics, research on cognitive economics instruments is scant.

As for practical aspects, the received results can be used at the national level in the development of technological development strategies, educational policy, strategies for the development of higher education institutions, and budget formation in strategic areas.

Nevertheless, some limitations should be reasonably admitted. Firstly, our study has its limitations related to the theoretical background of the research, since we have just developed a measurement instrument for evaluating cognitive processes. Secondly, we used data for a certain period, namely, for ten years. Further work may follow this line of research.

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