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ORIGINAL RESEARCH

# State Economic Strength and Some Methodological Issues on Its Assessment

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**Abstract**
At present, many international organizations and scholars, who are aimed to compare and assess country-specific economy or competitiveness, have set different standards and indicators and tried to assess the economic strength of individual country. But most of these standards and indicators are for the assessment of individual aspects and what is worse, they are not suitable for the real situation of the countries concerned. This paper deals with methodological issues on the assessment of *state economic strength*. To this end, authors investigate the preceding studies on the assessment of economy of a given country, conceptualize the state economic strength, set a new system of indicators for assessing it and on this basis, produce a methodology for the synthetic assessment of state economic strength. The findings are that state economic strength must be defined in a view of economic capability which any country can exhibit by itself even under uncertain external environment, the indicators for assessing it include a variety of indicators in line with its essence, and assessment methodology must be synthetic one based on considering the weights of indicators. These findings may help, on the one hand, in assessing the economy of a given country and taking an economic and technical measures for its strengthening for policy-makers, and on the other hand, in comparing and assessing the country-specific economy for organizations or scholars in a new perspective.

**Keywords** State economic strength (SES) · Economic structure · Economic strength assessment · Knowledge-based economy

## 1 Introduction

Setting the targets for strengthening their economic strengths, today, all countries over the world are making every possible effort for its realization. The assessment of economic strength is aimed to analyze and assess its present situation, set up a promising plan to increase it to a higher level and take an economic and technical measures for its realization.

However, it is seen that there have not been the unified view about what State Economic Strength (SES) is and how it is assessed in previous studies. In most cases, until now,

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previous studies have been conducted focusing on assessing the economic size or competitiveness of a given country. And with the long-term history of economic development, different views have been raised on the indicators for assessing the economy of a country.

In this regard, many international organizations and scholars, who are aimed to compare and assess country-specific economy or competitiveness, have set different standards and indicators and tried to assess using them.

What is the typical among these is to emphasize indicators such as Gross Domestic Products (GDP) or GDP per capita and by using those indicators, assess the economic size or economic competitiveness of a given country. These indicators have been adopted as those for assessing country-specific economies by individual researchers and authoritative international organizations including OECD (Organization for Economic Cooperation and Development), the World Bank and the UN (United Nations), who have published the data related to these indicators every year. Besides, macroeconomic indicators such as the growth rate of real GDP, the structure of GDP, inflation rate, employment, investment, saving, per-capita real GDP, per-capita real GDP by purchasing power parity (GDP PPP), national income, gross national income, etc. have been set as the indicators reflecting the economy of a given country, and by using them, its economy has been calculated and compared.

Under the emphasis of the limitation of GDP in the aspect of human welfare, on the other hand, attempts have been made to set new different indicators by means of which to assess the economic strength of the country involved.

With the advent of knowledge-based economy, international organizations, countries and regions, and scholars have set knowledge-related indicators to assess the economy according to countries. Typical indicators are the intensity of R&D (research and development), the production volume of intellectual products, the number of patents and inventions, school enrollment rate, the number of scientists and technologists per 100 000 persons of population, etc.

Some views have been suggested on the methodology for assessment. The typical one is to standardize the values of indicators so as to compare with each other and on this basis, average them simply. And various methods for applying the new hybrid and econometrical models have been proposed for the purpose of assessing or forecasting the economic growth according to countries.

As seen above, however, there have been no exact explanation of the essence and nature of SES. It is a common practice that economic strength has been assessed on the basis of regarding it as competitiveness from the viewpoint of economic globalization, and the economy of a country has been compared and assessed in individual aspects by means of individual macroeconomic indicators.

Furthermore, at present, globalization of economy is facing with severe challenges, which are those related to trade dispute between countries, protectionist policy in trade, worldwide polarization of wealth, disease such as COVID-19 pandemic and so on. These are the major factors significantly affecting the trade of world, as well as individual country, which, in turn, negatively affect the production and consumption of a country. In particular, factors such as COVID-19 pandemic and US-China trade war severely affect the country-specific economy in real world. This requires that each country reconsiders the own economy and economic policy, thus constructing the one which a little affects by uncertain external environments. On the other hand, there exists some doubts about significances of indicators such as GDP, GNP, those expressed per capita, and so on as those reflecting the economic size of a given country. In other words, there exists views which abovementioned indicators are inappropriate for reflecting the real situation of given economy.

This study is motivated by following arguments; a) what is the real SES? b) how can the system of indicators for reflecting the real situation of given economy be set? and c) how can the SES be assessed? Only by understanding what SES is and what components it consists of, is it possible to set various indicators well-suited to assessment aim, thus analyzing and assessing its real realities.

Therefore, this paper is aimed to clarify the nature of SES from new perspective, set a new system of indicators for its assessment and on this basis, produce the methodology for assessing the economic strength synthetically. For the purpose of study, the paper is organized as follows. The second section is devoted to the analysis of the preceding studies relating to the attempts to assess the economy of a country and the revelation of their limitation. In this section, economic issues related to economic size, competitiveness, and the economic indicators are discussed. The third section is for clarifying the nature of SES, setting a system of indicators, and describing the assessment method. In this part, essence and nature of SES is defined in new viewpoint and the system of indicators for assessing and comparing SES is set. Also, a methodology is explained to synthetically assess economic strength on the basis of important indicators and assumed data. The fourth section addresses the results and discussions, and the fifth section—the conclusion, which includes the findings, contribution, limitation, and further research of this study. The findings are as follows; (a) SES must be defined in a view of economic capability which any country can exhibit by itself even under uncertain external environment, (b) the indicators for assessing SES include a variety of indicators in line with its essence, and (c) assessment methodology must be synthetic one based on considering the weights of indicators. These findings may help, on the one hand, in assessing the economy of a given country and taking an economic and technical measures for its strengthening for policymakers, and on the other hand, in comparing and assessing the country-specific economy for organizations or scholars in a new perspective.

## 2 Analysis of Previous Studies

The analysis of already-made research findings relating to the assessment of economic strength is prerequisite for correctly clarifying the nature of SES and for producing a scientific assessment methodology. This is because indicators are of different significance in assessing the economic strength of a country involved. From significances of literature research, in this section, a variety of economic concepts, indicators, and methods related to assessment of SES are discussed. A lot of indicators and methodologies have been raised so far, but this paper focuses on typical research findings.

Firstly, there have been different definitions of economy and its size, and competitiveness. Many databases describes the concept of economy in various aspects. According to them, economy is the system according to which the money, industry, and trade of a country or region are organized (For example, Collins Dictionary), it—activities related to the production and distribution of goods and services in a particular geographic region, or the correct and effective use of available resources (For example, InvestorWords), and it—an entire network of producers, distributors, and consumers of goods and services in a local, regional, or national community (For example, Business Dictionary). On the other hand, according to Merriam-Webster.com, national economy is referred to as the economy of a nation as a whole that is an economic unit and is usually held to have a unique existence greater than the sum of the individual units within it. Researching the evolution of theory

of the national economy, Starostina and Prushkivska (2013) emphasize that the structure of the national economy is expedient to explore through the structure of the whole economic structure and models of operation. Regarding the size of economy as economic strength, Moffatt (2019) suggests that measuring the size of a country's economy involves several different key factors, but the easiest way to determine its strength is to observe its Gross Domestic Product (GDP) (Also, Mallard 2012; World Bank 2012b). Also, there exist different views on competitiveness. The typical ones among them are as follows; according to Wikipedia Encyclopedia, competitiveness is referred to as the ability and performance of a firm, sub-sector or country to sell and supply goods and services in a given market, in relation to the ability and performance of other firms, sub-sectors or countries in the same market (Also, Lawrence 2002); competitiveness is defined as the institutions, policies, and factors that determine the level of productivity of a country (For example, World Economic Forum 2019). As seen above, various international organizations, scholars, and databases have suggested different views on economy, economic size, and economic competitiveness, which are of certain significance in displaying the economy of a country. However, it is seen that these definitions and views have limitations of not considering the actual strength of given economy theoretically, only considering the denotative aspects of economy, not connotative. In other words, it is our views that not only denotative but also connotative aspects ought to be considered in revealing the actual strength of economy or SES. This issue is revealed in more details in next section.

Next, authoritative international organizations and researchers have suggested many indicators for assessing the economy of a country. The typical indicators are macroeconomic aggregate indicators and per-capita economic volume indicators, among of which GDP and per-capita GDP can be used to compare and assess country-specific economy. In this context, Giovannini (2008a) sets the GDP as the indicator related with the "health" of a particular economic system, and says that the level of GDP per head of population is the most commonly used shorthand measurement of the economic well-being of a given country. In this case, GDP represents a total measurement of the income produced over a certain period of time. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products and GDP per capita is the value of GDP divided by midyear population (For example, Rutherford 2002; Abdul and Musharaf 2015a; National Bureau of Statistics of China; World Bank; United Nations Database). World Bank (2010) defines that GDP is a single figure representing all production in a given country during a given period and it is called domestic because it only includes production within the country's economic territory.

Researchers also suggest that the economy of a given country should be assessed not by nominal GDP but real GDP or real GDP PPP and its per-capita volume. Economic aggregates expressed in current prices do not enable to determine the extent of variations observed over a certain period due to variations in quantities or variations in prices. In this case, the resulting economic aggregates expressed in constant prices are calculated "in real terms", in opposition to those "in nominal terms," and GDP PPP per capita is gross domestic product converted to international dollars using purchasing power parity rates divided by midyear population (For example, Giovannini 2008b). Besides, international organizations and many researchers suggest that the economy of a given country may be assessed by means of different economic aggregate indicators such as the structure of GDP, sectional growth rate, national income, investment, employment, consumer price index (CPI), saving, exchange rate, money supply, and the like (For example, Abdul and Musharaf 2015b; World Bank; National Bureau of Statistics of China).

On the other hand, it says that GDP or GDP per capita is of significance in reflecting economy, but these have some limitations in expressing human wellbeing and environmental factors. In this context, United Nations Development Programme (2009) develops the human development quotient which measures a nation's achievement in three dimensions of human development: long and healthy life, knowledge, and decent standard of living. Some scholars suggest the Genuine Progress Indicator, which starts with the same personal consumption data as GDP, and it adjusts for factors such as income distribution, adds factors such as the value of household and volunteer work, and subtracts factors such as the costs of crime and pollution (For example, Daly and Cobb 1994; Talberth, et al. 2006). Another indicator is the Ecological Footprint Indicator which measures how much land and water area persons require to produce the resources and to absorb its wastes (Global Footprint Network 2009). Marks (2006) proposes the Happy Planet Index, which measures the ecological efficiency with which human wellbeing is delivered. As seen above, the limitations of various economic indicators have been pointed out in not representing the human wellbeing and environmental factors, but these points, also, may be one-sided in representing the SES.

It is noticeable that economic strength is regarded as competitiveness and thus, the latter can be assessed by proposal of various indicators. Typical indicator is the Global Competitiveness Index (GCI) published by World Economic Forum, which it provides a weighted average of over 100 different variables (ranging from socio-economic to demographic), where each variable is considered to reflect one aspect of competitiveness. Global Competitiveness Index (GCI) is based on 12 pillars of competitiveness, providing a comprehensive picture of the competitiveness landscape in countries around the world at all stages of development. The pillars are: institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, goods market efficiency, labour market efficiency, financial market development, technological readiness, market size, business sophistication, and innovation (World Economic Forum 2019). Indeed, it is certain that regarding the competitiveness as the economic strength is reasonable in making some indicators of competitiveness possible to represent the some aspects of economic strength. However, as seen from above theoretical consideration, competiveness is the concept closer to foreign economic strength, rather than internal strength of economy. Of course, it can say that two concepts are closely correlated; it is said that strong economic strength is an essential precondition for strong competitiveness.

Meanwhile, it is worth saying that many countries set different competitive indicators, as required by the advent of knowledge-based economy, to assess country-specific competitiveness. According to Dutta (2011), INSEAD (INStitut Européen d'ADministration des Affaires), a top-ranking international business school with campuses in Europe and Asia, produces the Global Innovation Index (GII), a composite index measuring the innovation potential and performance of economies around the world. The latest (2019) report includes 129 countries and provides not only the overall GII results but also scores and rankings for each of the 80 components included in the analysis (World Intellectual Property Organization 2019). From significance of innovation for knowledge-based economy, the GII has several components that focus directly on factors important to the knowledge economy—primary and secondary education, higher education, research and development, knowledge workers, knowledge creation, knowledge impact, and knowledge diffusion (DeVol et al. 2002). Knowledge Assessment Methodology (KAM) published by the World Bank is called the most inclusive methodology in comparing and assessing the level of KE according to countries (World Bank 2012a). Knowledge Assessment Methodology (KAM) involves four pillars of KE and assesses the level of KE of countries. The pillars include the

Economic Incentive and Institutional Regime, Education and Human Resources, Innovation System, and ICT (Information and Communication Technologies. The results of this assessment are presented through two basic indices, namely the Knowledge Index (KI) and the KE Index (KEI). Rim et al. (2019) establish the indicators characterizing the level of knowledge economy as (1) Research and Development (R&D) expenditure, (2) growth rate of invention and rationalization plans, (3) the degree of contribution by science and technology to economic growth and growth rate of application of inventions and patent, and 4) the proportion of knowledge-intensive industry in economic structure, and suggest the methodology for assessing the level of knowledge economy based on those indicators. Indicators used in assessing the level of knowledge economy may be applicable for assessing the SES, because the actual situation of economy considerably depends on technological level of economic foundation.

Next, international organizations and researchers have suggested the methods for assessing the level of economy or for evaluating and forecasting the economic growth according to countries. The simplest method is the one for assessing and comparing the economic performances according to countries by means of aggregate indicators such as GDP, GNP, and GNI, or those per capita. This method is often used by international organizations. However, this has limitations in assessing the SES due to demerits of abovementioned indicators. Also, simple and weighted average methods are widespread in the level of given economy. These methods are mostly used in assessing the competitiveness or level of knowledge economy. That is why above assessment must consider many factors affecting the levels of competitiveness or knowledge economy. Thus, these methods are acceptable for assessing the level of SES according to countries. Recently, applications of more complex methods are attempted for assessing or forecasting the economic growth, and these are welcomed due to ensuring the more correctness in economic calculation or forecasting. The typical methods are various statistical and econometrical approaches, which include the Principal Component Analysis (PCA), artificial intelligence approach, gene expression programming model approach and the like. Principal Component Analysis is a multivariate data analysis method, which is a technique used to decrease a large number of interdependent variables to a small number of correlated ones; these variables are referred to as principal components or factors (Jolliffe 2002). Taghizadech and Ahmadi (2019) conduct the statistical and econometrical analysis of knowledge-based economy indicators affecting economic growth in Iran by using the PCA approach and Tukey and ARDL bounds tests. They prove the independent convergence vector between knowledge and economic growth, indicating that there is a long-run relationship among knowledge-based economy components by using data related to GDP growth and knowledge-based economy indicators in Iran during 1993–2013. Also, Ahmadi et al. (2019) present a new hybrid algorithm for forecasting economic growth using indicators of knowledge-based economy. According to them, the algorithm consists of three steps, namely preprocessing, processing, and postprocessing. They suggest the applicability of various methods including PCA, multilayer perceptron (MLP), adaptive neuro-fuzzy inferences system, and gene expression programming (GEP) in each steps and explore the best indicators and model for predicting the economic growth. And comparing the gene expression programming (GEP) and ARDL bounds testing approaches, Ahmadi and Taghizadech (2019) find that GEP model is the best in forecasting the economic growth using knowledge-based economy indicators. Other than them, in the past studies, various methods such as correlation and regression analysis and Cobb–Douglas production function approach have been introduced in revealing the relations among economic variables and the impacts of factors affecting the result, or in predicting the economic results. Abovementioned methods are mostly of great significance

in forecasting the economic growth, or revealing the impacts of factors, but these have some limitations in assessing the SES. That is why SES assessment is related to assessing and comparing the level of SES as of certain time. Of course, these methods are of certain significance in selecting the major indicators suitable for SES assessment, or in synthetically assessing the level of SES. Therefore, in this context, with using the weighted average method, the method of defining the weights of indicators by econometric techniques can be applied in SES assessment.

Based on analysis of previous studies, authors clarify the essence and nature of SES in new viewpoint, set the indicators system for assessing the level of SES in line with its essence and nature, and suggest new methodology for assessing and comparing its level according to countries in next section and its subsections. In particular, authors use the analytic hierarchy process (AHP) and pair-comparison judgment techniques to select the indicators suitable for reflecting the level of SES and to determine the importance of them. After inspecting the accuracy of pair-comparison judgment, authors standardize the statistical data corresponding to selected indicators using the mean and standard deviation, sigmoid, and (0, 1) transformation techniques, and based on standardized values and weights of indicators, synthetically assess the level of SES of a given country using the weighted average method. Then, authors describe the applicability of suggested methodology by assumed data.

## 3 New Definition of SES and Its Assessment Methodology

### 3.1 New Understanding of SES

The clarification of the nature of SES should start with the aim of economic construction.

The aim of economic construction in any society is to satisfy the material and cultural need of people. Therefore, the nature of economic strength should be clarified from the standpoint of the satisfaction of the people's need. In this angle, economic strength can be said to be the capability to meet the need of people for material and cultural wealth by itself, regardless of external uncertain environment, and this capability is expressed by economic foundation.

What is important here is to clarify what character economic strength takes on, because it is a measure to assess economic strength. From the point of view of this direction of economic construction and previous studies, authors focus on following aspects for clarifying the character of SES.

First, SES can be characterized by self-reliance of economy.

Self-reliant economic strength refers to versatile and synthetic economic strength to domestically satisfy the national demand for material means.

Versatile economic foundation is what consists of production sectors which can meet all the material demands arising in economic construction and people's livelihood improvement; synthetic economic foundation means what includes the whole course of social production ranging from raw materials exploitation to finished goods production and all the organically-connected links of reproduction cycle.

Versatility and synthesis expressing the self-reliance of economic strength are different in contents but closely connected. Versatile economic foundation is prerequisite for synthesis and versatility results from synthesis. Without versatility, synthesis cannot be achieved; without the achievement of versatility, synthesis cannot display its might. After all,

building up the economic foundation which can meet the material demand arising in economic construction and people's livelihood improvement by domestic production means ensuring the versatility and synthesis of economic structure. In the past, too, many authors emphasized the self-reliance. Typically, Godfrey (2008) defines that economic self-reliance is the individual's ability to acquire and hold resources of economy in excess of their basic needs. Analyzing the relation between self-reliance and economic interdependence in China, Tisdell (2013) concludes that the achievement of self-reliance is an important Chinese goal, and with reform and openness policy, China has become more dependent for its economic welfare on international trade, but its dependence is much less than that of many other countries.

Recently, facing with the rapidly changing world situation and various kinds of challenges, many countries stress the importance of self-reliance. In particular, Democratic People's Republic of Korea (DPRK) strives to construct the self-reliant and multifaceted economy by itself, countervailing the economic sanction (Xinxuanet.com 2019). In China, too, President Xi Jinping underlined the importance of self-reliance in food security, the real economy and manufacturing as the country faces rising unilateralism and trade protectionism internationally (Chinadaily.com 2018). This shows that self-reliance is the most significant character of SES concerned to destiny of a country. As seen, the self-reliance reflects the degree of standing on one's own feet with no dependence on other countries.

Second, SES can be characterized by ultramodernness of economy. The essence of the economic strength relying on cutting-edge science and technology is that it is technologically based on cutting-edge technology and centers on knowledge-based industry, hi-tech industry.

From the viewpoint of economic foundation, the economic strength with cutting-edge technology as its technological basis means that it is equipped with cutting-edge technology.

The scientific and technological basis of a powerful country with knowledge-based economy is not general science and technology but cutting-edge technology such as IT, nano technology, bioengineering, etc. Cutting-edge technology is not an individual technology of individual studies but the most advanced, synthetic and industrial-value technology in the aspect of science, technology and skill. Such cutting-edge technology is the technological basis of a powerful country with knowledge-based economy.

When economic strength is considered from the point of view of economic structure, the economic strength centering on knowledge-based industry, hi-tech industry is what includes it as a pillar industry. The industry representing the era of knowledge-based economy is knowledge-based industry, hi-tech industry. In this industry, production is carried out by means of knowledge resources and accordingly, the products are all intellectual. This is the indispensable result from the fact that knowledge-based industry, hi-tech industry develops on knowledge resources. In a powerful country with knowledge-based economy, there are knowledge-based industry, hi-tech industry, as well as the existing industries. Therefore, forming the economic structure of the powerful country does not require the lockout or disposal of the existing industries. The important thing is, transforming those existing industries into the industry which operates on knowledge.

Knowledge-based industry, hi-tech industry, is a newly-emerging industry as compared with the existing ones. A powerful country with knowledge-based economy is an economic giant where that knowledge-based, hi-tech industry plays a leading role. From importance of knowledge-based economy, as seen from Sect. 2, many studies related to it have been conducted until now. This shows that SES in the era of knowledge-based economy reaches the highest level of technology, IT level, from the viewpoint of economic foundation and is

equipped with the self-reliant economic structure centering on knowledge-based industry, hi-tech industry.

Lastly, SES can be the economic strength which can satisfy the need of people for bountiful and cultured life.

Self-reliance character and cutting-edge science and technology characterize SES in the aspect of creating material wealth; substantially satisfying the need of people for bountiful and cultured life characterizes SES in the aspect of consuming material wealth. Only when the nature of SES is clarified from the viewpoint of people's livelihood improvement as well as the development level of production means, can it say that the nature of SES has rightly been understood.

The final aim of developing production so as to strengthen economic strength and increasing national income on the nation-wide scale is to provide people with better living conditions. If material wealth is not consumed for the promotion of people's wellbeing, although much of it has been created, it cannot be said to characterize an economic strength in a genuine sense.

Such understanding of SES nature serves a theoretical basis for analyzing and assessing it statistically.

### 3.2 System of Indicators for Assessing SES

In order to assess SES, it is necessary to set a right system of statistical indicators, because the assessment is made on the basis of those indicators.

The indicators for assessing SES may be set, considering several aspects according to the aim of assessing SES and its content. The aim is to assess the state and level of SES correctly and take measures to strengthen it. SES is a material strength, in other words, one's own strong economic foundation and cannot be assessed only with a single indicator. This is because the preconditions for the consolidation of economic foundation, its potentiality, its substantial merits and the factors acting on its consolidation are all varied and so, SES should be assessed in different aspects according to assessment aim.

Therefore, statistical indicators can be set in different aspects according to the assessment aim, such as the resources and their use for the development of SES, economic foundation and its structure, its substantial merits and level, and the factors; they can also be set in the absolute and comparative aspects and/or physical and value aspects.

First, statistical indicators can be set to reflect the state and use of resources of a given country for the development of its SES.

A country's SES, especially its economic foundation is determined by the state of resources and their use. The self-reliant economic structure of a given country is mainly determined by its natural resources. This is because natural resources and their use determine whether the economic structure is versatile and synthetic and how much that country relies on its own resources.

On the other hand, the economic structure relying on cutting-edge science and technology is determined by human resources, especially scientific and technological forces and knowledge resources, which enable hi-tech industries to become pillar industries in the economic structure and all economic sectors to be equipped with advanced technology. Therefore, it says that the indicators reflecting human, material and knowledge resources and their use are as important as to be included in a system of indicators for assessing SES.

These indicators can be subdivided into the indicators reflecting their volume, composition and use, according to the assessment aim.

Second, statistical indicators can be set to reflect the existing state and level of economic foundation, the entity of SES.

These indicators are essential in a system of indicators, because the state of natural resources and their use act on laying economic foundation but they themselves cannot reflect SES, that is, the state of natural resources cannot determine SES by themselves. SES is expressed directly by how much it meets varied needs for product and this requires that economic foundation should be assessed in its potential and actual aspects. Therefore, indicators reflecting the state and level of economic strength can be classified into potential and actual.

According to assessment aim, indicators showing the potential level of SES can be divided into the indicators showing the size of economic foundation itself such as production capacity, fixed assets, etc. and various indicators showing the structural level of economic foundation such as versatility, synthesis, self-reliance and ultramodernness, etc. Versatility, synthesis, self-reliance and ultramodernness, etc. can be concretized into coefficient of sectional structure, ratio of inter-sectional or intra-sectional components, ratio in production volume between initial and final stages, coefficient of satisfaction of the need for product, proportion of hi-tech industries, degree of equipment with hi-tech technology, and so on.

The indicator reflecting the actual level of SES can be the volume of production, that is, the strength displayed actually by productive capacity constituting economic foundation. The volume of production can be set as total output value or can be subdivided into the volume of production according to sections or important physical indicators. And according to the assessment aim of production and consumption, the volume of production can be set as an indicator for major production means, and the volume of consumption—as an indicator for major consumer goods.

Third, statistical indicators can be set to measure the state and level of economic foundation in physical or value aspects.

While the assessment of SES in the physical aspect is of significance in reflecting the actual size of economic strength more directly, the assessment of SES in the value aspect is necessary for reflecting the actual size of economic strength generally. What is more important here is physical indicators, because the need for product itself is expressed in a physical way.

Typical physical indicators are production capacity, and the volumes of production and consumption according to major physical indices. It can say that the indicators showing the state and level of economic strength are significant in that they themselves reflect the need of people physically, but they have some limitations in reflecting the state and level of economic strength as its whole size. Therefore, indicators can be set to show the state and level of economic strength in terms of value. Typical indicators are the total sum of fixed assets showing the total size of economic strength potentially, GDP showing the whole of actual size of economic strength, national income, etc.

Fourth, statistical indicators can be set to show the per-head level of economic strength which is expressed by the comparison of the absolute size of economic strength with population.

It can say that indicators such as GDP and the volumes of production and consumption according to major physical indicators are significant in showing the absolute size of economic strength of a given country itself and give the possibility of making aggregate, dynamic analysis and assessment, but they have some limitations in showing SES actually. This is because economic strength itself is expressed by how much the material need is satisfied and it is impossible to say that SES is strong if per-head proportion of material

wealth is small although a country is abundant in it. In other words, one can understand the actual level of SES directly when it is assessed not by its absolute size but by per-head proportion of population. Therefore, it is reasonable to set per-head size of economic strength as the indicator for assessing SES.

The indicators showing per-head level of SES can be per-head GDP, per-head sum of fixed assets, per-head national income, per-head real income, per-head volume of production or consumption according to important physical indicators, per-head size of resources, etc.

Fifth, the analyses of the factors which affect the strengthening of SES can be set as one of statistical indicators.

These factor-analyzing indicators must be set because assessing SES is aimed not to analyze or assess SES itself but to take measures to develop it further. Strengthening SES affects other social phenomena and vice versa. Therefore, only when such influence is rightly understood, can it be possible to take timely measures to develop SES.

Typical indicators can be the level of resources development, capital investment, the development of science and technology, the development of education, etc. and accordingly, various indicators can be set according to assessment aim so as to characterize the effect of the factors on the development of SES. On the other hand, the development of SES influences on people's living and other fields, and thus, this influence can be analyzed and assessed by using various indicators according to assessment aim.

The following is a table of statistical indicators for the assessment of SES (See Table 1).

Besides, statistical indicators for assessing SES may include various dynamic indicators characterizing its change and development.

The indicators so far mentioned above enable us to analyze and assess SES in various aspects according to assessment aim, and to take measures to strengthen it further.

### 3.3 Method for Assessing SES

As seen from Sect. 2, various methodologies have been suggested to assess economy or competitiveness.

In this subsection, authors set a few indicators reflecting economic strength and on this basis, produce a methodology for assessing economic strength, putting main stress on weighted average method.

In order to assess SES, it is necessary to assess individual indicators reflecting the level of SES. In addition, it is also important to assess those individual indicators synthetically by generalizing them. This is because individual indicators reflect nothing but individual aspects of SES and so, have some limitation in producing basic data necessary for setting the goal to strengthen economic strength and in taking synthetic measures for its accomplishment. In other words, among two individual indicators, one indicator has reached the world or high level, while the other is in low level. In this case, a certain standard or indicator which can characterize SES synthetically is needed to take measures purposefully for its improvement.

And the aim of characterizing SES synthetically lies in assessing and comparing the level of economic strength of a given region or country.

If the values of individual indicators differ from each other, it is necessary to get a methodology so as to compare and assess the level of economic strength of a region or a country.

**Table 1** System of statistical indicators for the assessment of SES. *Source*: Own study

| | | | |
|---|---|---|---|
| System of statistical indicators | Indicators reflecting the state of resources and its use of a given country | Volume of human, material and knowledge resources | |
| | | Component of human, material and knowledge resources | |
| | | Use of human, material and knowledge resources | |
| | Indicators reflecting the potential level of SES | General state of economic foundation | |
| | | Level of self-reliance | Particulars |
| | | Ultramodernness | Particulars |
| | Indicators reflecting the actual level of SES | Products | Volume of production according to section, major physical indices |
| | | Money | GDP, national income |
| | | Actual per-head level of economic strength | GDP, national income, real income, the volume of production and consumption according to section, major physical indicators |
| | Indicators of factors affecting on the strengthening of SES | Capital investment | |
| | | Development of science and technology | |
| | | Development of education | |
| | Synthetic assessment of the level of general assessment | | |

Suppose that in a country or region, while per-head total output value is in low level, per-head size of fixed assets is in middle level, scientists and technologist occupy a high proportion in total population. In this case, if we want to assess the level of economic strength of that country synthetically as compared with other country or region, it is necessary to assess by means of the combination of different indicators showing its economic strength.

There are several methods for synthetically assessing economic strength by means of the combination of different indicators.

The first method is that if there are various indicators showing economic strength, calculation is made on condition that each indicator has the same weight in showing the level of economic strength.

Typical indicators can be individual indicators such as per-capita total output value, the proportion occupied by hi-tech industries in total output value, coefficient of satisfaction of the need for product, domesticalization ratio, contribution by science and technology, degree of equipment with advanced technology, labour productivity, degree of per-head equipment with fixed assets, number of scientists and technologists per 10 000 of population. It is assumed that the above indicators have the same weight for the first method.

Suppose that calculation values have been obtained for 9 indicators collected in 10 regions or countries (See Table 2).

Regions or countries are graded according to the numerical values of 10 indicators. The grades for each indicator are added up. The region or country which gets the lowest value can be assessed as having the highest level of economic strength (See Table 3).

The second method is that if there are various indicators showing economic strength, calculation is made on condition that each indicator has different weights in showing the level of economic strength.

To apply this method, two problems have to be solved. One is how to determine weights and the other is to standardize measurement units because they differ from indicator to indicator.

Analytic hierarchy process (AHP) can be used to determine which indicator has the largest weight and which one has the smallest weight.

To use this method, first, pair-comparison judgment is made for individual indicators showing the level of economic strength. To make calculation simple, authors use only 5 individual indicators such as per-capita total output value, degree of equipment with hi-tech machinery, domesticalization ratio, degree of equipment with fixed assets, number of scientists and technologist per 100 000 of population.

Next, the pair-comparison judgment for these indicators is conducted. In order to ensure the accuracy of competitiveness assessment, authors calculate the values of pair-comparison judgment by applying 18 scale methods including the 1 ~ 9, 9/9 ~ 9/1, 0/10 ~ 18/2 scales, etc. to pair-comparison judgment, and then select the scale method which the value of pair-comparison judgment is minimum and determine the matrix of pair-comparison judgment.

There are linear and nonlinear judgment in pair-comparison judgment. Authors use nonlinear judgment.

Let us assume the results of pair-comparison judgment for five assessment indicators as follows (See Table 4).

Next, numerical values of different standards are made correspondent to the results of subjective pair-comparison judgment by means of language. The following is the results obtained by making 1 ~ 9 standards correspondent to assessment language to construct pair-comparison judgment matrix (See Table 5). And calculation is made to inspect the

**Table 2** Calculation values for 10 indicators. *Source*: Own elaboration

| Region or country indicators | a | b | c | d | e | f | g | h | i | j |
|---|---|---|---|---|---|---|---|---|---|---|
| Per-capita total output value (100 000 USD) | 23 | 45 | 46 | 28 | 37 | 39 | 29 | 38 | 30 | 41 |
| Proportion occupied by hi-tech industries in total output value (%) | 30 | 28 | 40 | 29 | 52 | 49 | 37 | 35 | 38 | 48 |
| Coefficient of satisfaction of the need for product (%) | 60 | 38 | 49 | 27 | 59 | 50 | 39 | 57 | 39 | 43 |
| Domesticalization ratio (%)[a] | 30 | 20 | 40 | 59 | 60 | 30 | 47 | 49 | 61 | 39 |
| Contribution by science and technology (%) | 29 | 30 | 26 | 40 | 32 | 41 | 38 | 41 | 39 | 46 |
| Degree of equipment with advanced technology (USD) | 50 | 80 | 49 | 65 | 75 | 73 | 57 | 68 | 72 | 49 |
| Labour productivity (USD) | 58 | 54 | 48 | 47 | 43 | 56 | 60 | 72 | 67 | 61 |
| Per-head level of equipment of fixed assets (USD) | 78 | 65 | 63 | 43 | 72 | 61 | 41 | 52 | 71 | 51 |
| Number of scientists and technologists per 10 000 of population (person) | 49 | 89 | 35 | 36 | 47 | 57 | 63 | 59 | 62 | 52 |

[a]Proportion of domestic production in total production

**Table 3** Ranking by assessment. *Source*: Own calculation

| Region or country indicator | a | b | c | d | e | f | g | h | i | j |
|---|---|---|---|---|---|---|---|---|---|---|
| Per-capita total output value (100 000 USD) | 10 | 2 | 1 | 9 | 5 | 4 | 8 | 6 | 7 | 3 |
| Proportion occupied by hi-tech industries in total output value (%) | 8 | 10 | 4 | 9 | 1 | 2 | 6 | 7 | 5 | 3 |
| Coefficient of satisfaction of the need for product (%) | 1 | 9 | 5 | 10 | 2 | 4 | 7 | 3 | 7 | 6 |
| Domesticalization ratio (%) | 8 | 10 | 6 | 3 | 2 | 8 | 5 | 4 | 1 | 7 |
| Contribution by science and technology (%) | 9 | 8 | 10 | 4 | 7 | 2 | 6 | 2 | 5 | 1 |
| Degree of equipment with hi-tech machinery (USD) | 8 | 1 | 9 | 6 | 2 | 3 | 7 | 5 | 4 | 9 |
| Labour productivity (USD) | 5 | 7 | 8 | 9 | 10 | 6 | 4 | 1 | 2 | 3 |
| PER-head level of equipment with fixed assets (USD) | 1 | 4 | 5 | 9 | 2 | 6 | 10 | 7 | 3 | 8 |
| NUMBER of scientists and technologists per 10 000 of population (person) | 7 | 1 | 10 | 9 | 8 | 5 | 2 | 4 | 3 | 6 |
| Total | 57 | 52 | 58 | 68 | 39 | 40 | 55 | 39 | 37 | 46 |
| Ranking | 7 | 5 | 8 | 9 | 2 | 3 | 6 | 2 | 1 | 4 |

**Table 4** Results of pair-comparison judgment of 5 indicators. *Source*: Own elaboration

| Assessment indicator 1 | Assessment indicator 2 | Assessment language |
|---|---|---|
| Per-head total output value | Degree of equipment with ultramodern machinery | A little important |
| Per-head total output value | Degree of equipment with fixed assets | A little important |
| Per-head total output value | Domesticalization ratio | A little important |
| Per-head total output value | Number of scientist and technologists per 100 000 of population | Equal |
| Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | A little important |
| Degree of equipment with ultramodern machinery | Domesticalization ratio | A little important |
| Number of scientist and technologists per 100 000 of population | Degree of equipment with ultramodern machinery | A little important |
| Degree of equipment with fixed assets | Domesticalization ratio | Equal |
| Number of scientists and technologists per 100 000 of population | degree of equipment with fixed assets | A little important |
| Number of scientists and technologists per 100 000 of population | Domesticalization ratio | A little important |

**Table 5** Pair-comparison judgment matrix. *Source*: Own elaboration

| Assessment indicators | Per-head total output value | Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | Domesticalization ratio | Number of scientists and technologists per 100 000 of population |
|---|---|---|---|---|---|
| Per-head total output value | 1 | 3 | 3 | 3 | 1 |
| Degree of equipment with hi-tech machinery | 1/3 | 1 | 3 | 3 | 1/3 |
| Degree of equipment with fixed assets | 1/3 | 1/3 | 1 | 1 | 1/3 |
| Domesticalization ratio | 1/3 | 1/3 | 1 | 1 | 1/3 |
| Number of scientists and technologists per 100 000 of population | 1 | 3 | 3 | 3 | 1 |

accuracy of pair-comparison judgment. The following is the calculation of the accuracy of the above pair-comparison judgment matrix.

$$C_I = \frac{\lambda_{\max} - n}{2a} = 0.0489$$

$$C_p = \sqrt{\frac{1}{n^3}\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n}\left(\frac{a_{ik}a_{kj}}{a_{ij}} - 1\right)^2} = 0.6532$$

$$C_q = \sqrt{\frac{1}{n^3}\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n}\left(Ln\frac{a_{ik}a_{kj}}{a_{ij}}\right)^2} = 0.4814$$

where $\lambda_{max}$: maximum eigenvalue of matrix of pair-comparison judgment, $n$: degree number of matrix, $a_{ij}$: element of matrix.

Next, authors construct the pair-comparison judgment matrix according to the scale relevant to the lowest value among the values expressing the accuracy of pair-comparison judgment. The following is the results obtained by assessing the accuracy of pair-comparison judgment matrix after constructing it by making the numerical values of various possible scale to the assessment language in the above table (See Table 6).

One can see from the above table that for those three assessment indicators, the scale whose accuracy value is the smallest is 9/9 ~ 9/1. Therefore, pair-comparison judgment matrix obtained by the correspondence of 9/9 ~ 9/1 scale to the assessment language is as follows (See Table 7).

And eigenvector corresponding to maximum eigenvalue of pair-comparison judgment matrix is calculated and standardized. The result is taken as the weight for each indicator (See Table 8).

**Table 6** Result obtained by assessing the accuracy of pair-comparison judgment matrix. *Source*: Permitted by Myong-Hun et al. (2019a)

| Title of scale | 1 | 2 | 3 |
|---|---|---|---|
| 1 ~ 9 scale | 0.0489 | 0.6532 | 0.4814 |
| 9/9 ~ 9/1 scale | 0.0025 | 0.1121 | 0.1101 |
| 0/10 ~ 18/2 scale | 0.0066 | 0.1862 | 0.1777 |
| 11/11 ~ 27/3 scale | 0.0105 | 0.2409 | 0.2238 |
| 2/12 ~ 36/4 scale | 0.0139 | 0.2836 | 0.2576 |
| 3/13 ~ 45/5 scale | 0.0168 | 0.3180 | 0.2833 |
| 4/14 ~ 54/6 scale | 0.0193 | 0.3464 | 0.3037 |
| 5/15 ~ 63/7 scale | 0.0215 | 0.3703 | 0.3203 |
| 6/16 ~ 72/8 scale | 0.0234 | 0.3908 | 0.3340 |
| 7/17 ~ 81/9 scale | 0.0250 | 0.4084 | 0.3455 |
| 19/19 ~ 27/3 scale | 0.0045 | 0.1523 | 0.1474 |
| 28/28 ~ 36/4 scale | 0.0039 | 0.1397 | 0.1359 |
| 37/37 ~ 45/5 scale | 0.0035 | 0.1331 | 0.1298 |
| 46/46 ~ 54/6 scale | 0.0033 | 0.1291 | 0.1261 |
| 55/55 ~ 63/7 scale | 0.0032 | 0.1264 | 0.1235 |
| 64/64 ~ 72/8 scale | 0.0031 | 0.1244 | 0.1217 |
| 73/73 ~ 81/9 scale | 0.0030 | 0.1229 | 0.1203 |
| 82/82 ~ 90/10 scale | 0.0030 | 0.1217 | 0.1192 |

**Table 7** Pair-comparison judgment matrix obtained by the correspondence of 9/9 ~ 9/1 standard to the assessment language. *Source*: Permitted by Myong-Hun et al. (2019b)

| Assessment indicator | Per-head total output value | Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | Domesticalization ratio | Number of scientists, technologists per 100 000 of population |
|---|---|---|---|---|---|
| Per-head total output value | 1 | 9/7 | 9/7 | 9/7 | 1 |
| Degree of equipment with hi-tech machinery | 9/7 | 1 | 9/7 | 9/7 | 9/7 |
| Degree of equipment with fixed assets | 9/7 | 9/7 | 1 | 1 | 9/7 |
| Domesticalization ratio | 9/7 | 9/7 | 1 | 1 | 9/7 |
| Number of scientists and technologists per 100,000 of population | 1 | 9/7 | 9/7 | 9/7 | 1 |

**Table 8** Weight of assessment indicator. *Source*: Own calculation

| Assessment indicator | Per-head total output value | Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | Domesticalization ratio | Per- head total output value | Geometric mean value | Weight of assessment indicator |
|---|---|---|---|---|---|---|---|
| Per-head total output value | 1 | 9/7 | 9/7 | 9/7 | 1 | 1.16 | 0.23045 |
| Degree of equipment with hi-tec machinery | 9/7 | 1 | 9/7 | 9/7 | 9/7 | 1 | 0.19819 |
| Degree of equipment with fixed assets | 9/7 | 9/7 | 1 | 1 | 9/7 | 0.86 | 0.17045 |
| Domesticalization ratio | 9/7 | 9/7 | 1 | 1 | 9/7 | 0.86 | 0.17045 |
| Number of scientists and technologists per 100 000 of population | 1 | 9/7 | 9/7 | 9/7 | 1 | 1.16 | 0.23045 |

The weight calculated in analytic hierarchy process shows that the indicators of per-head total output value and the number of scientists and technologists per 100 000 of population get 23%, the indicator of degree of equipment with hi-tech machinery—about 20%, the indicators of degree of equipment with fixed assets and domesticalization ratio—about 17%, respectively.

Another problem to be solved in assessing the level of economic strength is how to transform statistical data.

In the case where one wants to make synthetic assessment by combining a lot of indicators, it is necessary to transform statistical data into standard ones in a certain method, because the units and scales to measure the data collected for synthetic comparison and assessment vary from each other. Comparison and assessment cannot be made in different measurement units. And if comparison and assessment is made in varied measurement scales, accuracy is not guaranteed. Therefore, the transformation of given data is one of the primary and indispensable process for the synthetic assessment on social phenomena.

The generally applied way of transforming statistical data is (0, 1) way, which is to reduce given data into the value between 0 and 1.

There are various (0, 1) transformation ways.

$$Y_{ik} = \frac{X_{ik} - X_k^{min}}{X_k^{max} - X_k^{min}} \tag{1}$$

$X_{ik}$: data of jth object on kth assessment indicator, $X_k^{max}$: maximum value of the data on kth assessment indicator, $X_k^{min}$: minimum value of the data on kth assessment indicator.

$$Y_{ik} = \frac{X_{ik}}{X_k^{max}} \tag{2}$$

These two ways are linear, and thus they are characterized by the fact that the comparative difference before transformation is reserved after transformation. The domain of transformation values in formula (1) is [0, 1] and that of formula (2) – (0, 1].

The use of linear-transformation way has some absurdity and so, various nonlinear ways are used at the same time.

$$Y_{ik} = \left( \frac{X_{ik} - X_k^{min}}{X_k^{max} - X_k^{min}} \right)^2 \tag{3}$$

$$Y_{ik} = \sqrt{\frac{X_{ik} - X_k^{min}}{X_k^{max} - X_k^{min}}} \tag{4}$$

The value domains of all the nonlinear ways are [0, 1].

It is reasonable to use the above linear and nonlinear ways on condition that the data of population is given. If one can get watertight data on all the assessment objects of population, he/she can use the above ways. But the data used in practice are not on population but sample. Therefore, the domain of transformation values should not be [0, 1] but (0, 1).

The transformation way explained below is a new way of transforming statistical data, which can be used in economic practice and also fall in with scientific contents.

This transformation can take place in the way of obtaining standardized transformation through several transformation processes—transformation by mean value and standard deviation, sigmoid transformation and (0, 1) transformation.

Transformation by mean value and standard deviation is made possible by using the following formula.

$$Z_{ik} = \frac{X_{ik} - \overline{X_k}}{\sigma_k} \left( i = \overline{1, n}, k = \overline{1, m} \right) \tag{5}$$

where $n$: number of regions or countries assessed, $m$: number of assessment indicators, $X_{ik}$: data on ith region or country on kth assessment indicator, $\overline{X_k}$: mean value of kth assessment indicator, $\sigma_k$: standard deviation of kth assessment.

Sigmoid transformation uses the following formula.

$$S_{ik} = \frac{\exp\left(Z_{ik}\right) - \exp\left(-Z_{ik}\right)}{\exp\left(Z_{ik}\right) + \exp\left(-Z_{ik}\right)} \left( i = \overline{1, n}, k = \overline{1, m} \right) \tag{6}$$

(0, 1) transformation is made as follows.

$$a_{ik} = \frac{S_{ik} + 1}{2} \left( i = \overline{1, n}, k = \overline{1, m} \right) \tag{7}$$

The domain of transformation values by the above formula is (0, 1) and thus, the greater the numerical values of the data, the closer to 1 and the smaller, the closer to 0.

The data obtained through these transformation ways are the standardized data which can be used for synthetic assessment and comparison of the level of economic strength. On the basis of these data, comparison and assessment is made synthetically.

Once weight has been determined, one can compare and assess the level of economic strength as follows by applying weight mean method. And on condition that the given data have been transformed into the values between 0 and 1 through the transformation by mean value and standard deviation, sigmoid transformation and (0,1) transformation, the following formula can be used to compare and assess the level of economic strength of each region or each country.

$$P_i = \sum_{k=1}^{m} W_k A_k \tag{8}$$

where $m$: number of assessment indicators, $n$: number of regions or countries, $W_k$: weight of assessment indicator, $A_k$: value of (0, 1) transformation of jth region or country on kth indicator, $P_i$: assessment value on the level of economic strength.

### 3.4 Practical Application of Method for Assessing SES

To describe the practical application of method suggested above, authors make calculation on SES assessment by using above formulas and assumed data concerned to indicators selected in subsection 3.3. Thus, authors use the weights of indicators from Table 8, on condition that pair-comparison judgment has already been conducted with respect to indicators selected. Then, authors start with standardization of data. To this end, it is necessary to transform data into comparable one.

The following is the example of transformation process.

Suppose that authors have the data concerning per-head total output value, degree of equipment with hi-tech machinery, degree of equipment with fixed assets, domesticalization ratio and number of scientists and technologists per 100 000 of population which are collected on 11 regions or countries (See Table 9).

According to the above data, transformation has been made by means of mean value and standard deviation as in formula (5). As a result, per-head total output value of the first region or country is,

$$Z_{ik} = \frac{X_{ik} - \overline{X_k}}{\sigma_k} = (740 - 361.18)/244.7 = 1.548$$

If transformation is made for each region or country in the same way, the results will be as follows (See Table 10).

Based on formula (6), per-head total output value of first region or country calculated by sigmoid transformation is,

$$S_{ik} = \frac{\exp(Z_{ik}) - \exp(-Z_{ik})}{\exp(Z_{ik}) + \exp(-Z_{ik})} = \frac{\exp(1.548) - \exp(-1.548)}{\exp(1.548) + \exp(-1.548)} = 0.913$$

If sigmoid transformation is made for each indicator of each region or country in the same way, the results will be as follows (See Table 11).

For sigmoid transformation data, (0, 1) transformation is made by means of formula (7) and the result is as follows.

Per-head total output value of the first region or country is,

$$a_{ik} = \frac{S_{ik} + 1}{2} = \frac{0.913 + 1}{2} = 0.957$$

If (0, 1) transformation is made for each indicator in the same way, the results will be as follows (See Table 12).

If one assesses the level of economic strength of the first region or country on the basis of the given data, using formula (8), the result will be,

$$P_1 = 0.23045 \times 0.957 + 0.19819 \times 0.334 + 0.17045 \times 0.895 + 0.17045 \times 0.214 + 0.23045 \times 0.985$$

In this way, one can assess and compare the level of economic strength of all the regions or countries, and the results are as follows (See Table 13).

The data given in Table 13 showing the general assessment of the development level of economic strength according to region or country can contribute to taking measures to strengthen economic strength further.

## 4 Results and Discussions

In order to strengthen SES, it is necessary to set the targets and put forward the work for its realization purposefully. To this end, it is required to have a right understanding of SES and make an accurate assessment of its reality.

From limitations of previous studies and consideration of economic instability owing to uncertain external environment, this study was motivated by following arguments; a) what is the SES? b) how can the system of indicators for reflecting the real situation of

**Table 9** Data on 5 indicators. *Source*: Own elaboration

| Region or country | Per-head total output value | Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | Domesticalization ratio | Number of scientists and technologists per 100 000 of population |
|---|---|---|---|---|---|
| 1 | 740 | 260.99 | 483 | 23 | 83 |
| 2 | 60 | 989.71 | 135 | 24 | 43 |
| 3 | 120 | 274.39 | 227 | 14 | 27 |
| 4 | 286 | 167.11 | 262 | 54 | 62 |
| 5 | 390 | 174.87 | 327 | 43 | 37 |
| 6 | 487 | 929.94 | 419 | 61 | 19 |
| 7 | 189 | 230.21 | 143 | 84 | 43 |
| 8 | 97 | 154.95 | 164 | 33 | 47 |
| 9 | 786 | 450.21 | 615 | 12 | 38 |
| 10 | 427 | 260.04 | 329 | 16 | 29 |
| 11 | 389 | 137.41 | 409 | 55 | 62 |
| Mean | 361.18 | 366.35 | 319.36 | 38.09 | 44.55 |
| SD | 244.67 | 305.96 | 152.76 | 23.23 | 18.44 |

**Table 10** Transformation by mean value and SD. *Source*: Own calculation

| Region or country | Per-head total output value | Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | Domesticalization ratio | Number of scientists and technologists per 100 000 of population |
|---|---|---|---|---|---|
| 1 | 1.548 | −0.344 | 1.071 | −0.650 | 2.085 |
| 2 | −1.231 | 2.037 | −1.207 | −0.607 | −0.084 |
| 3 | −0.986 | −0.301 | −0.605 | −1.037 | −0.951 |
| 4 | −0.307 | −0.651 | −0.376 | 0.685 | 0.947 |
| 5 | 0.118 | −0.626 | 0.050 | 0.211 | −0.409 |
| 6 | 0.514 | 1.842 | 0.652 | 0.986 | −1.385 |
| 7 | −0.704 | −0.445 | −1.115 | 1.976 | −0.084 |
| 8 | −1.072 | −0.691 | −1.017 | −0.219 | 0.133 |
| 9 | 1.736 | 0.274 | 1.935 | −1.123 | −0.355 |
| 10 | 0.269 | −0.347 | 0.063 | −0.951 | −0.843 |
| 11 | 0.114 | −0.748 | 0.587 | 0.728 | 0.947 |

**Table 11** Sigmoid transformation data. *Source*: Own calculation

| Region or country | Per-head total output value | Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | Domesticalization ratio | Number of scientists and technologists per 100 000 of population |
|---|---|---|---|---|---|
| 1 | 0.913 | 0.331 | 0.790 | −0.571 | 0.970 |
| 2 | −0.843 | 0.967 | −0.836 | −0.542 | −0.084 |
| 3 | −0.756 | −0.292 | −0.540 | −0.777 | −0.740 |
| 4 | −0.298 | −0.572 | −0.359 | 0.595 | 0.738 |
| 5 | 0.117 | −0.555 | 0.050 | 0.208 | −0.388 |
| 6 | 0.473 | 0.951 | 0.573 | 0.756 | −0.882 |
| 7 | −0.607 | −0.418 | −0.819 | 0.962 | −0.084 |
| 8 | −0.790 | −0.599 | −0.769 | −0.216 | 0.132 |
| 9 | 0.940 | 0.267 | 0/959 | −0.809 | −0.341 |
| 10 | 0.263 | −0.334 | 0.063 | −0.740 | −0.687 |
| 11 | 0.113 | −0.634 | 0.528 | 0.622 | 0.738 |

given economy be set? and c) how can the SES be assessed? Therefore, this paper is aimed to clarify the nature of SES from new perspective, set a new system of indicators for its assessment and on this basis, produce the methodology for assessing the economic strength synthetically.

For the purpose of study, first, we have investigated previous studies in three ways; a) theoretical consideration of economy and competitiveness related to economic strength, b) the indicators and methods related to assessment of economy or competitiveness of a given country, and c) methods for assessing the level of economy or competitiveness and for predicting or forecasting the economic growth considering the effects of various factors. As a results of investigation, we have recognized that so far, there have been a few studies on economic strength, the economy or competitiveness of a given country has been assessed by on the one hand, using per-capita GDP, national income and various indicators

**Table 12** (0, 1) transformation data. *Source*: Own calculation

| Region or country | Per-head total output value | Degree of equipment with hi-tech machinery | Degree of equipment with fixed assets | Domesticalization ratio | Number of scientists and technologists per 100 000 of population |
|---|---|---|---|---|---|
| 1 | 0.957 | 0.334 | 0.895 | 0.214 | 0.985 |
| 2 | 0.079 | 0.983 | 0.082 | 0.229 | 0.458 |
| 3 | 0.122 | 0.354 | 0.230 | 0.112 | 0.130 |
| 4 | 0.351 | 0.214 | 0.321 | 0.797 | 0.869 |
| 5 | 0.559 | 0.222 | 0.525 | 0.604 | 0.306 |
| 6 | 0.737 | 0.975 | 0.787 | 0.878 | 0.059 |
| 7 | 0.197 | 0.291 | 0.090 | 0.981 | 0.458 |
| 8 | 0.105 | 0.201 | 0.116 | 0.392 | 0.566 |
| 9 | 0.970 | 0.634 | 0.980 | 0.096 | 0.330 |
| 10 | 0.631 | 0.333 | 0.531 | 0.130 | 0.156 |
| 11 | 0.557 | 0.183 | 0.764 | 0.811 | 0.869 |

**Table 13** Assessment of the level of economic strength of each region or country. *Source*: Own calculation

| Region or country | Assessment value | Ranking |
|---|---|---|
| 1 | 0.703 | 1 |
| 2 | 0.372 | 8 |
| 3 | 0.186 | 11 |
| 4 | 0.514 | 5 |
| 5 | 0.436 | 6 |
| 6 | 0.660 | 2 |
| 7 | 0.391 | 7 |
| 8 | 0.281 | 10 |
| 9 | 0.608 | 4 |
| 10 | 0.360 | 9 |
| 11 | 0.633 | 3 |

of economic aggregates, and on the other hand, using a variety of indicators reflecting the qualitative aspect of a given economy, and there have been attempts to assess the competitiveness of a given country by means of simple and weighted average methods, and methodologies to evaluate and forecast the economic growth by means of statistical and econometric approaches. From results of investigation, we found that SES must be defined from new perspective, system of indicators for assessing the level of SES—set based on supplement of new ones and inclusion of some old ones in line with essence and nature of SES, and level of SES—assessed based on statistical and econometric techniques to select the indicators, determine their weights, standardize their values, and make calculation, apart from various methods for assessing the size and competitiveness of a given economy, or for forecasting the economic growth.

Next, we have defined the essence and nature of SES, set the system of indicators, and suggested the method for synthetically assessing the level of SES. The concept of economic strength is not a simple concept reflecting individual aspects of economy and so, it should be assessed according to the actual reality of each country. In particular, in era

of globalization when all economies become more interlinked, assessing the outness and insideness of a given economy rightfully is of significance in policy-making related to economic development. From this viewpoint, we have defined the nature of economic strength as the capability of satisfying the need for material and cultural wealth and clarified the character of SES in three aspects; (a) SES is self-reliant economic strength, (b) SES—the economic strength relying on cutting-edge science and technology, and c) SES—the economic strength which can satisfy the need of people for bountiful and cultured life. And we set the system of indicators according to following directions, and presented its results in Table 1. Direction for setting the indicators are as follows; first, statistical indicators can be set to reflect the state and use of a country's resources for the development of its SES, second, statistical indicators—to reflect the existing state and level of economic foundation, the entity of SES, third, statistical indicators—to measure the state and level of economic foundation in physical or/and value aspects, fourth, statistical indicators—to show the per-head level of economic strength which is expressed by the comparison of the absolute size of economic strength with population, fifth, statistical indicators—to reflect the analyses of the factors which affect the strengthening of SES. Also, we have suggested methods for assessing SES, and made calculation based on formulas and assumed data in order to describe the practical application. This paper has set 5 individual indicators showing the level of economic strength and made pair-comparison judgment on them, to the result of which different numerical data are made correspondent, so as to construct pair-comparison judgment matrix. The accuracy of pair-comparison judgment has been inspected, eigenvectors corresponding to maximum eigenvalues of high-accuracy pair-comparison judgment matrix calculated, and the result obtained by standardizing the eigenvectors set as weight of each assessment indicators. The weight calculated in analytic hierarchy process shows that the indicators of per-head total output value and the number of scientists and technologists per 100 000 of population get the highest values (respectively, about 23% and 23%), followed by the indicator of degree of equipment with hi-tech machinery (about 20%), and the indicators of degree of equipment with fixed assets and domesticalization ratio (about 17%).

Based on already-used formulas, this paper has explained those processes of transforming statistical data collected in 11 regions or countries on 5 indicators, and on this basis, calculated the values, which have been combined with already-determined weight to assess the ranking of economic strength according to region or country. Results of above calculations are displayed in Tables 8, 10, 11, 12, and 13.

As a final result, region or country 1 is shown to be in the highest level of economic strength. This shows that economic strength is determined by synthetic assessment of indicators, not a single one. In other words, although any region or country is the highest among others with respect to any indicator, it is impossible to say that mentioned region or country is the one with the highest level of economic strength, except for case with the highest values with respect to all indicators.

## 5 Conclusion

From results and discussions, we can conclude as follows.

First, actual economic strength of a given country must be defined by considering the external and internal aspects of economy. It follows from that as the world economy gets globalized increasingly, many economies are negatively affected by uncertain external

environment, and while some countries stress the internal aspects of economy, others—the external aspects. In theoretical viewpoint, we can say that concepts and indicators related to size and competitiveness of economy mostly focus on external aspects. Only when economic strength is defined in view of capability of satisfying the need for material and cultural wealth by itself, can it say that rightful understanding of economic strength is established, and developmental potentialities of given country can be captured correctly. Also, this may be helpful advice for some countries where disregard the strengthening of internal aspects of economy, with focusing on size of GDP or GDP per capita. And this may be helpful for economists and organizations which strive to study economic policies and to take timely economic measures with rightful recognition of economic strength.

Second, actual economic strength of a given country must synthetically be assessed by using the indicators capable of showing the all aspects. It follows from limitations of individual indicators abovementioned in assessing the size or competitiveness of given economy. Therefore, economic strength ought to be assessed in line with essence and nature of SES, considering the self-reliance, ultramodernness, and livelihood of given country. This viewpoint is reasonable in that economic construction for any country is aimed to ensuring the productive, technological, and consumptive demands by itself. This may be helpful in reviewing the merits and demerits of existing indicators, overcoming the limitations of some indicators, and developing the new system of indicators for synthetically assessing the SES. Using this system, on the one hand, policy-makers can discover the weaker and the stronger links of own countries compared with other countries, thus taking economic and technological measures to eradicate the weak links, and on the other hand, international organizations can assess and compare the actual situation of economy according to countries more rightfully.

Of course, this study has some limitations. First limitation is that about accessibility of indicators. Among indicators for assessing SES, some are available or accessible, but others—not. In particular, it is a common practice that indicators related to self-reliance are not available or accessible due to calculation for own use of each country. From this, it is necessary to use the substitutable indicators accessible to databases. For example, import dependence index expressed by ratio of imports to GDP may be used instead of indicators reflecting the self-reliance. Second limitation is that about application of methodology. One methodology for assessing SES has been explained in this paper. In addition to analytic hierarchy process, date envelopment analysis (DEA) and other various methodologies can be applied. In this case, assessment results differ from methodology to methodology, which raises a problem of deciding which methodology is the most correct. Therefore, it is necessary to apply various methodologies, calculate the obtained results, and inspect their accuracy. Third limitation is that about the significance of indicators. Indicators explained above may have some limitation in country-specific comparison and assessment, because each country has its own peculiarities. Therefore, what is important in this case is to set the most typical indicators which can be applied to all countries. Nevertheless, these data can contribute to comparing and assessing the development level of region-specific or country-specific economic strength and taking measures to strengthen it further.

From above limitations, further research ought to be conducting in the following directions; (a) development of indicators available for assessment and accessible to databases, (b) application of rightful techniques to ensure the accuracy of calculations, and (c) selection of typical indicators applicable for all countries.

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## Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References


Abdul, R., & Musharaf, W. K. (2015a). 2015 Key Socio-Economic Statistics On IDB member countries, Islamic Development Bank, Kingdom of Saudi Arabia, p 10.

Abdul, R., & Musharaf, W. K. (2015b). 2015 Key Socio-Economic Statistics On IDB member countries, Islamic Development Bank, Kingdom of Saudi Arabia, p 123.

Ahmadi, M., Jafarzadeh-Ghoushchi, S., Taghizadeh, R., et al. (2019). Presentation of a new hybrid approach for forecasting economic growth using artificial intelligence approaches. *Neural Computing and Applications, 31*(12), 8661–8680. https://doi.org/10.1007/s00521-019-04417-0.

Ahmadi, M., & Taghizadeh, R. (2019). A gene expression programming model for economy growth using knowledge-based economy indicators: A comparison of GEP model and ARDL bounds testing approach. *Journal of Modelling in Management, 14*(1), 31–48. https://doi.org/10.1108/JM2-12-2017-0130.

Business Dictionary. Available at: http://www.businessdictionary.com/definition/economy.html.

Chinadaily.com. (2018). Xi stresses nation's self-reliance. Available at:http://www.chinadaily.com.cn/kindle/2018-09/27/content_36987060.htm.

Collins Dictionary. Available at; https://www.collinsdictionary.com/amp/english/national-economy.

Daly, H., & Cobb, J. B. (1994). *For the common good* (p. 534). Boston, MA: Beacon Press.

DeVol, R., Koepp, R., & Fogelback, F. (2002). State technology and science index: Comparing and contrasting California, Milken Institute, (September, 2002).

Dutta, S. (Ed.). (2011). The Global Innovation Index 2011, INSEAD (2011). http://www.globalinnovationindex.org/gii/.

Giovannini, E. (2008a). Understanding economic statistics, an OECD perspective. ISBN 978-92-64-03312-2 @ OECD 2008, p. 13.

Giovannini, E. (2008b). Understanding economic statistics, an OECD perspective. ISBN 978-92-64-03312-2 @ OECD 2008, p. 49.

Global Footprint Network. (2009). Data and results website. http://www.footprintnetwork.org.

Godfrey, P. C. (2008). What is economic self-reliance? *ESR Review, 10*(1), 4–7.

InvestorWords, Available at: http://www.investorwords.com/1652/economy.html#ixzz6O7FwvMZO.

Jolliffe, I. (2002). *Principal component analysis*. London: Wiley.

Lawrence, R. Z. (2002). Competitiveness. In Henderson, D. R. (eds), *Concise encyclopedia of economics*, 1st edn. Library of Economics and Liberty. OCLC 317650570, 50016270, 163149563.

Mallard, G. (2012). Modelling cognitively bounded rationality: An evaluative taxonomy. *Journal of Economic Surveys*, *26*, 674–704. https://doi.org/10.1111/j.1467-6419.2010.00673.x.

Marks, N. (2006). The Happy Planet Index, New Economics Foundation, p. 57.

Merriam-Webster.com Dictionary. (2020). National economy. Merriam-Webster. Available at: https://www.merriam-webster.com/dictionary/national%20economy. Accessed 31 May. 2020.

Moffatt, M. (2019). Measuring the size of the economy: Using gross domestic product to determine economic strength and power, Thoughtco, February 22, 2019. Available at: https://www.thoughtco.com/measuring-the-size-of-the-economy-1146998.

Myong-Hun, A., Gyong-Yong, R., & Gwang-Nam, R. (2019a). Intellectual product and method of assessing the competitiveness of an enterprise with it. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-019-00593-5.

Myong-Hun, A., Gyong-Yong, R., & Gwang-Nam, R. (2019b). Intellectual product and method of assessing the competitiveness of an enterprise with it. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-019-00593-5.

National Bureau of Statistics of China, National Data. Available at: http://www.stats.gov.cn/english/.

Rim, G., Kim, G., Hwang, S., et al. (2019). Some problems in statistically assessing the level of knowledge economy. *Journal of the Knowledge Economy, 10*(3), 974–996. https://doi.org/10.1007/s13132-017-0510-0.

Rutherford, D. (2002). *Dictionary of economics* (2nd ed.). Abingdon: Taylor & Francis Publishing House.

Starostina, A., & Prushkivska, E. (2013). Economic content of the national economy definition and its structure in conditions of economic instability. *Ukrainian Journal Ekonomist, 6,* 29–32.

Taghizadech, R., & Ahmadi, M. (2019). Statistical and econometrical analysis of knowledge-based economy indicators affecting economic growth in Iran: The new evidence of principal component analysis—Tukey and ARDL bound test, Preprint: January 2019. https://doi.org/10.13140/RG.2.2.26515.02087.
Talberth, J., Cobb, C., & Slattery, N. (2006). The Genuine Progress Indicator 2006: A Tool for Sustainable Development. Redefining Progress.
Tisdell, C. (2013). Economic self-reliance and China's development: Changing perspectives. *International Journal of Development Issues, 12*(3), 239–252. https://doi.org/10.1108/IJDI-03-2013-0029.
United Nations Development Programme. (2009). Statistics Website. Available at: http://hdr.undp.org/en/statistics/.
World Bank. (2012a). KEI and KI Indexes (KAM 2012). Available at: http://info.worldbank.org/etools/kam2/KAM_page2.asp.
World Bank. (2012b). KEI and KI Indexes (KAM 2012). Available at: http://info.worldbank.org/etools/kam2/KAM_page2.asp.
World Bank Institute. (2010). Development Economics, p. 7.
World Economic Forum. (2019). The Global Competitiveness Report 2017–2018, Accessed Nov. 29, 2019. Available at: https://www.alianciapas.sk/wp-content/uploads/2017/09/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf.
World Intellectual Property Organization (WIPO). (2019). Global Innovation Index 2019, https://www.wipo.int/publications/en/details.jsp?id=4434.
Xinhuanet.com. (2019). DPRK stresses importance of self-reliance. Available at: http://www.xinhuanet.com/english/asiapacific/2019-04/11/c_137968467.htm.



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