Comparative Study of Knowledge-Based Economic Strength Between China and the USA

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Abstract
Entering the era of knowledge economy, knowledge is the important source of economic growth and is the basis for ensuring the sustainable development of economy even under any disadvantageous environment. This paper addresses the comparison of economic strength between China and the USA from a view of knowledge economy. To this end, based on analysis of previous studies, the authors conceptualize the knowledge-based economic strength, establish the indicators system for its comparison between China and the USA, and conduct the comparison and analysis based on them. The findings are that (1) while China gets ahead of the USA in exports of high-tech manufactures and numbers of knowledge resources, the USA gets ahead of China in GDP per capita, receipts of intellectual properties, human capital, financial expenditure, and ICT infrastructure, (2) China has mostly focused on quantitative growth of knowledge resources rather than qualitative growth, (3) China has devoted many efforts to the decrease of differences in almost all aspects of knowledge-based economic strength from the USA, and (4) for both countries, degrees of contributions of resource indicators to GDP per capita are different. Given that competition between China and the USA enters the new stage, this comparative study may serve as the policy basis in taking the technological measures for further strengthening its own economic strength for China.

Keywords Knowledge economy (KE) · Knowledge-based economic strength (KBES) · China-US comparative studies · Chinese economy · Economic strength

Introduction
Today, China and the USA form two pillars of world economy, and Chinese economy exerts its great influence on world economy. China has already emerged as the second-best economic power, and experts outlook that China will catch up
with the USA as soon as possible. However, factors such as intensification of contradiction between China and the USA, US’s continuous pressure on China, deepening of COVID-19 pandemic, political and economic instability, and risk in relation with marginal countries and the like are the obstacles for China’s influence on world economy, and in turn, these are the difficulties in strengthening economic strength for China. On the other hand, strengthening its own economic strength for China is the important condition for holding the dominant position in competition with the USA. China regards that it still has weakness in many aspects compared to the USA. In this context, many experts and international organizations compare the economics between China and the USA based on different indicators, and among them, what is noticeable is to compare based on macroeconomic indicators including GDP (gross domestic products) and trade volume (e.g., Barbieri, 1995; Oneal & Russett, 1997; United Nation; World Bank; Organisation for Economic Co-operation and Development). Besides, they evaluate the country-specific competitiveness using the indicators including global competitiveness index (GCI) and global innovation index (GII). However, it is our view that these have limitations in evaluating the economic strength in a qualitative aspect and in a view of sustainable development for today which is the era of knowledge economy (KE). In other words, these evaluations focus on external comparison and assessment. Furthermore, in a view of sustainable development of economy discussed in abstract, economic strength cannot be assessed only by abovementioned indicators, and this requires that comparative study must be conducted focusing on internal strength of economy. Economic strength is the greatly complex concept and consists of various components, and thus, it requires new consideration of comparative study on economic strength between China and the USA. In this regard, this study is motivated by following arguments. (1) What is the knowledge-based economic strength (KBES)? (2) What are the problems in evaluating KBES? (3) What are the strong and weak aspects in comparing KBES between China and the USA? (4) What are the significant factors mostly affecting the KBES among two countries? This paper aims to set the indicators for comparing and evaluating KBES, compare the economic strengths between China and the USA based on those indicators, and discuss the measures for sustainable development of economy based on knowledge. From this, this paper is organized as follows. The second section analyzes the previous studies related to assessment of the level of KE and comparison of economics between China and the USA. The third section addresses the indicators system for comparing and evaluating KBES between China and the USA. The fourth section collects the concerned data based on indicators and, after transforming the primary data into comparable values, conducts the comparison of KBES between China and the USA. And this section reveals the interrelation between indicators and their influences on economic growth by means of correlation and regression analysis methods. The last section addresses the results, discussions, conclusions, and further study. This makes it possible to newly evaluate the economic strength in a view of KE and to take the technological measures for overcoming the weakness of economy in a view of KE and strengthening its own economic strength for China.
Analysis of Previous Studies

Assessment of KE

So far, international organizations including the World Bank and many authors have set indicators related to KE. With the emergence of the term “knowledge economy,” many researchers have suggested various kinds of views and approaches regarding the KE (Ayan & Pabuccu, 2018; Drucker, 1998; Durazzi, 2019; Foray, 2004; Godin, 2006; Milewska, 2018; Sagiyeval et al., 2018; Saridogan & Kaya, 2019; Smith, 2000). According to definition of OECD (1996), knowledge-based economy refers to as those that are directly based on the production, distribution, and use of knowledge and information. Powell and Snellman (2004) define the KE as a way of creating a product based on activities dependent on knowledge and expertise that contribute to the creation of scientific and technological progress. Houghton and Sheehan (2000) focus on the driving forces of KE, that is, the increasing knowledge level of economic operations and the globalization of economic events, and Dudová (2011) stresses two prerequisites for the emergence of knowledge economies, which include the gradual increase of intangible capital and the emergence and growth of the diffusion of information and communication technologies. Other researchers focus on effective policy-making approach and strategic combination of highly specialized knowledge and skills in transforming into KE (e.g., Alnafrah & Mouselli, 2019; Lüthi et al., 2011). With the development of the KE, there have been attempts and approaches to assess and measure the KE. In this context, some authors suggested the pillars of the KE:

• Collison and Parcel (2005) showed the three pillars of the KE, that is, (a) people who are willing to learn and share knowledge, (b) the information infrastructure, and (c) processes that facilitate sharing, codification, and knowledge discovery.
• Sundac and Krmpotic (2011), four basic elements: long-term investment in education, innovative skills, the modernization of information base, and the creation of a favorable business environment.
• Chen and Dahlman (2005), four pillars suggested by the World Bank: economic incentives and the institutional system, educated and skilled human resources, an effective business innovation system, and a modern and appropriate information and communication structure.
• Barkhordari et al. (2019): institutions, human capital and research, infrastructure, and business sophistication.

Also, some authors and international organizations set the indicators relating with assessment of level of KE according to countries and regions. What is noteworthy among them is methodology suggested by World Bank (2004). This methodology includes the 109 structural and qualitative variables for 146 countries in the world to measure country-specific performance on the abovementioned
four pillars of KE and assesses the level of KE every year. According to Dutta (2011), INSEAD, a top-ranking international business school with campuses in Europe and Asia, suggests the global innovation index (GII), which includes 125 countries and provides not only the overall GII results but also scores and rankings for each of the 20 components included in the analysis. The global competitiveness index (GCI) annually published by the World Economic Forum (WEF) includes 12 pillars of competitiveness, among which three of the pillars relate most directly to the KE: higher education and training, technological readiness, and innovation (World Economic Forum, 2019). Besides, some authors suggest the indicators to measure the level of KE. For example, Roberts (2001) divided the KE indicators into four groups: indicators based on innovation and entrepreneurship, total R&D expenditure by industry, enterprise R&D (research and development) expenditure by size of enterprise, and the number of scientific and technical publications per capita; indicators based on human capital; indicators based on information and communication technologies; and indicators based on economic and social impacts. Rim et al. (2019) establish the indicators characterizing the level of KE as (a) R&D expenditure, (b) growth rate of invention and rationalization plans, (c) the degree of contribution by science and technology to economic growth and growth rate of application of inventions and patent, and (d) the proportion of knowledge-intensive industry in economic structure. Širá et al. (2020) divide the indicators of the KE into two categories: one category related to the basic characteristics of the KE, which includes the share of the KE in the whole economy of the country, and another, the performance or output indicators, which includes the production of high-tech industries, high-tech exports, GDP growth, and labor productivity growth (Arundel et al., 2008). On the other hand, there have been attempts to measure the level of KE according to regions. According to Atkinson and Andes (2010), the Information Technology and Innovation Foundation, a Washington, DC think tank, produced the new economy index (NEI), which was based on 26 individual indicators grouped according to the five primary dimensions about the new economy: knowledge jobs, globalization, economic dynamism, transformation to a digital economy, and technological innovation capacity. Milken Institute (2001) produced what was termed the knowledge-based economy index (KBEI), and this includes measures of educational attainment, R&D and patent activity, and business start-up–related activities. According to DeVol et al. (2002), another index produced by Milken Institute is the state technology and science index (STSI), which on 2010 was constructed from 79 individual indicators classified into five groups with their own composite indexes. Three of these groups relate most closely to the KE: human capital investment, R&D inputs, and technology and science workforce. As seen above, entering the era of KE, many efforts and attempts have been devoted to assessment of the level of KE. These may be the basis for comparing and evaluating the economic strength between China and the USA in a view of KE. In the next section, the authors will discuss the indicators system based on the abovementioned views, pillars, and indicators regarding the KE.
Comparison of Economics Between Countries

Before comparison of KBES between China and the USA, there are needs to reveal the concepts of economic power, competitiveness, and economic strength. This is because depending on concepts, purposes and indicators for comparison vary.

In general, power is defined as an ability to exert influence and control over other people’s thoughts and actions in the field of politics (Morgenthau & Thompson, 1997). After the end of the cold war, competition among countries also shifted from military power to economic power (Cooper, 1968). Therefore, economic impact has replaced force as the main means of national foreign policy (Luttwak, 1990). In order to maintain and strengthen dominance in bilateral relations, major powers gradually introduce economic mechanisms into interstate relations, thus enhancing their attractiveness to other countries through foreign trade and investment (Rio & Lores, 2017) and thereby influencing and controlling other countries’ decision-making (Hu et al., 2019).

Therefore, at present, economic power is manifested in the ability of a country to use its own economic strength to force other countries to change their will in the process of bilateral economic exchange activities (Kappel, 2010). In reality, the most common and influential relationship among actors is asymmetric interdependence (Gilpin, 1987). Because of asymmetric economic interdependence, one party with a low degree of dependence has the economic power to influence and control the behavior of another party in bilateral relations (Keohane & Nye, 1977); thus, asymmetric economic interdependence has increasingly become an important means for countries to exert strategic influence over others (O’Loughlin & Anselin, 1996). On the other hand, there exist different views on competitiveness. The typical ones among these 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 (Lawrence, 2002); competitiveness is defined as the institutions, policies, and factors that determine the level of productivity of a country (World Economic Forum, 2019). Competitiveness has become a major topic of research for academic institutions and think tanks. The reports on competitiveness are published by think tanks from major countries and economies including the USA, the EU, Japan, and the UK. Economic competitiveness means the ability of a country to create wealth and provide for national welfare (Scott & Lodge, 1985). In a view of KE, there have been discussions on competitiveness (Atanassova et al., 2018; Brodowska-Szewczuk, 2019; Dukic et al., 2018; Gorokhova, 2018; Hadad, 2018; Lomachynska & Podgorna, 2018). According to them, the ability to generate and absorb knowledge and use it effectively helps to create innovations, achieve competitive advantages and economic efficiency, and produce human capital and in turn determines the effectiveness of economic development.

In this context, until now, there have been attempts to measure and compare the economic power or competitiveness according to countries or between China and the USA. Barbieri (1995) and Oneal and Russett (1997) first used bilateral trade data to study asymmetric interdependence between countries, using both the proportion
of bilateral trade in a country’s total foreign trade and GDP separately as indicators to measure the economic power of one country. Thereafter, scholars performed further analyses on asymmetric interdependence from the perspectives of foreign investment, finance, and exchange rate (O’Loughlin & Anselin, 1996; Lim, 2010; Fei, 2017). In recent years, there have been two main researches on China’s economic power (Lu & Du, 2013; Du et al., 2016). The first uses trade data to study the bilateral asymmetric relations between China and other countries or regions, including the USA (Yang et al., 2017), the EU (Grosse, 2014), Japan (Wang, 2009), Southeast Asian countries (Zong & Zeng, 2017), and others (Yu & Wu, 2019; Liang et al., 2019). The second constructs a comprehensive index of economic power evaluation based on the theory of compound interdependence, which studies the evolutionary trend and spatial pattern of China’s economic power (Hu & Men, 2012; Hu et al., 2015). Also, the authoritative international organizations including the UN (United Nations), World Bank, OECD (Organisation for Economic Co-operation and Development) and the like measure and compare the economic power or competitiveness of countries using different indicators such as gross domestic products (GDP) or GDP per capita, 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, and so on, in a view of macroeconomics.

Also, comparative studies on national competitiveness and comprehensive strengths between China and the USA have been carried out by some scholars from different dimensions (Hu et al., 2015; Chen et al., 2009; Guo, 2014; Ni & Li, 2016; Ni & Wang, 2017; Liu & Lin, 2010; Yao et al., 2020; Yin, 2015; Zhao & Feng, 2007).

As seen above, it can say that economic power or competitiveness is a concept mostly focused on external aspects of a given economy. It is our views that economic power greatly focuses on economic influence of one country to exert on other country and economic competitiveness – share of given country in world economy or market. In a view of sustainability, the economy of a given country must be evaluated in internal aspect. In other words, economic strength can be the concept reflecting the interiority of given economy. According to Rim et al. (2020), economic strength is defined in a view of capability of satisfying the need for material and cultural wealth by itself even under uncertain environments. Furthermore, entering the age of KE, knowledge is the most important resource for sustainable growth of economy, and the KBES is the basis for economic power or competitiveness. In this regard, the authors discuss the concept of KBES, indicator system for its comparison between China and the USA, and materials and methods in following sections.

Materials and Methods

Theoretical Framework

For comparative studies of KBES between China and the USA, there are needs to clarify the KE in a new perspective. In general, until now, KE have been defined as the
one that is based on the creation, distribution, and use of knowledge by international organizations and researchers. This view mostly focuses on economics of knowledge. It is our views that economics of knowledge is not the same as KE. Clearly speaking, the KE is the knowledge-based one, that is, the one developing based on the strength of knowledge as the word itself. In other words, it is the knowledge-intensive one. Under the KE, knowledge is not only the productive resource but also commodity by itself. From this, in the era of KE, knowledge industry and high-tech industry are formed. According to An et al. (2020), intellectual products can be divided into intangible and tangible ones. While intangible products include intellectual ones such as program, patent, trademark, industrial process design, scientific and technological article, and copyright, tangible ones include high-tech manufactures produced using the intellectual property, that is, information technology product, bioengineering product, pharmaceutical product, aircraft and related goods, electronic and electric product, and so on; while intangible products are created in knowledge industry including science and education, high-tech products are created in high-tech industry including information technology industry, bioengineering industry, electronic industry, air- and space-related industry, pharmaceutical industry, and so on which produce the knowledge-intensive products. Therefore, entering the era of KE, there exist inherent inputs and outputs corresponding to this era. In other words, there exist the resources for constructing the KE and results of the KE. This framework makes it possible to clarify the KBES and set the indicators system for its comparison between China and the USA.

Based on abovementioned standpoint of the KE, the KBES can be defined as the capability of ensuing the sustainable development of a given economy through creating and using the knowledge resource by itself even under uncertain environments. The process of creating the knowledge resource necessitates the corresponding human and material and financial resources. The major creators of knowledge resource are scientists and technologists, who are employed and trained in sectors of science (research and development) and education. And in turn, scientific research and education entail a great deal of money. Apart from information and communication technology (ICT) and its network, creation and application of scientific and technological knowledge are impossible. The process of creating knowledge resource is the one of researching and developing the science and technology or of renewing the exiting science and technology using ICT. In this regard, ICT infrastructure emerges as the material and technological resource for the KE. On the other hand, as a result of application of created knowledge resource, new cutting-edge industries are formed, sectors of traditional industries are equipped with high technology, and in turn, sustainable growth of economy is ensured. This shows that KBES can be characterized in following aspects:

- Resource (input) – knowledge, researcher, fund, ICT infrastructure
- Result (output) – cutting-edge industry, equipment with high technology, growth of economy

From the above revelation of KBES, the indicators system for its comparison between China and the USA can be set as follows (see Table 1).
This indicator system is the main one for comparison of KBES. It is obvious that depending on purpose of study and accessibility of data, this can be detailed. For example, indicators reflecting the human resource for the KE can be detailed into following ones: the proportion of PhDs, scientists, and engineers in the overall workforce, proportion of the population 25 years and older with at least a BA degree, and proportion of the population 25 years and older with a degree higher than a BA.

In the next subsection, the authors collect the primary data and process them based on abovementioned indicators system due to inaccessibility of data.

**Collection of Primary Data**

For comparison, the authors use databases of World Bank, the WTO (World Trade Organization), and the WIPO (World Intellectual Property Organization). Data for study is collected regarding the resource and result based in Table 1. To ensure the comparability of study between two countries, data is collected with not absolute but relative values. Also, while the study period for recent comparison between two countries is limited to 8 years, that is, period of 2010–2017, that for correlation and regression analysis includes 20 years, that is, period of 2000–2019. The reasons of selecting the data for period of 2000–2019 are concerned to facts that, in general, knowledge economy is relatively new concept and data relating to some indicators abovementioned is missing.

Under the above preconditions regarding data, the authors collect primary data based on following indicators (see Table 2).

As shown in Table 2, all of indicators are calculated with relative values for comparability. The authors collected data for resident with regard to knowledge resources, because data for nonresident does not reflect domestic realities of a given country. Also, the authors selected the export data regarding results. That is reason why data regarding the output or proportion of high-tech industry of a given country is not given. Thus, the authors replaced the output of high-tech industry into high-tech exports. Proportion of high-technology exports is calculated dividing the exports of high-tech manufactures by GDP. Thus, while high-technology exports (% of GDP) mean

| System of Statistical Indicators | Indicators reflecting the resources for KE | Knowledge resource | Indicators reflecting the results of KE |
|----------------------------------|------------------------------------------|--------------------|---------------------------------------|
|                                  |                                          | Patent, Trademark, Scientific and technological article, Industrial design etc | Export of cutting-edge industry |
|                                  |                                          | Researcher, Science graduate | Equipment of traditional industry with hi-tech |
|                                  |                                          | R&D expenditure, Expenditure for education | |
|                                  |                                          | ICT infrastructure |  |

Source: Own elaboration

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Table 1 System of statistical indicators for comparison of KBES between China and the US

| System of Statistical Indicators | Indicators reflecting the resources for KE | Knowledge resource | Indicators reflecting the results of KE |
|----------------------------------|------------------------------------------|--------------------|---------------------------------------|
|                                  |                                          | Patent, Trademark, Scientific and technological article, Industrial design etc | Export of cutting-edge industry |
|                                  |                                          | Researcher, Science graduate | Equipment of traditional industry with hi-tech |
|                                  |                                          | R&D expenditure, Expenditure for education | |
|                                  |                                          | ICT infrastructure |  |
### Table 2  Statistical indicators for collection of primary data

| Knowledge resource | Patent applications (resident, per million people), scientific and technical journal articles (per million people), industrial design applications (resident, per million people), trademark applications (resident, per million people) |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Human resource     | Researchers in R&D (per million people), school enrollment (tertiary, % of gross population)                                                                                                |
| Resources          | Research and development expenditure (% of GDP), education expenditure (% of GNI)                                                                                                              |
| Financial resource | Individuals using the Internet (% of population), secure Internet servers (per million people), fixed broadband subscriptions (per 100 people), fixed telephone subscriptions (per 100 people), mobile cellular subscriptions (per 100 people) |
| Technical resource |                                                                                                                                                                                               |
| GDP per capita     |                                                                                                                                                                                               |
| Results            | High-technology exports (% of GDP)                                                                                                                                                              |
|                    | Receipts for the use of intellectual property (% of GDP)                                                                                                                                         |

Source: own elaboration
the tangible intellectual products, receipts for the use of intellectual property (% of GDP) – intangible ones. Primary data collected based on abovementioned procedures is the basis for comparison of KBES between China and the USA.

Methods

For comparison, first of all, there are needs to convert primary data into standardized one to compare the KBES between China and the USA. Different methods can be applied in standardizing the primary data, which include method using the mean and standard deviation, sigmoid transformation, (0, 1) transformation method, TOPSIS (technique for order preference by similarity to ideal solution) method, CV (coefficient of variance) method, MCDM (multi criteria decision-making) method, and the like. These methods are of significance in standardizing, comparing, and evaluating the primary data according to countries. However, there are certain preconditions in applying these methods; application of these methods requires many objects for study as possible. Thus, it is seen that it is inappropriate to apply these methods in this study for comparing two countries. If given that year- and indicator-specific data of two countries are given, the authors apply the method of calculating the standardized values after calculating the standard deviation and degree of variance based on primary data according to years, but it is difficult to ensure the being scientifically accurate depending on difference of period for study, that is, years included in study. On the other hand, there can be the method of standardizing the primary data using the abovementioned procedures based on year-specific data of two countries, but it seems that this method ignores the realities of a given country because influences of factors for China differ from the USA.

In this context, the authors calculate comparable standardized values by converting the primary data according to China and the USA on the basis of year- and indicator-specific world averages. These are calculated by following formulas:

\[
S_i = \frac{X_i}{W_i}, \quad S_{ij} = \frac{X_{ij}}{W_{ij}}
\]

(1)

where

- \(S_i\) – standardized value of \(i^{th}\) indicator
- \(W_i\) – world average of \(i^{th}\) indicator
- \(X_i\) – primary value of \(i^{th}\) indicator
- \(S_{ij}\) – standardized value of \(i^{th}\) indicator for \(j^{th}\) year
- \(W_{ij}\) – world average of \(i^{th}\) indicator for \(j^{th}\) year
- \(X_{ij}\) – primary value of \(i^{th}\) indicator for \(j^{th}\) year

\((i = 1, 2, \ldots, n), (j = 1, 2, \ldots, m)\)

Thus, standardized value shows at what degree primary value of each country differs from the world average. If its value is below one, it shows that level of a given indicator in a given country is below the world average level; if its value is above one, it shows that the level of a given indicator in a given country is above the
world average level. This makes it possible to understand the development level and difference of individual aspect of KBES for a given country and for a given year.

Summing up the standardized values of each indicator, it shows the total value of each indicator, which in turn, reflects the differences according to two countries. The process of summing up the standardized values can be shown by following formulas:

\[ P_j = \sum_{i=0}^{n} S_{ij} = \sum_{i=0}^{n} \frac{X_{ij}}{W_{ij}} \]  

(2)

where

\( P_j \) – totaled value of all indicators for \( j^{th} \) year

This formula makes it possible to compare the KBES according to results, resources, and in the whole. Also, one can understand the differences between China and the USA according to individual aspects of KBES based on values calculated by this formula.

After calculating the standardized values, year- and indicator-specific differences of country A from country B can be calculated by the following formulas:

\[ d^A_B = \frac{S^A_{ij}}{S^B_{ij}} \]  

(3)

\[ D^A_B = \frac{\sum_{i=0}^{n} S^A_{ij}}{\sum_{i=0}^{n} S^B_{ij}} \]  

(4)

where

\( d^A_B \) – difference of individual indicator for country A from country B

\( D^A_B \) – differences in sums of indicators for country A from country B in individual year

Next, there are needs to reveal the interrelations between resource and result, or between resources. Of course, the hypothesis which resources for KE affect the economic growth was proven by theory and practice in the past. However, degrees of interrelation between resources and results, or between resources are different according to countries, and only when the interrelations between indicators are revealed, can one select appropriate model. In general, degrees of interrelation are explained using the correlation matrix. For correlation analysis, GDP per capita (output indicator) is selected as the dependent variable (output indicator), and the independent variables (input indicator) include all of the resource indicators except for education expenditure (% of GNI) and secure Internet servers (per million people). This is because for two countries, education expenditure is almost same for all years and data for secure
Internet servers is missing for period of 2000–2009 with regard to primary data. Thus, it seems that these variables are excluded in correlation and then regression analysis. As a result of constructing the correlation matrix, it is revealed that correlations differ and all of resource indicators except for fixed telephone subscriptions (per 100 people) have positive correlations with result (GDP per capita) for China and the USA. However, it is seen that degrees of correlation between variables differ according to countries. Of course, these environments are conditional, because correlations differ depending on results indicators. However, this interpretation makes it possible to understand that there exist specific features in socioeconomic development according to two countries. Also, there exist the correlations between resources indicators. In other words, this shows that factors affecting the results are closely interrelated. This revelation of correlations makes it possible to select appropriate model for comparison. Correlation is significant at the 0.01 level and 0.05 level (2-tailed).

Next, linear multiple regression models are constructed and analyzed for two countries under study in order to illustrate the influences of resource indicators on GDP per capita, result indicator. This aims to analyze the impacts of KE indicators on economic growth and to discuss the measures for strengthening KBES. The authors conduct the linear multiple regression analysis using the statistical software package SPSS16. Conducting the linear multiple regression analysis is based on the assumption that GDP per capita and diverse resources are in a linear relation and these elements affect the GDP per capita diversely. Also, the degree of changes in GDP per capita according to changes of diverse resources can easily be estimated by drawing regression models. Premises on data are same as correlation analysis. Construction and analysis of regression models are conducted according to each country, considering country-specific features. The results of construction and analysis are presented in the Appendix. As a result of regression analysis, significances and validity of regression models were tested, and thus, based on them, influences of resources indicators on GDP per capita according to countries can be analyzed, and country-specific GDP per capita is estimated.

In the next section, the results obtained by the abovementioned methods are discussed.

**Results and Discussions**

First of all, the authors conducted the comparison and assessment between China and the USA. This aims to understand the development level of KBES for both countries. For this, the authors collected primary data from databases of the WTO, World Bank, and the WIPO based on theoretical framework discussed in previous subsection. Of course, the authors processed primary data obtained from databases as required in Table 2. For example, the authors calculated the number of knowledge resources per million people by dividing the absolute number of patents, scientific and technological articles, industrial designs, and trademarks into researchers per million people, respectively. Also, the authors calculated the high-technology exports (% of GDP) by dividing the exports of high-technology manufactures into GDP and receipts for the use of intellectual property (% of GDP) – by dividing the receipts for the use of intellectual property into GDP. Other data are from databases; thus, the authors
used themselves as primary ones for calculation. After collecting the primary data, the authors calculated the standardized values and their sums according to indicators for China and the USA, respectively, using Eqs. (1), (2), and (3).

For two countries, calculation results according to indicators are presented in Tables 3 and 4.

For intuitive comparison, the authors put calculation results into figures according to individual aspects of KBES for China and the USA.

First, for the resultant aspects of KBES, differences between China and the USA compared to world averages are described as follows (Fig. 1).

As seen from Fig. 1, one can see that for China, while the levels of GDP per capita and receipts for the use of intellectual property are below world averages, high-technology exports – above world averages for the period under study. For the USA, while the level of high-technology exports are below world averages, the level of GDP per capita and receipts for the use of intellectual property are above world averages. This shows that while China mostly focuses on tangible products (high-technology exports), the USA – intangibles (receipts for use of intellectual property) for the given period.

Second, for the knowledge resources of KBES, differences between China and the USA compared to world averages are described as follows (Fig. 2).

As seen in Fig. 2, one can see that while for China, the level of scientific and technical journals per million people is below world averages for the period of 2010–2015 and then is above world averages for the period of 2016–2017; for the USA, the level of industrial design applications per million people is below world averages for the whole period under study. In addition, while China gets ahead of the USA for the industrial design applications per million people, the USA – ahead of China for patent applications per million people and scientific and technical journals per million people.

Table 3  Standardized values according to indicators for China

| Year | Indicator | Results | Knowledge resource | Human resource | Financial resource | Technical resource |
|------|-----------|---------|--------------------|---------------|-------------------|-------------------|
|      | Y1 | Y2 | Y3 | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 |
| 2010 | 0.48 | 2.31 | 0.04 | 1.31 | 0.83 | 2.56 | 1.60 | 0.69 | 0.82 | 0.85 | 0.42 | 1.19 | 0.01 | 1.18 | 1.22 | 0.82 |
| 2011 | 0.54 | 2.35 | 0.03 | 1.68 | 0.83 | 2.67 | 1.85 | 0.75 | 0.82 | 0.89 | 0.42 | 1.23 | 0.01 | 1.27 | 1.21 | 0.86 |
| 2012 | 0.60 | 2.34 | 0.03 | 1.94 | 0.82 | 2.80 | 1.98 | 0.79 | 0.88 | 0.94 | 0.43 | 1.24 | 0.01 | 1.35 | 1.21 | 0.91 |
| 2013 | 0.65 | 2.26 | 0.02 | 2.28 | 0.87 | 3.48 | 1.91 | 0.83 | 0.97 | 1.00 | 0.44 | 1.25 | 0.01 | 1.39 | 1.21 | 0.96 |
| 2014 | 0.70 | 2.08 | 0.02 | 2.48 | 0.91 | 3.91 | 2.16 | 0.85 | 1.19 | 0.98 | 0.44 | 1.20 | 0.02 | 1.40 | 1.19 | 0.96 |
| 2015 | 0.79 | 1.93 | 0.02 | 2.77 | 0.95 | 3.49 | 2.38 | 0.82 | 1.25 | 0.99 | 0.45 | 1.21 | 0.03 | 1.71 | 1.16 | 0.94 |
| 2016 | 0.79 | 1.79 | 0.02 | 3.03 | 0.99 | 3.06 | 2.57 | 0.85 | 1.28 | 1.00 | 0.45 | 1.19 | 0.04 | 1.84 | 1.08 | 0.96 |
| 2017 | 0.82 | 1.61 | 0.09 | 3.10 | 1.03 | 3.58 | 3.03 | 0.87 | 1.30 | 1.00 | 0.45 | 1.11 | 0.06 | 2.02 | 1.04 | 1.01 |

Source: own calculation

Y1 GDP per capita, Y2 high-technology exports (% of manufactured exports), Y3 charges for the use of intellectual property (% of GDP) X1 patent applications (resident, per million people), X2 scientific and technical journal articles (per million people), X3 industrial design applications (resident, per million people), X4 trademark applications (resident, per million people), X5 researchers in R&D (per million people), X6 school enrollment (tertiary, % gross), X7 research and development expenditure (% of GDP), X8 education expenditure (% of GNI), X9 Internet users (% of population), X10 Internet servers (per million people), X11 fixed broadband subscriptions (per 100 people), X12 fixed telephone subscriptions (per 100 people), X13 mobile cellular subscriptions (per 100 people)
However, for the level of trademark applications per million people, the USA gets ahead of China for period of 2010–2011 and falls behind China for period of 2012–2017.

Third, for the human resources of KBES, the differences between China and the USA compared to world averages are described as follows (Fig. 3)*.

As seen in Fig. 3, one can see that for two countries, all aspects of human resource for China fall behind those for the USA. Concretely, while the level of researchers in R&D per million people for China is behind world averages, that for the USA is above world averages for the given period. And while school enrollment (tertiary) for China is behind world averages for period of 2010–2013 and since 2014, it gets ahead of world averages, that for the USA – above world averages for the whole period.

Next, for the financial resources of KBES, differences between China and the USA compared to world averages are described as follows (Fig. 4).

As seen in Fig. 4, one can explain similarly with human resources. In other words, all aspects of financial resources for China fall behind those for the USA. However, concrete trends differ among two countries. For R&D expenditure, while China falls behind world averages for the given period except for 2017, the USA – vice versa.

Next, for the technological resources of KBES, differences between China and the USA compared to world averages are described as follows (Fig. 5).

Table 4 Standardized values according to indicators for the USA

| Year | Indicator | Knowledge resource | Human resource | Financial resource | Technical resource |
|------|-----------|---------------------|----------------|-------------------|-------------------|
|      | Y1 | Y2 | Y3 | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 |
| 2010 | 5.07 | 0.33 | 1.77 | 4.66 | 4.71 | 0.54 | 2.10 | 3.03 | 3.13 | 1.35 | 1.14 | 2.49 | 13.25 | 3.49 | 2.74 | 1.21 |
| 2011 | 4.76 | 0.36 | 1.88 | 4.31 | 4.66 | 0.49 | 2.00 | 3.14 | 2.99 | 1.38 | 1.19 | 2.24 | 12.50 | 3.16 | 2.69 | 1.14 |
| 2012 | 4.87 | 0.36 | 1.82 | 4.21 | 4.60 | 0.45 | 1.87 | 3.11 | 2.85 | 1.32 | 1.09 | 2.18 | 11.82 | 3.15 | 2.67 | 1.10 |
| 2013 | 4.93 | 0.34 | 1.76 | 4.02 | 4.48 | 0.47 | 1.61 | 3.19 | 2.65 | 1.36 | 1.08 | 1.95 | 11.61 | 3.11 | 2.66 | 1.06 |
| 2014 | 5.03 | 0.34 | 1.59 | 3.80 | 4.36 | 0.53 | 1.57 | 3.28 | 2.48 | 1.31 | 1.08 | 1.83 | 11.39 | 3.00 | 2.68 | 1.16 |
| 2015 | 5.55 | 0.32 | 1.39 | 3.54 | 4.29 | 0.62 | 1.47 | 3.03 | 2.41 | 1.30 | 1.10 | 1.79 | 11.09 | 2.77 | 2.74 | 1.22 |
| 2016 | 5.63 | 0.32 | 1.38 | 3.19 | 4.14 | 0.58 | 1.22 | 3.01 | 2.38 | 1.30 | 1.11 | 1.91 | 9.03 | 2.64 | 2.78 | 1.22 |
| 2017 | 5.55 | 0.24 | 1.35 | 3.14 | 4.06 | 0.57 | 1.00 | 3.13 | 2.33 | 1.31 | 1.11 | 1.78 | 8.62 | 2.42 | 2.74 | 1.20 |

Same as Table 3
Source: own calculation

Fig. 1 Differences between China and the USA according to resultant aspects of KBES. Source: own drawing
As seen in Fig. 5, one can see that all aspects of technological resources for China are behind those for the USA. However, concrete trends differ among two countries. For the levels of Internet users, fixed broadband subscriptions, and fixed telephone subscriptions, China and the USA are above the levels of world average for the whole period, but while China falls behind world averages for the Internet servers (for the whole period) and for the mobile cellular subscriptions (for the given period except for 2017), the USA – ahead of world averages for all aspects (for the whole period). In particular, the USA holds the dominant position compared to China for Internet servers.

Finally, for the whole of KBES, differences between China and the USA compared to world averages are described as follows (Fig. 6).
As seen in Fig. 6, for total volume of KBES, the USA is higher than China in 2010 as well as 2017. However, the differences for both years are different.

For detailed comparison and discussions, there are needs to calculate the change rates and differences according to countries and years. Tabulating the differences between China and the USA according to all aspects of KBES in 2010 and 2017, respectively, is as follows (see Table 5).

From Table 5, the following points can be discussed in comparison of China with the USA.

- **Resultant Aspects**
  
  While China gets ahead of the USA for high-technology exports, the USA – ahead of China for GDP per capita and receipts for the use of intellectual property. However, there are differences in change rates regarding resultant aspects.
China decreased the difference of GDP per capita from the USA by about 3.8 times (10.56–6.76) and the difference of receipts for the use of intellectual property from the USA by about 29.25 times (44.25–15) as of 2017. On the other hand, the USA decreased the difference of high-technology exports from China by about 0.3 times as of 2017. Accordingly, for sum of resultant indicators, the USA gets ahead of China by about 2.53 times (7.17/2.82) in 2010 and about 2.83 (7.14/2.52) in 2017. In this context, although difference of GDP per capita between two countries has largely decreased, there still exist significant differences of receipts for the use of intellectual property. Of course, it is surprising that China has decreased its difference from the USA by about 29.25 times for the given period. On the other hand, the difference of high-technology exports for the USA is not large compared to the difference of receipts for the use of intellectual property. This shows that while the creation and application of intangible intellectual products have a significant contribution in economic growth for the USA, the production and application of tangible intellectual products – for China.

**Knowledge Resource**

Considering the differences for all knowledge resources, there are differences in change rates. On the one hand, China decreased the differences of patent applications per million people and scientific and technical journal articles per million people from the USA by about 2.55 times (3.56–1.01) and about 1.1 times (5.67–4.57) as of 2017, respectively. On the other hand, while China increased the difference of industrial design applications per million people from the USA by about 1.54 times (6.28–4.74) as of 2017, the USA – the difference of trademark applications per million people from China by about 0.13 times (1.44–1.31) as of 2017. Accordingly, for sum of knowledge resources, the USA gets ahead of China by about 1.91 times (12.03/6.3) in 2010 and about 0.82 (8.78/10.74) in 2017. In other words, China decreased the difference regarding the knowledge resources from the USA by about 1.9 times (1.91–0.82) as of 2017. This shows that China has given a great attention to creation of intellectual properties. However, in this regard, there are some issues to discuss. It is concerned to facts that although China creates many intellectual properties, the
Table 5  Differences between China and the USA according to all aspects of KBES

| Aspects                     | China                      | USA                       | Year-specific comparison between China and the USA | Differences (2010–2017), times |
|-----------------------------|----------------------------|---------------------------|---------------------------------------------------|--------------------------------|
|                             | 2010 | 2017 | Change rate (compared to 2010) | 2010 | 2017 | Change rate (compared to 2010) | 2010 (times) | 2017 (times) |
| Results                     |      |      |                                 |      |      |                                 |              |              |
| GDP per capita              | 0.48 | 0.82 | 1.7                             | 5.07 | 5.55 | 1.09                           | 10.56        | 6.76         | 3.8           |
| High-technology exports (% of manufactured exports) | 2.31 | 1.61 | 0.7                             | 0.33 | 0.24 | 0.73                           | 7            | 6.7          | 0.3           |
| Charges for the use of intellectual property (% of GDP) | 0.04 | 0.09 | 2.25                            | 1.77 | 1.35 | 0.76                           | 44.25        | 15           | 29.25         |
| Sum                         | 2.83 | 2.52 | 0.89                            | 7.17 | 7.14 | 0.99                           | 2.53         | 2.83         | -0.3          |
| Knowledge resource          |      |      |                                 |      |      |                                 |              |              |
| Patent applications (resident, per million people) | 1.31 | 3.10 | 2.37                            | 4.66 | 3.14 | 0.67                           | 3.56         | 1.01         | -2.55         |
| Scientific and technical journal articles (per million people) | 0.83 | 1.03 | 1.24                            | 4.71 | 4.06 | 0.86                           | 5.67         | 4.57         | -1.1          |
| Industrial design applications (resident, per million people) | 2.56 | 3.58 | 1.4                             | 0.54 | 0.57 | 1.05                           | 4.74         | 6.28         | 1.54          |
| Trademark applications (resident, per million people) | 1.60 | 0.69 | 1.89                            | 2.10 | 1.00 | 0.48                           | 1.31         | 1.44         | 0.13          |
| Sum                         | 6.30 | 10.74| 1.7                             | 12.03| 8.78 | 0.72                           | 1.91         | 0.82         | -1.9          |
| Human resources             |      |      |                                 |      |      |                                 |              |              |
| Researchers in R&D (per million people) | 0.69 | 0.87 | 1.26                            | 3.03 | 3.13 | 1.03                           | 4.39         | 3.6          | 0.79          |
| School enrollment (tertiary, % gross) | 0.82 | 1.30 | 1.58                            | 3.13 | 2.33 | 0.74                           | 3.82         | 1.79         | 2.03          |
| Sum                         | 1.51 | 2.17 | 1.44                            | 6.16 | 5.46 | 0.87                           | 4.08         | 2.52         | 1.56          |
Table 5 (continued)

| Aspects                          | China          | USA            | Year-specific comparison between China and the USA | Differences (2010–2017), times |
|----------------------------------|----------------|----------------|--------------------------------------------------|-------------------------------|
|                                  | 2010 | 2017 | Change rate (compared to 2010) | 2010 | 2017 | Change rate (compared to 2010) | 2010 (times) | 2017 (times) |
| Financial resources              |      |      |                                  |      |      |                                  |              |              |
| Research and development expenditure (% of GDP) | 0.85 | 1.00 | 1.17 | 1.35 | 1.31 | 0.97 | 1.59 | 1.31 | 0.28 |
| Education expenditure (% of GNI) | 0.42 | 0.45 | 1.07 | 1.14 | 1.11 | 0.97 | 2.71 | 2.47 | 0.24 |
| Sum                              | 1.27 | 1.45 | 1.14 | 2.49 | 2.42 | 0.97 | 1.96 | 1.67 | 0.29 |
| Technological resources          |      |      |                                  |      |      |                                  |              |              |
| Internet users (% of population) | 1.19 | 1.11 | 0.93 | 2.49 | 1.78 | 0.71 | 2.09 | 1.6  | 0.49 |
| Internet servers (per million people) | 0.01 | 0.06 | 6  | 13.25 | 8.62 | 0.65 | 1325 | 143.67 | 1181.33 |
| Fixed broadband subscriptions (per 100 people) | 1.18 | 2.02 | 1.71 | 3.49 | 2.42 | 0.69 | 2.96 | 1.2  | 1.76 |
| Fixed telephone subscriptions (per 100 people) | 1.22 | 1.04 | 0.85 | 2.74 | 2.74 | 1  | 2.25 | 2.63 | -0.38 |
| Mobile cellular subscriptions (per 100 people) | 0.82 | 1.01 | 1.23 | 1.21 | 1.20 | 0.99 | 1.48 | 1.18 | 0.3 |
| Sum                              | 4.42 | 5.24 | 1.19 | 23.18 | 16.76 | 0.72 | 5.24 | 3.2  | 2.04 |
| Total                            | 16.32 | 22.11 | 1.35 | 51.03 | 40.56 | 0.79 | 3.13 | 1.83 | -1.3 |

Source: own calculation from Tables 3 and 4
level of receipts for the use of intellectual properties is greatly lower than that of the USA (see Fig. 1). By our views, it is concerned to efficiency of research and development. For China and the USA, the authors calculated the efficiency of R&D expenditure based on primary data as follows (see Table 6).

As seen in Table 6, efficiency of R&D expenditures for the USA is greatly higher than that for China (by about 12.17 times in 2017). This shows that the USA mostly focuses on research related to core technology with high value-added. On the other hand, this shows that China must give an attention to qualitative growth of knowledge resources rather than quantitative growth in order to ensure sustainable development of own economy.

- **Human Resource**
  China falls behind the USA for all human resources. However, one can see that differences in change rates have appeared as of 2017. This shows that China has tried to decrease the differences of all aspects from the USA and has given particular attention to tertiary education. Accordingly, China has decreased the difference in sum of all aspects by about 2.52 times (5.46/2.17) as of 2017 compared to about 4.08 times (6.16/1.51) in 2010.

- **Financial Resource**
  China falls behind the USA for all financial resources. However, China has tried to decrease these differences from the USA. Accordingly, China has decreased the difference in sum of all aspects by about 1.67 times (2.43/1.45) as of 2017 compared to about 1.96 times (2.49/1.27) in 2010. In other words, China has paid more attention to R&D expenditure. This is proved by facts that while by 2017, R&D expenditure has reached the level of world average and decreased the difference of R&D expenditure (0.28 times) by more than that of education expenditure (0.25 times), the level of education expenditure has not reached the half level of world average for the whole period.

- **Technological Resource**
  China falls behind the USA for all technological resources. However, calculation results of change rates show that China has tried to decrease the differences in all technological resources (except for fixed telephone subscriptions) from the USA. The results of decreasing the differences are as follows: 0.49 (2.09–1.6) for Internet users,

| Table 6 | Efficiency of R&D expenditure for China and the USA (US$) |
|---|---|---|---|---|
| | Efficiency of R&D expenditure (per 10,000 US$) | Difference from world average (times) |
| China | USA | World | China | USA | Compared to USA |
| 2010 | 0.80 | 23.16 | 17.76 | 0.034 | 1.304 | 37.930 |
| 2011 | 0.55 | 24.91 | 18.27 | 0.022 | 1.364 | 61.436 |
| 2012 | 0.64 | 24.83 | 17.96 | 0.026 | 1.383 | 53.651 |
| 2013 | 0.46 | 25.03 | 19.32 | 0.019 | 1.295 | 69.901 |
| 2014 | 0.32 | 24.42 | 20.10 | 0.013 | 1.215 | 93.249 |
| 2015 | 0.47 | 22.44 | 21.02 | 0.021 | 1.068 | 50.492 |
| 2016 | 0.49 | 21.86 | 20.52 | 0.022 | 1.065 | 47.721 |
| 2017 | 1.82 | 21.48 | 20.85 | 0.085 | 1.031 | 12.172 |

Source: own calculation
1181.33 (1325–143.67) for Internet servers, 1.76 (2.96–1.2) for fixed broadband subscriptions, and 0.3 (1.48–1.18) for mobile cellular subscriptions, respectively. Among these, the greatest effort is devoted to decrease of difference in Internet servers. In other words, this shows that China has paid the greatest attention to construction of Internet which processes a great deal of data used in creating knowledge resources for period under study. As a result, China has decreased the difference in sum of all technological aspects by about 3.2 times as of 2017 compared to about 5.24 times in 2010.

• Total

While China’s difference from the USA is 3.13 (51.03/16.32) in 2010, that – 1.83 (40.56/22.11) in 2017. China has decreased the difference in total volume of KBES by about 1.3 times (3.13–1.83).

Next, the authors conducted the regression analysis to reveal the impacts of resources on result with regard to KBES. Another purpose of this study is in discussing the measures for strengthening KBES for China. In this context, there are needs to reveal the impacts of resource factors on economic growth within KBES. This may be possible on the basis of regression analysis. Also, regression analysis makes it possible to judge the goodness and significance of indicators in comparison and analysis between China and the USA. For regression analysis, the authors collected and calculated data for period of 2000–2019 based on premise regarding data explained in Subsection 3.3. In addition, the authors used the nonstandardized and relative values in regression analysis. The results of regression analysis are presented in Appendix. Regression equations according to countries can be described as follows (see Tables 9 and 10).

For China:

\[
Y_{China} = 1300.922 - 2.11X_1 - 4.175X_2 - 3.535X_3 \\
- 0.617X_4 + 1.5X_5 + 22.366X_6 + 286.272X_7 \\
- 156.978X_9 + 52.17X_{11} - 209.321X_{12} + 178.641X_{13}
\]

(5)

For the USA:

\[
Y_{US} = 104906.078 - 18.106X_1 - 10.849X_2 + 14.292X_3 \\
+ 15.579X_4 + 0.222X_5 - 146.298X_6 - 9735.679X_7 \\
+ 6.179X_9 + 504.549X_{11} - 396.767X_{12} + 7.576X_{13}
\]

(6)

where

\(Y_{China}\), GDP per capita for China;
\(Y_{US}\), GDP per capita for the USA;
\(X_1\), patent applications (residents, per million people); \(X_2\), scientific and technical journal articles (per million people); \(X_3\), industrial design applications (resident, per million people); \(X_4\), trademark applications (resident, per million people); \(X_5\), researchers in R&D (per million people); \(X_6\), school enrollment (tertiary, % gross); \(X_7\), research and development expenditure (% of GDP); \(X_9\), Internet users (% of population); \(X_{11}\), fixed broadband subscriptions (per 100 people); \(X_{12}\), fixed telephone subscriptions (per 100 people); and \(X_{13}\), mobile cellular subscriptions (per 100 people).
First, there is a need to test whether or not the above regression equations are statistically meaningful. In this part, hypotheses are made as follows:

Null hypothesis: \( H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{11} = \beta_{12} = \beta_{13} = 0 \) (not meaningful)

Alternative hypothesis: \( H_1: \) at least \( \beta_j \neq 0 \) (meaningful) where \( \beta \) – coefficient of regression.

To test abovementioned hypotheses, the authors conducted the analysis of variance (ANOVA) (see Table 8). As a result, the following is obtained.

Significance probability \( (p \text{- value}) = 0.000 < \alpha = 0.05 \)

From this result, it is concluded that these regression equations are statistically meaningful.

Second, there is a need to reveal the validity of regression analysis. For this, the authors calculated the contribution degree of independent variables, that is, coefficients of determination \( (R^2) \) (see Table 7).

From Table 7, one can see that for China and the USA, coefficients of determination are 0.999 and 0.998, respectively. This shows that while for China, independent variables explain 99.9% of changes in GDP per capita and error interval of GDP per capita is in \( \pm 122.2166 \) (US$), for the USA – 99.8% and \( \pm 616.86569 \) (US$), respectively. Thus, it can be believed that regression equations are statistically significant and valid.

Third, there is a need to reveal the significance of regression coefficients to explain the contribution of resource indicators to GDP per capita. For this, one can refer to \( t \) statistic in Tables 9 and 10. In general, it says that the larger the absolute value of \( t \) statistic is, the higher the contribution of independent variable is. According to \( t \) statistic in abovementioned tables, it can say that while for China, scientific and technical journal articles, researchers in R&D, school enrollment, research and development expenditure, fixed broadband subscriptions, and mobile cellular subscriptions have relatively great contribution to GDP per capita, for the USA – industrial design applications, trademark applications, researchers in R&D, Internet users, fixed broadband subscriptions, and mobile cellular subscriptions.

Fourth, there is a need to consider the multicollinearity problem among independent variables. The most logical case in regression analysis is the absence of collinearity between independent variables. However, social phenomena are closely related, and it is common for collinearity to exist to a certain extent among independent variables. From this, it is inevitable that multicollinearity exists in a regression model that includes all independent variables. The existence of multicollinearity could increase the standard error of the estimate, confuse the effect of the predictors, increase the variance, and cause instability in the equation. This requires that multicollinearity be considered in regression analysis. Multicollinearity statistics are represented by indicators such as variance inflation factor (VIF) and tolerance, and these indicators are in reciprocal relationships. The smaller the value of VIF, the more effective the regression equation is, and the higher the accuracy of the prediction is considered. In general, the value of VIF is said to be acceptable for
multiple regression when in the range of 5–10. The multicollinearity statistics presented in Tables 9 and 10 show that regression Eqs. (5) and (6), including all variables, cannot guarantee the accuracy of prediction. In order to alleviate or eliminate the multicollinearity, it is common to write a regression equation by including only representative independent variables. From this, the authors prepared a regression model corresponding to various cases by combining various factors of knowledge resources, human resources, and financial resources and calculated multicollinearity statistics accordingly. The reason why did not include technical resources in the regression model creation is based on the fact that the technical resources mentioned in the study do not practically directly affect the GDP per capita and therefore have weak explanatory power for the dependent variable. Multicollinearity statistics corresponding to eight cases by a combination of each representative explanatory variable are presented in Tables 9 and 10. According to the collinearity statistics, valid cases in China are 1st (X1, X5, X7) and 7th (X4, X5, X7), and all cases in the USA are applicable. To choose the best case for the study, the authors selected the cases where the standard error of estimation, multicollinearity (VIF), and standard deviation of residual were relatively small in the regression equations of these valid cases (see tables in the Appendix). According to this, the most suitable case in China is 1st (X1, X5, X7), and in the USA, 3th (X2, X5, X7), 6th (X3, X6, X7), and 8th (X4, X6, X7). Therefore, the regression equations accordingly are as follows.

For China:

$$Y_{China} = -2872.854 + 4.8911X_1 + 0.098X_5 + 3611.303X_7$$

(7)

For the USA:

$$Y_{US} = 1 + 16.358X_2 + 23.173X_5 + 6656.947X_7$$

(8)

$$Y_{US} = 38945.573 + 551.681X_3 + 111.554X_6 + 17809.132X_7$$

(9)

$$Y_{US} = -25617.408 + 38.144X_4 + 305.521X_5 + 3441.104X_7$$

(10)

where $Y_{China}$, GDP per capita for China; $Y_{US}$, GDP per capita for the USA; $X_1$, patent applications (residents, per million people); $X_2$, scientific and technical journal articles (per million people); $X_3$, industrial design applications (resident, per million people); $X_4$, trademark applications (resident, per million people); $X_5$, researchers in R&D (per million people); $X_6$, school enrollment (tertiary, % gross); and $X_7$, research and development expenditure (% of GDP).

According to the abovementioned regression equations, it is explained that while the number of patents, researchers, and R&D expenditure in China contributes mostly to the GDP per capita, all of the knowledge resources, researchers, school enrollment, and R&D expenses, that is, all of representative resources in the USA, contribute to the GDP per capita. In addition, checking the standardized residuals makes it possible to confirm the significance of regression analysis. From Table 11, one can see that absolute values of standardized residuals are below 2.5, and thus we can conclude that regression analysis is significant.
Conclusion

From the discussions of results, the following conclusions can be drawn. First, China falls behind the USA for all aspects of KBES except for some knowledge resources and high-technology exports. As of 2017, China is about 1.83 times lower than the USA for total value of KBES. This shows that China has paid more attention to high-technology manufactures, that is, tangible intellectual products rather than intangibles. It follows from that while the share of exports of high-technology manufactures is higher than that of the USA, receipts for use of intellectual properties – lower than that of the USA. Second, China has mostly focused on quantitative growth of knowledge resources rather than qualitative growth. According to our own calculations, efficiency of R&D expenditure (which is calculated as receipts for use of intellectual properties per R&D expenditure) is about 12.17 times lower than that of the USA in 2017 (see Table 6). Third, China has devoted many efforts to the decrease of differences in almost all aspects of KBES from the USA. It follows from that differences of China in most aspects of KBES from the USA in 2017 have significantly decreased compared to 2010 (see Table 5). Fourth, for both countries, degrees of contributions of resource indicators to GDP per capita are different. It follows from the regression analysis. According to regression Eqs. (7)–(10), while for China, the number of patents, researchers, and R&D expenditure contributes mostly to the GDP per capita, all of the knowledge resources, researchers, school enrollment, and R&D expenses, that is, all of representative resources in the USA, have relatively great contributions to the GDP per capita. From these conclusions, following recommendations for China can be suggested in order to ensure the sustainable development of Chinese economy based on KBES. First of all, it is necessary for China to enhance the efficiency of R&D, that is, to ensure qualitative improvement of R&D. This shows that China must focus on research related to core technology in the future. Next, it is necessary for China to create the institutional and social environments which make it possible to promote application of knowledge resources into practice more easily and rapidly. Next, it is necessary for China to devote own efforts more and more to overcoming the differences from the USA in aspects such as human resources, financial resources, and technological resources. Next, it is necessary for China to focus on effective use of knowledge resource. From the results of comparison and regression analysis, although China gets ahead of the USA with regard to some knowledge resource, its contributions to GDP per capita are relatively less than that of the USA (see Tables 5, 9, and 10).

Of course, this study has some limitations. First limitation is about accessibility of data. Among the detailed indicators for assessing KBES, some are available or accessible, but others – not. From this, it is necessary to use the substitutable indicators accessible to databases. For example, our study used the exports of high technology manufactures instead of the output of high-technology industry due to inaccessibility of data, and it is not seen that those replacement is correct. Second limitation is about period for study. Our study includes 8 years (2010–2017) for comparison and assessment, on the one hand, and 20 years (2010–2019) for correlation and regression analysis, on the other hand, due to missing data. As a result, we compared the values for 2010 with ones for 2017 and calculated the difference.
between two years for comparison and assessment among two countries. If data for this study is ensured or accessible for a longer period, the results of analysis may vary. In addition, we conducted the regression analysis focusing on multicollinearity problem. As a result, we included the representative independent variables to alleviate or eliminate the multicollinearity, and therefore, this study did not consider all the resources in regression analysis at the same time. Thus, it is seen that our study is valid, but it is conditional.

Nevertheless, this study can contribute to comparing and assessing the development level of region-specific or country-specific KBES and taking measures to strengthen it further. From above limitations, further research ought to be conducted in the following directions: (a) development of indicators available for assessment and accessible to databases, (b) inclusion of rightful period for study to ensure the objectivity of calculations and comparison, (c) selection of typical indicators applicable for all countries, and (d) consideration of all cases in statistical analysis.

Appendix Results of regression analysis

**Table 7** Contribution of independent variables to dependent variable

| Model | Independent variable | $R^2$ | Adjusted $R^2$ | Std. error of the estimate |
|-------|----------------------|-------|----------------|---------------------------|
| China | All                  | .999  | .999           | 122.21660                 |
|       | X1, X5, X7           | .984  | .981           | 450.41113                 |
|       | X1, X6, X7           | .984  | .981           | 445.36264                 |
|       | X2, X5, X7           | .960  | .952           | 708.83994                 |
|       | X2, X6, X7           | .973  | .968           | 581.08009                 |
|       | X3, X5, X7           | .958  | .950           | 725.22676                 |
|       | X3, X6, X7           | .984  | .981           | 442.87291                 |
|       | X4, X5, X7           | .981  | .978           | 479.63222                 |
|       | X4, X6, X7           | .982  | .978           | 478.80145                 |
| USA   | All                  | .998  | .995           | 616.86569                 |
|       | X1, X5, X7           | .938  | .927           | 2311.24155                |
|       | X1, X6, X7           | .881  | .859           | 3212.81860                |
|       | X2, X5, X7           | .916  | .900           | 2698.18664                |
|       | X2, X6, X7           | .740  | .692           | 4744.59295                |
|       | X3, X5, X7           | .934  | .922           | 2386.06735                |
|       | X3, X6, X7           | .922  | .908           | 2591.67370                |
|       | X4, X5, X7           | .968  | .962           | 1659.45504                |
|       | X4, X6, X7           | .984  | .980           | 1194.95590                |

Source: compiled by authors

*a*Predictors: (Constant), X1, patent applications (residents, per million people); X2, scientific and technical journal articles (per million people); X3, industrial design applications (resident, per million people); X4, trademark applications (resident, per million people); X5, researchers in R&D (per million people); X6, school enrollment (tertiary, % gross); X7, research and development expenditure (% of GDP); X9, Internet users (% of population); X11, fixed broadband subscriptions (per 100 people); X12, fixed telephone subscriptions (per 100 people); X13, mobile cellular subscriptions (per 100 people)

*b*Dependent variable: GDP per capita
### Table 8  Test of significance

| Country | Independent variable | Model | Sum of squares | df | Mean square | F     | Sig    |
|---------|----------------------|-------|----------------|----|-------------|-------|--------|
| China   | All                  | Regression 1.984E8 | 11 | 1.804E7 | 1.208E3 | .000a |
|         |                      | Residual 119495.184 | 8 | 14936.898 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X1, X5, X7           | Regression 1.953E8 | 3 | 6.510E7 | 320.876 | .000a |
|         |                      | Residual 3245922.928 | 16 | 202870.183 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X1, X6, X7           | Regression 1.954E8 | 3 | 6.512E7 | 328.313 | .000a |
|         |                      | Residual 3173566.148 | 16 | 198347.884 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X2, X5, X7           | Regression 1.905E8 | 3 | 6.350E7 | 126.376 | .000a |
|         |                      | Residual 8039264.919 | 16 | 502454.057 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X2, X6, X7           | Regression 1.931E8 | 3 | 6.438E7 | 190.660 | .000a |
|         |                      | Residual 5402465.075 | 16 | 337654.067 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X3, X5, X7           | Regression 1.901E8 | 3 | 6.337E7 | 120.492 | .000a |
|         |                      | Residual 8415261.706 | 16 | 525953.857 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X3, X6, X7           | Regression 1.954E8 | 3 | 6.513E7 | 332.075 | .000a |
|         |                      | Residual 3138182.699 | 16 | 196136.419 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X4, X5, X7           | Regression 1.949E8 | 3 | 6.495E7 | 282.339 | .000a |
|         |                      | Residual 3680753.033 | 16 | 230047.065 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
|         | X4, X6, X7           | Regression 1.949E8 | 3 | 6.496E7 | 283.338 | .000a |
|         |                      | Residual 3668013.180 | 16 | 229250.824 |        |        |
|         |                      | Total 1.985E8 | 19 |         |        |        |
Table 8 (continued)

| Country | Independent variable | Model | Sum of squares | df | Mean square | F     | Sig      |
|---------|----------------------|-------|---------------|----|-------------|-------|----------|
| USA     | All                  | Regression | 1.384E9 | 11 | 1.258E8 | 330.543 | .000³ |
|         |                      | Residual | 3044186.285 | 8 | 380523.286 |       |          |
|         |                      | Total    | 1.387E9 | 19 | 4.337E8 | 81.192 | .000³ |
| X1, X5, X7 | Regression | 1.301E9 | 3      |   |           |       |          |
|         |                      | Residual | 8.547E7 | 16 | 5341837.483 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |
| X1, X6, X7 | Regression | 1.221E9 | 3      |   | 4.072E8 | 39.444 | .000³ |
|         |                      | Residual | 1.652E8 | 16 | 1.032E7 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |
| X2, X5, X7 | Regression | 1.270E9 | 3      |   | 4.234E8 | 58.155 | .000³ |
|         |                      | Residual | 1.165E8 | 16 | 7280211.156 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |
| X2, X6, X7 | Regression | 1.026E9 | 3      |   | 3.421E8 | 15.199 | .000³ |
|         |                      | Residual | 3.602E8 | 16 | 2.251E7 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |
| X3, X5, X7 | Regression | 1.296E9 | 3      |   | 4.318E8 | 75.850 | .000³ |
|         |                      | Residual | 9.109E7 | 16 | 5693317.394 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |
| X3, X6, X7 | Regression | 1.279E9 | 3      |   | 4.264E8 | 63.480 | .000³ |
|         |                      | Residual | 1.075E8 | 16 | 6716772.559 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |
| X4, X5, X7 | Regression | 1.343E9 | 3      |   | 4.475E8 | 162.510 | .000³ |
|         |                      | Residual | 4.406E7 | 16 | 2753791.031 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |
| X4, X6, X7 | Regression | 1.364E9 | 3      |   | 4.546E8 | 318.358 | .000³ |
|         |                      | Residual | 2.285E7 | 16 | 1427919.598 |       |          |
|         |                      | Total    | 1.387E9 | 19 |           |       |          |

Source: compiled by authors

³Predictors: (Constant), X1, patent applications (residents, per million people); X2, scientific and technical journal articles (per million people); X3, industrial design applications (resident, per million people); X4, trademark applications (resident, per million people); X5, researchers in R&D (per million people); X6, school enrollment (tertiary, % gross); X7, research and development expenditure (% of GDP); X9, Internet users (% of population); X11, fixed broadband subscriptions (per 100 people); X12, fixed telephone subscriptions (per 100 people); X13, mobile cellular subscriptions (per 100 people)

bDependent variable: GDP per capita
Table 9 Regression coefficients for China

| Model | Unstandardized coefficients | Standardized coefficients | t | Sig | Collinearity statistics |
|-------|-----------------------------|---------------------------|---|-----|------------------------|
|       | B                           | Std. error                | Beta | Tolerance | VIF |
| All (Constant) | 1300.922 | 1507.871 | .863 | .413 | |
|         | −2.110                  | 1.508                     | −.225 | −1.399 | .199 | .003 | 343.979 |
| X1     | 4.175                   | 3.551                     | .140 | 1.176 | .273 | .005 | 189.721 |
| X2     | −3.535                  | 2.300                     | −.188 | −1.537 | .163 | .005 | 199.300 |
| X3     | −.617                   | .296                      | −.302 | −2.088 | .070 | .004 | 277.753 |
| X4     | 1.500                   | .814                      | .113 | 1.843 | .103 | .020 | 50.110 |
| X5     | 22.366                  | 13.773                    | .102 | 1.624 | .143 | .019 | 52.312 |
| X6     | 286.272                 | 1679.393                  | .039 | 1.70  | .869 | .001 | 682.677 |
| X7     | −156.978                | 67.323                    | −1.043 | −2.332 | .048 | .000 | 2.659E3 |
| X8     | 52.170                  | 49.998                    | .164 | 1.043 | .327 | .003 | 330.341 |
| X9     | −209.321                | 60.174                    | −.329 | −3.479 | .008 | .008 | 118.805 |
| X10    | 178.641                 | 49.139                    | 2.029 | 3.635 | .007 | .000 | 4.139E3 |
| 1 (Constant) | −2872.854 | 741.205                  | −3.876 | .001 | |
| X1     | 4.890                   | .725                      | .522 | 6.741 | .000 | .171 | 5.859 |
| X5     | .098                    | .940                      | .007 | .104  | .918 | .203 | 4.919 |
| X7     | 3611.303                | 671.627                   | .487 | 5.377 | .000 | .124 | 8.039 |
| 2 (Constant) | −2790.591 | 693.929                  | −4.021 | .001 | |
| X1     | 5.666                   | 1.428                     | .604 | 3.968 | .001 | .043 | 23.218 |
| X6     | −24.459                 | 39.890                    | −1.11 | −.613 | .548 | .030 | 33.044 |
| X7     | 3875.920                | 667.676                   | .523 | 5.805 | .000 | .123 | 8.126 |
| 3 (Constant) | −1340.087 | 2014.701                 | −.665 | .515 | |
| X2     | 27.365                  | 9.221                     | .921 | 2.968 | .009 | .026 | 38.036 |
| X5     | −1.795                  | 1.790                     | −.135 | −1.002 | .331 | .139 | 7.207 |
| X7     | 1371.865                | 1912.910                  | .185 | .717  | .484 | .038 | 26.331 |
| 4 (Constant) | −2580.927 | 1266.302                 | −2.038 | .058 | |
| X2     | 11.444                  | 7.031                     | .385 | 1.628 | .123 | .030 | 32.906 |
| X6     | 89.784                  | 29.435                    | .409 | 3.050 | .008 | .095 | 10.569 |
| X7     | 1534.766                | 1530.570                  | .207 | 1.003 | .331 | .040 | 25.084 |
| 5 (Constant) | −2535.867 | 1741.344                 | −1.456 | .165 | |
| X3     | 12.201                  | 4.398                     | .650 | 2.775 | .014 | .048 | 20.686 |
| X5     | 1.796                   | 1.495                     | .135 | 1.201 | .247 | .208 | 4.802 |
| X7     | 1580.500                | 1961.906                  | .213 | .806  | .432 | .038 | 26.459 |
| 6 (Constant) | −338.114   | 1131.568                 | −.299 | .769 | |
| X3     | 10.723                  | 2.672                     | .571 | 4.013 | .001 | .049 | 20.479 |
| X6     | 108.665                 | 19.589                    | .495 | 5.547 | .000 | .124 | 8.058 |
| X7     | −390.916                | 1191.258                  | −.053 | −.328 | .747 | .038 | 26.159 |
| 7 (Constant) | −4836.798 | 567.152                  | −8.528 | .000 | |
| X4     | .659                    | .107                      | .322 | 6.179 | .000 | .426 | 2.349 |
| X5     | −.481                   | 1.024                     | −.036 | −.470 | .645 | .194 | 5.153 |
| X7     | 5654.587                | 566.327                   | .763 | 9.985 | .000 | .198 | 5.041 |
Table 9 (continued)

| Model | Unstandardized coefficients | Standardized coefficients | t | Sig | Collinearity statistics |
|-------|-----------------------------|---------------------------|---|-----|-------------------------|
|       | B   | Std. error | Beta |     | Tolerance | VIF |
| 8     | (Constant) | -4733.269 | 657.743 | -7.196 | .000 | |
|       | X4  | .574   | .169  | .281 | 3.386 | .004 | .168 | 5.945 |
|       | X6  | 18.468 | 35.080 | .084 | .526 | .606 | .045 | 22.110 |
|       | X7  | 5059.157 | 835.291 | .683 | 6.057 | .000 | .091 | 11.004 |

Source: compiled by authors

a Dependent variable: GDP per capita

b Predictors: (Constant), X1, patent applications (residents, per million people); X2, scientific and technical journal articles (per million people); X3, industrial design applications (resident, per million people); X4, trademark applications (resident, per million people); X5, researchers in R&D (per million people); X6, school enrollment (tertiary, % gross); X7, research and development expenditure (% of GDP); X9, Internet users (% of population); X11, fixed broadband subscriptions (per 100 people); X12, fixed telephone subscriptions (per 100 people); X13, mobile cellular subscriptions (per 100 people)
| Model | Unstandardized coefficients | Standardized coefficients | t  | Sig | Collinearity statistics |
|-------|-----------------------------|---------------------------|----|-----|------------------------|
|       | B                           | Std. error                | Beta |     | Tolerance | VIF |
| All (Constant) | 104906.078 | 34635.834 | 3.029 | .016 |           |     |
|       | X1  | −18.106 | 9.698 | −.232 | −1.867 | .099 | 56.152 |
|       | X2  | −10.849 | 11.711 | −.122 | −.926 | .381 | 62.963 |
|       | X3  | 14.292 | 76.577 | .019 | .187 | .857 | 37.315 |
|       | X4  | 15.579 | 4.334 | .323 | 3.595 | .007 | 29.374 |
|       | X5  | .222 | 2.187 | .007 | .102 | .921 | 18.655 |
|       | X6  | −146.298 | 79.291 | −.124 | −1.845 | .102 | 16.361 |
|       | X7  | −9735.679 | 5009.657 | −.122 | −1.943 | .088 | 14.342 |
|       | X9  | 6.179 | 63.665 | .009 | .097 | .925 | 29.053 |
|       | X11 | 504.549 | 348.091 | .621 | 1.449 | .185 | 668.060 |
|       | X12 | −396.767 | 154.449 | −.542 | −2.569 | .033 | 162.156 |
|       | X13 | 7.576 | 74.854 | .026 | .101 | .922 | 234.984 |
| 1 (Constant) | −56565.174 | 15091.657 | −3.748 | .002 |           |     |
|       | X1  | 31.206 | 9.610 | .399 | 3.247 | .005 | 3.927 |
|       | X5  | 16.770 | 4.315 | .549 | 3.886 | .001 | 5.176 |
|       | X7  | 5507.303 | 7652.032 | .069 | .720 | .482 | 2.384 |
| 2 (Constant) | −48497.816 | 21788.537 | −2.226 | .041 |           |     |
|       | X1  | 61.349 | 12.549 | .785 | 4.889 | .000 | 3.466 |
|       | X6  | −53.093 | 170.748 | −.045 | −.311 | .760 | 2.797 |
|       | X7  | 20301.655 | 9275.858 | .254 | 2.189 | .044 | 1.813 |
| 3 (Constant) | −81666.253 | 16585.018 | −4.924 | .000 |           |     |
|       | X2  | 16.358 | 8.772 | .184 | 1.865 | .081 | 1.847 |
|       | X5  | 23.173 | 4.004 | .758 | 5.787 | .000 | 3.270 |
|       | X7  | 6656.947 | 8929.959 | .083 | .745 | .467 | 2.382 |
| 4 (Constant) | −114107.156 | 28417.700 | −4.015 | .001 |           |     |
|       | X2  | 41.026 | 27.072 | .460 | 1.515 | .149 | 5.688 |
|       | X6  | 28.570 | 374.471 | .024 | .076 | .940 | 6.168 |
|       | X7  | 40502.022 | 12286.141 | .507 | 3.297 | .005 | 1.458 |
| 5 (Constant) | −47430.305 | 17174.258 | −2.762 | .014 |           |     |
|       | X3  | 376.718 | 126.231 | .498 | 2.984 | .009 | 6.777 |
|       | X5  | 11.807 | 5.939 | .386 | 1.988 | .064 | 9.200 |
|       | X7  | 10636.441 | 8026.248 | .133 | 1.325 | .204 | 2.461 |
| 6 (Constant) | −38945.573 | 17846.698 | −2.182 | .044 |           |     |
|       | X3  | 551.681 | 81.949 | .729 | 6.732 | .000 | 2.421 |
|       | X6  | 111.554 | 116.843 | .094 | .955 | .354 | 2.013 |
|       | X7  | 17809.132 | 7500.403 | .223 | 2.374 | .030 | 1.821 |
| 7 (Constant) | −34622.888 | 12122.784 | −2.856 | .011 |           |     |
|       | X4  | 28.663 | 4.811 | .594 | 5.958 | .000 | 5.002 |
|       | X5  | 12.067 | 3.279 | .395 | 3.680 | .002 | 5.799 |
|       | X7  | 2216.820 | 5534.320 | .028 | .401 | .694 | 2.419 |
Table 10 (continued)

| Modelb | Unstandardized coefficients | Standardized coefficients | t | Sig | Collinearity statistics |
|--------|-----------------------------|---------------------------|---|-----|-------------------------|
|        | B                           | Std. error                | Beta | Tolerance | VIF |
| 8      | (Constant) −25617.408       | 8392.001                  | −3.053 | .008     |                |
|        | X4 38.144                   | 2.311                     | .790 | 16.506 | .000  | .449         | 2.226 |
|        | X6 305.521                  | 47.734                    | .258 | 6.401  | .000  | .633         | 1.580 |
|        | X7 3441.104                 | 3817.954                  | .043 | .901   | .381  | .450         | 2.220 |

Source: compiled by authors

Dependent variable: GDP per capita

Predictors: (Constant), X1, patent applications (residents, per million people); X2, scientific and technical journal articles (per million people); X3, industrial design applications (resident, per million people); X4, trademark applications (resident, per million people); X5, researchers in R&D (per million people); X6, school enrollment (tertiary, % gross); X7, research and development expenditure (% of GDP); X9, Internet users (% of population); X11, fixed broadband subscriptions (per 100 people); X12, fixed telephone subscriptions (per 100 people); X13, mobile cellular subscriptions (per 100 people)
Table 11  Residuals statistics\(^a\)

| Case (set of independent variables) | Indicator       | China                        | USA                        |
|-----------------------------------|-----------------|------------------------------|----------------------------|
|                                   | Minimum         | Maximum                      | Mean                       | Std. Deviation | Minimum         | Maximum                      | Mean                       | Std. Deviation |
| All                               | Predicted value | 864.3561                     | 1.0199E4                   | 4.8082E3       | 3231.54516     | 3.6456E4                     | 6.4793E4                   | 4.9396E4       | 8533.43797    |
|                                  | Residual        | -1.61843E2                   | 1.78343E2                  | .00000         | 79.30460       | -1.03818E3                    | 6.47433E2                  | .00000         | 400.27532     |
|                                  | Std. predicted value | -1.220                     | 1.668                      | .000         | 1.000          | -1.516                        | 1.804                      | .000         | 1.000         |
|                                  | Std. residual   | -1.324                       | 1.459                      | .000         | .649           | -1.683                        | 1.050                      | .000         | .649          |
| X1, X5, X7                       | Predicted value | 492.2199                     | 9.8423E3                   | 4.8082E3      | 3205.98340     | 3.4779E4                     | 6.1172E4                   | 4.9396E4       | 8275.34860    |
|                                  | Residual        | -9.26152E2                   | 8.40569E2                  | .00000        | 413.32560      | -3.67882E3                    | 5.16353E3                  | .00000        | 2120.94070    |
|                                  | Std. predicted value | -1.346                     | 1.570                      | .000         | 1.000          | -1.766                        | 1.423                      | .000         | 1.000         |
|                                  | Std. residual   | -2.056                       | 1.866                      | .000         | .918           | -1.592                        | 2.234                      | .000         | .918          |
| X1, X6, X7                       | Predicted value | 587.0557                     | 9.8963E3                   | 4.8082E3      | 3206.57817     | 3.7126E4                     | 5.9530E4                   | 4.9396E4       | 8017.94251    |
|                                  | Residual        | -9.46141E2                   | 9.49500E2                  | .00000        | 408.69279      | -4.56075E3                    | 7.71601E3                  | .00000        | 2948.28454    |
|                                  | Std. predicted value | -1.316                     | 1.587                      | .000         | 1.000          | -1.530                        | 1.264                      | .000         | 1.000         |
|                                  | Std. residual   | -2.124                       | 2.132                      | .000         | .918           | -1.420                        | 2.402                      | .000         | .918          |
| X2, X5, X7                       | Predicted value | 64.5121                      | 9.5553E3                   | 4.8082E3      | 3166.39450     | 3.4533E4                     | 6.1103E4                   | 4.9396E4       | 8176.12865    |
|                                  | Residual        | -1.47223E3                   | 8.94858E2                  | .00000        | 650.47614      | -6.01931E3                    | 4.69474E3                  | .00000        | 2476.02587    |
|                                  | Std. predicted value | -1.498                     | 1.499                      | .000         | 1.000          | -1.818                        | 1.432                      | .000         | 1.000         |
|                                  | Std. residual   | -2.077                       | 1.262                      | .000         | .918           | -2.231                        | 1.740                      | .000         | .918          |
| X2, X6, X7                       | Predicted value | -52.5405                     | 9.8399E3                   | 4.8082E3      | 3188.23354     | 3.73494E4                    | 5.7168E4                   | 4.9396E4       | 7350.03508    |
|                                  | Residual        | -8.96000E2                   | 1.01191E3                  | .00000        | 533.23566      | -8.51367E3                    | 9.18249E3                  | .00000        | 4353.93710    |
|                                  | Std. predicted value | -1.525                     | 1.578                      | .000         | 1.000          | -1.639                        | 1.057                      | .000         | 1.000         |
|                                  | Std. residual   | -1.542                       | 1.741                      | .000         | .918           | -1.794                        | 1.935                      | .000         | .918          |
| X3, X5, X7                       | Predicted value | 196.9764                     | 9.1665E3                   | 4.8082E3      | 3163.26806     | 3.7224E4                     | 6.2025E4                   | 4.9396E4       | 8257.44581    |
|                                  | Residual        | -1.23899E3                   | 1.39848E3                  | .00000        | 665.51372      | -4.09569E3                    | 4.13853E3                  | .00000        | 2189.60557    |
|                                  | Std. predicted value | -1.458                     | 1.378                      | .000         | 1.000          | -1.474                        | 1.529                      | .000         | 1.000         |
|                                  | Std. residual   | -1.708                       | 1.928                      | .000         | .918           | -1.717                        | 1.734                      | .000         | .918          |
Table 11 (continued)

| Case (set of independent variables) | Indicator | China                            | USA                            |
|------------------------------------|----------|----------------------------------|--------------------------------|
|                                    |          | Minimum                          | Maximum                        | Mean             | Std. Deviation     | Minimum                          | Maximum                        | Mean             | Std. Deviation     |
| X3, X6, X7                         | Predicted value | 454.2133                        | 9.916E3                        | 4.8082E3         | 3206.86854        | 3.7422E4                        | 6.1792E4                | 4.9396E4        | 8.205.09320      |
|                                    | Residual            | -8.41239E2                      | 9.12307E2                      | .000000          | 406.40806         | -3.84045E3                      | 5.39763E3               | .000000          | 2378.28289       |
|                                    | Std. predicted value            | -1.358                          | 1.593                          | .000000          | 1.000             | -1.459                          | 1.511                | .000000          | 1.000             |
|                                    | Std. residual                      | -1.900                          | 2.060                          | .000000          | .918              | -1.482                          | 2.083                | .000000          | .918              |
| X4, X5, X7                         | Predicted value | 204.8397                        | 1.0185E4                        | 4.8082E3         | 3202.41308        | 3.7857E4                        | 6.5071E4               | 4.9396E4        | 8.405.99797      |
|                                    | Residual            | -7.12630E2                      | 7.54530E2                      | .000000          | 440.14071         | -3.01391E3                      | 2.78190E3               | .000000          | 1522.82038       |
|                                    | Std. predicted value            | -1.437                          | 1.679                          | .000000          | 1.000             | -1.373                          | 1.865                | .000000          | 1.000             |
|                                    | Std. residual                      | -1.486                          | 1.573                          | .000000          | .918              | -1.186                          | 1.676                | .000000          | .918              |
| X4, X6, X7                         | Predicted value | 143.0885                        | 1.01764                        | 4.8082E3         | 3202.51776        | 3.6695E4                        | 6.4437E4               | 4.9396E4        | 8.472.14998      |
|                                    | Residual            | -7.64830E2                      | 8.16282E2                      | .000000          | 439.37834         | -2.13651E3                      | 1.46540E3               | .000000          | 1096.56674       |
|                                    | Std. predicted value            | -1.457                          | 1.676                          | .000000          | 1.000             | -1.499                          | 1.775                | .000000          | 1.000             |
|                                    | Std. residual                      | -1.597                          | 1.705                          | .000000          | .918              | -1.788                          | 1.226                | .000000          | .918              |

*aDependent variable: GDP per capita

*b$X1$ patent applications (residents, per million people), $X2$ scientific and technical journal articles (per million people), $X3$ industrial design applications (resident, per million people), $X4$ trademark applications (resident, per million people), $X5$ researchers in R&D (per million people), $X6$ school enrollment (tertiary, % gross), $X7$ research and development expenditure (% of GDP), $X9$ Internet users (% of population), $X11$ fixed broadband subscriptions (per 100 people), $X12$ fixed telephone subscriptions (per 100 people), $X13$ mobile cellular subscriptions (per 100 people)

Source: compiled by authors
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Declarations

Conflicts of Interest  The authors declare no competing interests.

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