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Shaping the future of application for information and communication technology in national economic analysis

Xiaojie Tu, Zhuofang Li*, Songyan Xie, Rongyi Yan, and Kairui Zuo

Abstract: Characterized by networking, digitization, and intellectualization, the new generation of Information and Communication Technologies (ICTs) has promoted integration of various national economic industries, with a more significant leading role in the socio-economic development. In order to describe the influence of ICT industries on economic growth, this paper has comprehensively analyzed the contribution mechanism of ICTs to current economy. Crucial indicators, such as Total Telecommunications Business (TTB), Data Traffic (DT), and Computing Power Development Index (CPDI), have been innovatively selected to sufficiently describe the data circulation scale and the processing capacity in the era of digital economy. Based on relevant statistics of 31 provinces (municipalities or autonomous regions) in China from 2011 to 2020, quantitative results have been put forward to interpret the impact of ICT industries on the national economy development by using correlation coefficient analysis and data regression analysis methods. The measurement results show that TTB, DT, and CPDI are positively correlated with the national economic development, indicating that each 1% increasement of TTB, DT, and CPDI increases Gross Domestic Product (GDP) by 0.08%, 0.09%, and 0.6%, respectively.

Key words: Information and Communication Technology (ICT); Gross Domestic Product (GDP); Total Telecommunications Business (TTB); Data Traffic (DT); Computing Power Development Index (CPDI)

1 Introduction

As one of the most important driving forces for socio-economic development, Information and Communication Technologies (ICTs) have gained wide attention in recent years. With the continuous promotion of the new round of scientific and technological revolution and industrial change, the improvement of ICTs is no longer stuck in the stage of individual breakthrough in the fields of mobile communication and Internet, but evolves to a new stage of novel technology explosion, where big data, Artificial Intelligence (AI), cloud computing, Internet of Things (IoT) and other new techniques have enabled collaborative innovations and converged progresses in different fields, based on 5G/6G communication networks. As a result, the booming of digital technologies has stimulated ICT industries to accelerate digital transformation for Chinese digital economy upgrading[1−6] .

Characterized by networking, digitalization, and intellectualization, the new generation of ICTs is deeply integrated with various national economic professions, leading to continuous innovations of industrial techniques, profound reforms of management modes, and further improvement of total factor production efficiency. That is, the basic, strategic and pioneering role of ICT industries in the national economy is becoming more and more prominent. In general, it mainly contains the following three aspects: (1) the exploitation and utilization of social information resources are effectively strengthened by using advanced high-quality telecommunications services; (2) massive data are collected and managed to support

• Xiaojie Tu, Zhuofang Li, Songyan Xie, Rongyi Yan, and Kairui Zuo are with the China Academy of Information and Communications Technology, Beijing 100191, China. E-mail: tuxiaojie@caict.ac.cn; lizhuofang@caict.ac.cn; xiesongyan@caict.ac.cn; yanrongyi@caict.ac.cn; zuokairui@caict.ac.cn.
∗ To whom correspondence should be addressed.
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industrial development via ubiquitous intelligent terminals; (3) the global, regional, or whole-process collaborative optimization and intelligent decision-making can be realized based on distributed high-performance computing resources. Consequently, high-quality telecommunications services, massive data traffic, and profound Computing Power (CP) have become typical indicators to measure the development level of the new generation of ICTs in each country, driving the growth of digital economy scale and promoting further integration between digital economy and real economy.

In order to accurately quantify the effect of ICTs on national economic operations, scholars have conducted numerous studies to verify the relationships between ICT industries and economic growth all over the world[7−15]. Focused on the impact of ICT capital investment on economic growth and productivity enhancement, Refs. [16−19] performed dynamic analysis and cointegration analysis on panel data, indicating that increasement of ICT capital stock can significantly stimulate long-term GDP growth. By studying GDP and productivity growth patterns in Organization for Economic Co-operation and Development (OECD) countries, Ref. [20] found that the technological updating embedded in new ICT capital products is the main source of output and productivity gains in ICT application sectors. Based on the Vector Error Correction Model (VECM), Ref. [21] showed that Korea’s GDP grew by 0.4% for every 1% increasement in ICT investment. For the influence relationships between ICT industries and national economic development, input-output analysis, regression analysis, cointegration analysis, and production function analysis have been applied[22−27]. References [28−33] studied the relationship between ICT industries and regional economic growth in Yangtze River Delta, central and western China, Guangxi, Anhui, Shaanxi, Xinjiang, and so on. Around the impact of ICT service penetration on the operation efficiency of economy and society, Refs. [34, 35] analyzed the driving effect of broadband services on China’s national economic growth; Refs. [36, 37] found that there was an overall positive net effect of cell phone penetration on national economic growth by analyzing panel data of several sub-Saharan African countries.

As shown in the above literatures, the effect of traditional ICT industries on national economic development has been mainly analyzed in terms of ICT capital investment, ICT industry scale, and penetration rate of key services. However, with the development of the new generation of ICTs, existing research results are limited due to the lack of comprehensive consideration on factors, such as productivity improvement, quality enhancement, and digital capability. In fact, in the field of traditional ICTs, telecommunications business has been incorporated into national economic accounting via relevant indicators, such as value indices of value-added telecommunications business and total telecommunications business, as well as physical indices of telecommunications services. In the field of emerging ICTs, on the one hand, digital technologies continue to penetrate into different industries, owing to the continous development and integration of 5G, IoTs, big data, and other technologies. Thus, massive industrial data have become the main carrier of information and communication business, reflecting the transmission and utilization of data production factors. On the other hand, 5G/6G, Mobile Edge Computing (MEC), AI, and other frontier technologies vigorously promote the ubiquity of computing resources, and CP has become the most important productivity in the era of digital economy, representing the construction level and development potential of digital industries in each country.

To address the presented issue, this paper has comprehensively analyzed the promotion mechanism of the new generation of ICTs on socio-economic growth. Then key indicators, such as TTB, DT, and CPDI, have been chosen to characterize the scale of data circulation and the processing capacity in the whole society. Within this framework, the quantitative relationship between ICT industries and national economic development has been deeply explored by utilizing correlation coefficient analysis, panel data regression, and cross-sectional data regression.

Empirical validations have been conducted based on the statistics of 31 provinces (municipalities or autonomous regions) in China from 2011 to 2020. Finally, research conclusions are drawn up. The main innovation points of this paper are summarized as follows:

(1) This paper has creatively introduced indicators, such as TTB, DT, and CPDI, to comprehensively analyze the impact of the new generation of ICTs on socio-economic development.

(2) Within the proposed framework, the improvement effects of ICTs on national economic growth have been quantitatively analyzed based on real industrial statistics.

The rest of this paper is organized into 4 sections. Section 2 mainly demonstrates the mechanism of the new generation of ICTs affecting economic growth and selects corresponding key indicators. In Section 3, the description of measurement model and statistical data are presented, constructing the data regression analysis model and explaining relevant variables. The measurement results are shown in Section 4, which are based on statistics of 31 provinces (municipalities or autonomous regions) in China from 2011 to 2020, and main remarks are drawn up. Finally, the conclusion of this paper and the future research plan are included in Section 5.

2 Design of indicators

2.1 Influence mechanism of ICTs on economic development

With the deep integration between the new generation of ICTs and various professions, ICT industries have effectively promoted the development and utilization of information resources in the whole society. Furthermore, social transaction costs have been significantly reduced by promoting knowledge spillover, reducing information asymmetry, optimizing factor resource allocation, and so on. Hence, national economy operates continuously smoothly, which provides a strong impetus to support the high-quality economic and social development. The influence can be summarized in the following three aspects.

(1) TTB

Until now, telecommunications business has been incorporated into national economic accounting via three ways. (1) The value-added telecommunications business is directly incorporated into national or regional GDP accounting. By using the value-added rate method, the total output of value-added telecommunications business is calculated at current prices, and then the current value-added rate is determined based on the annual report information last year and relevant production status in the current period. Finally, the added value is obtained by multiplying the above two terms. For example, the value-added telecommunications business in 2021 is 799.69 billion RMB, which is directly included in the national GDP accounting of that year. (2) As a value index of telecommunications business, TTB affects local GDP accounting and national value-added service accounting quarterly. Based on the growth rate of TTB and other statistical information, the value-added growth rates of information transmission, software, and information technology services are projected. Then, the current value-added regional quarterly GDP accounting and national quarterly value-added service accounting are derived by multiplying the added value in the same time last year by the projected growth rate. (3) As a physical index of telecommunications business excluding price factors, TTB is directly included in the statistics of monthly service industry production index in order to reflect the short-term (monthly) output changes of economic activities in the enterprise market of service industries.

(2) DT

In recent years, digital technologies have been continuously penetrating into various national production fields, employing data as the main carrier of information and communication services and driving socio-economic growth. As a key production factor, massive data are increasingly relevant to national economy, as shown in Fig. 1. On the one hand, data comprehensively optimize the production supply level. By leading innovation, promoting cross-border integration, optimizing factor allocation, and reforming production organization, data can effectively inspire

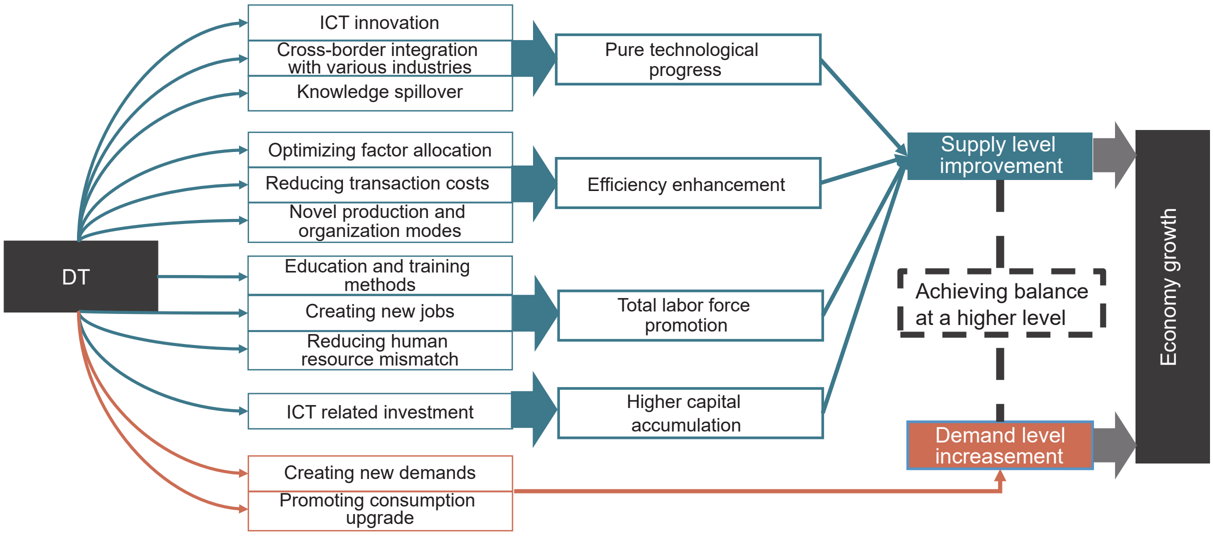

Fig. 1 Impacting mechanism of DT on economic growth.

technological progress, accelerate capital accumulation, as well as enrich human resources, which enhances the supply level and gives a strong impetus to promote economic growth. On the other hand, data significantly raise the level of consumer demands. By promoting information consumption to activate the large domestic market, data help to achieve a higher level of balance between domestic supply and demand, playing an important driving role in maintaining economic growth. Along with China's rapid digitalization process, the fundament role of DT has become more and more prominent in promoting productivity and transforming production relation. As an important representation of both the emerging service industries and the digital transformation of traditional manufacturing industries, DT can more comprehensively reflect the development of global economy in the new era.

(3) CP

As emerging technologies, such as big data, AI, and MEC, accelerate the technological innovation of traditional industries, the digital economy has been flourishing. By strategically bearing the operation of information systems in various industries, CP has become one of the core productivities in the digital economy era, supporting the development of digital economy, digital society, and digital government, as shown in Fig. 2. In the field of digital economy, CP helps to process massive industrial data, accelerate the

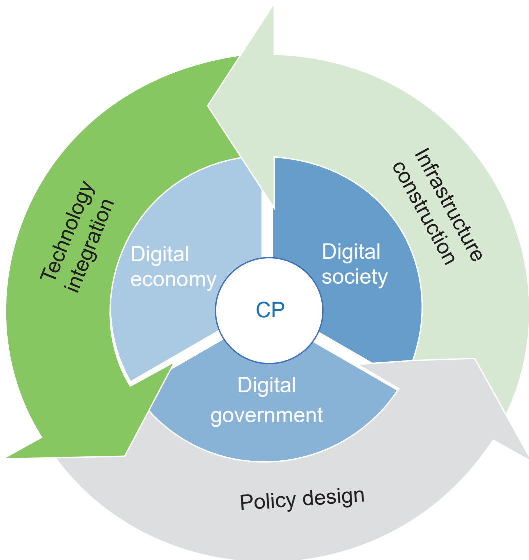

Fig. 2 Impacting mechanism of CP on economic growth.

circulation of data factors, and promote the development of data trading market, which improves quality and efficiency with intelligent decision-making abilities. In the field of digital society, CP is useful to construct new business modes, such as online office, consumer entertainment, telemedicine, and so on, helping the government cooperate with market and multiple social subjects to develop, govern, and share the whole society. In the field of digital government, CP enables us to create a complete management system with multi-level and multi-dimensional collaborative development capability in politics, economy, society, culture, and ecological civilization[38]. On this basis, the construction of CP infrastructure, the formulation of national strategic policies, and the integrated innovation of emerging technologies are mutually driven and jointly empowered. Hence, the connotation of CP keeps outreaching extensively, and CP becomes one of the key elements driving the current national economic development. According to “National Strategic Computing Initiative Update: Pioneering the Future of Computing” released by the United States in 2019, CP has been included in the national development strategy. As illustrated in the “2021−2022 Global Computing Power Index Assessment Report” jointly reported by International Data Corporation (IDC), Longchamp Information, and Tsinghua University Global Industry Research Institute, the digital economy and GDP grow by 3.5‰ and 1.8‰ for every 1 point increase in CP on average, respectively.

2.2 Selection of key indicators

At present, ICTs are deeply integrated with the real economy in China. Consequently, penetration rates of cell phone users and fixed broadband users have exceeded 100%, and the penetration rate of mobile Internet users has also exceeded 90%. Compared with user penetration rate, physical indicators, such as actual service usage, can better measure the integration level between ICTs and the real economy, the circulation degree of data elements, and the scale of computing resources.

For the sake of data availability and representativeness, this paper selects TTB, DT, and CPDI as the key indicators to measure the interaction relationships between the new generation of ICTs and the development level of national economy, which are denoted as T_s, D_t, and C_p, respectively. From the aspect of productivity factors, TTB describes the social use of telecommunications services, reflecting the development of digital services, the activeness of digital business, and the achievement of enabling tertiary industries; DT represents the transmission and utilization of data production factors, accurately characterizing the fluctuations of socio-economic levels in real time; CPDI shows the capability of aggregating, processing, and transacting massive industrial data, indicating the scale of digital market and the development potential of digital economy.

According to the existing statistics of ICT industries, TTB is obtained by converting 6 types of business volume into monetary amounts at constant prices and summing them up, which contains fixed and mobile voice, fixed data and Internet services, mobile data and Internet, mobile value-added service and emerging businesses; DT is the sum of access data traffic from both mobile Internet networks and fixed Internet broadband; CPDI is a comprehensive development index of CP scale, CP environment, and CP application, where CP scale mainly includes basic CP, intelligent CP, and supercomputing power.

3 Model construction and data description

3.1 Correlation analysis

In order to study the correlation relationship between the selected indicators of ICT industries and the development level of national economy, this paper adopts Pearson correlation coefficient to evaluate the correlation relationships between T_s, D_t, C_p, and GDP, which is governed by

$$\rho_{X_i,G} = \frac{\mathrm{cov}(X_i, G_t)}{\sigma_{X_i}\sigma_{G_t}} = \frac{E(X_i G_t) - E(X_i)E(G_t)}{\sqrt{E(X_i{}^2) - E^2(X_i)}\sqrt{E(G_t{}^2) - E^2(G_t)}} \quad (1)$$

where $X_i (i = 1,2,3)$ denote statistics of TTB, DT, and CPDI, respectively; G_t is GDP at constant prices of time t; $E(\cdot)$ represents the expectation of data; $\rho_{X_i,G}$ is the corresponding correlation coefficient satisfying $\rho_{X_i,G} \in [-1,1]$, where the closer the value of $|\rho_{X_i,G}|$ is to 1, the more highly correlated it is. In this paper, it is considered to be directly correlated enough with GDP for statistics X_i being applied for regression analysis in the case $|\rho_{X_i,G}| > 0.6$.

3.2 Model construction

In order to quantitatively analyze the influence relationships between the new generation of ICTs and national economy development, according to the empirical research methods on the relationships between telecommunications industries and economic growth proposed by scholars such as Pradhan et al.[39], Chakraborty and Nandi[40], as well as the ideas on the relationships between telecommunications infrastructure/Internet and total factor productivity presented by scholars, such as Jin and Li[41], and Guo and Luo[42], the following regression analysis model is introduced for statistical indicators significantly correlated with GDP,

$$\ln G_{i,t} = \beta_0 + \beta_1 \ln T_{c_{i,t}} + \beta_2 \ln K_{i,t} + \beta_3 \ln L_{i,t} + \mu_i + \varepsilon_{i,t} \quad (2)$$

where i denotes the i-th region and t is time (year); $\ln(\cdot)$ represents natural logarithm operation; G denotes the explained variables; T_c denotes key indicators of ICT industries; K and L are control variables; μ denotes non-observed individual fixed effects, and ε denotes stochastic errors.

In Eq. (2), the explained variable is GDP at constant prices in a given year, which represents the development of domestic economy. According to the mechanism analysis in Section 2, TTB, DT, and CPDI can more comprehensively reflect the development level of the world economy in the new era. According to the correlation analysis results in Section 3.1, explaining variables T_c can be selected as indicators such as TTB, DT, and CPDI. As for actual measurement analysis, GDP and ICT industry statistics of 31 provinces (municipalities or autonomous regions) in China from 2011 to 2020 are used.

The control variables include two core elements: labor and capital, where K denotes the actual capital stock and L represents the total labor force. The total number of employees in the tertiary industry is chosen as the labor factor. Since there is no direct statistical data on capital stock in China, inspired by relevant estimation methods in previous literatures, the capital stock is derived according to the perpetual inventory method[43]. The estimation formula is given by

$$F_{i,t} = (1 - \delta_{i,t}) K_{i,t-1} + I_{i,t} \quad (3)$$

where $F_{i,t}$ is the total value of social fixed assets in each region at the base period price of time t; $K_{i,t-1}$ is the total value of social fixed assets in each region at the base period price of time $t-1$; $\delta_{i,t}$ is the depreciation rate, generally taken as 5%; $I_{i,t}$ is the amount of investment in fixed assets at the base period price of time t.

3.3 Description of statistics

The statistics of 31 provinces (municipalities or autonomous regions) in China from 2011 to 2020 are chosen as the sample for measurement analysis. Because the constant unit price of TTB is updated every five years, TTB from 2011 to 2015 is calculated based on the constant unit price in 2010, and that from 2016 to 2020 is calculated based on the constant unit price in 2015. Since TTBs calculated on different benchmarks are not comparable, for the sake of convenience, statistics of GDP, TTB, and DT are divided into two datasets according to the time periods of 2011−2015 and 2016−2020, in order to measure correlation relationships as well as regression analysis based on panel data. GDP is calculated with constant price values for the base period according to the price index. Owing to the fact that the fixed asset investment price index in 2020 has not yet been published, that in 2019 is used for estimation. DT is the sum of mobile data traffic and fixed data traffic, which is gathered from 2016 nationwide, so the correlation and regression analyses between GDP and DT are conducted only from 2016 to 2020. The calculation of CPDI adopts relevant industrial statistics released by China Academy of Information and Communications Technology (CAICT) , which is started from 2020 and statistics in 2021 have not yet been released. Therefore, the correlation and regression analysis of CPDI is performed via the cross-sectional data in 2020.

According to available statistics, for GDP and TTB, either contains 155 observations for the above two time periods; for GDP and DT, a total of 155 observations are included; for GDP and CPDI, there are 31 observations. The reliability of correlation coefficient calculation and panel data regression analysis can be ensured by utilizing a relatively large amount of data. The description of variables used in the empirical measurement is shown in Table 1.

4 Measurement result

4.1 Correlation analysis result

4.1.1 Correlation relationship between TTB and GDP

According to Section 3.1, the correlation relationship

Table 1 Description of relevant measurement variables.

Variable type	Symbol	Description	Number of observations
Explained variable	G	GDP at constant prices	310
Explaining variable	T_s	TTB in distinct regions during different periods	310
	D_t	DT in distinct regions during different periods	155
	C_p	CPDI in distinct regions	31
Control variable	K	Actual capital stock	310
	L	Total labor force	310

between TTB and GDP for each region in different periods is considered into two datasets. The first one is TTB and GDP of Chinese 31 provinces (municipalities or autonomous regions) from 2011 to 2015, and the second one is those from 2016 to 2020. Based on Eq. (1), the correlation coefficient of TTB and GDP in 31 provinces (municipalities or autonomous regions) from 2011 to 2015 is 0.912, being highly positively correlated, and the scatter plot is shown in Fig. 3. That is 0.694 from 2016 to 2020, which is also positively correlated but weakened compared with the previous period from 2011 to 2015, and the scatter plot is illustrated in Fig. 4.

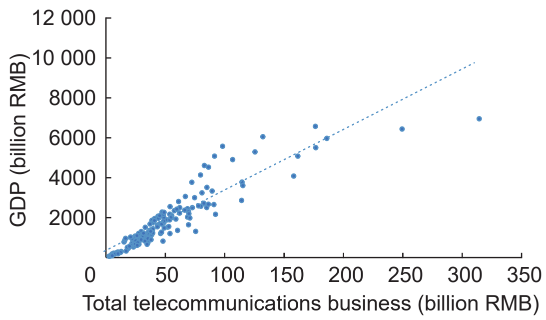

Fig. 3 Correlation relationship between TTB and GDP from 2011 to 2015 (calculated at the constant price of 2010).

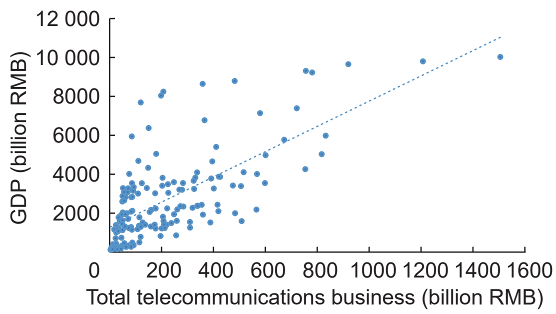

Fig. 4 Correlation relationship between TTB and GDP from 2016 to 2020 (calculated at the constant price of 2015).

4.1.2 Correlation relationship between DT and GDP

Since China started to comprehensively gather statistics of DT from 2016, the correlation relationship between DT and GDP is analyzed only from 2016 to 2020. Based on Eq. (1), the correlation coefficient between DT and GDP for 31 provinces (municipalities or autonomous regions) in China from 2016 to 2020 is 0.769, indicating an obviously positive correlation. The scatter plot is presented in Fig. 5, which fully demonstrates the important role of DT in promoting the development of productivity and the revolution of production relations in the digital economy era.

4.1.3 Correlation relationship between CPDI and GDP

In 2021, CAICT released “White Paper for Computing Power Development Index of China”, which provides relevant statistics for 31 provinces (municipalities or autonomous regions) in China in 2020. By using the given cross-section dataset of CPDI, the correlation coefficient between CPDI and GDP for 31 provinces (municipalities or autonomous regions) in China in 2020 is analyzed. The calculation result is 0.8336, showing a significant positive correlation. The scatter plot is presented in Fig. 6.

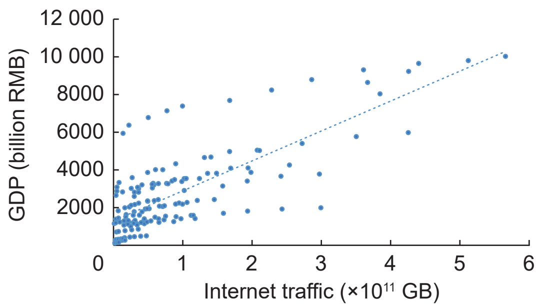

Fig. 5 Correlation relationship between DT and GDP from 2016 to 2020 (calculated at the constant price of 2015).

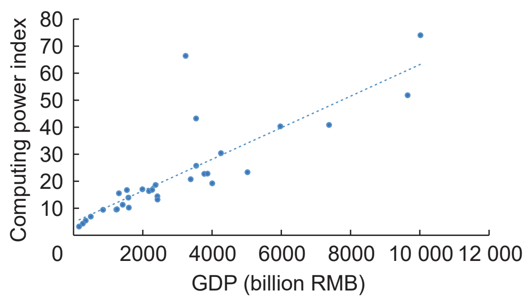

Fig. 6 Correlation relationship between CPDI and GDP in 2020 (calculated at the constant price of 2015).

4.2 Analysis results based on regression models

In this section, we select statistical data of GDP, TTB, DT, and CPDI of 31 provinces (municipalities or autonomous regions) in China in different periods as samples for regression analysis. As shown in the context below, Model 1 refers to the regression model in Eq. (2) where T_c represents TTB from 2011 to 2015. Similarly, Model 2 takes TTB from 2016 to 2020 as the core explaining variable; Model 3 takes DT from 2016 to 2020 as the core explaining variable; and Model 4 takes CPDI in 2020 as the core explaining variable. The regression analysis results of different models are shown in Tables 2 and 3. Results in Tables 2 and 3 are calculated by EVIEWS 11, where *** indicates statistically significant level at 1% and ** indicates significant level at 5%.

4.3 Main remarks

(1) Within the framework of transforming technology systems in digital and intelligence ways, ICT industries are closely related to the national economy development.

Nowadays, the new generation of ICT revolutions is deepening the high-quality development of national economy. In this context, the integrated innovation and synergistic development of 5G, AI, IoT, big data, cloud computing and other technologies are urging new industrial modes to emerge. Aa a result, crucial digital production factors, represented by telecommunications services, DT and CP, are promoted to enhance circulation and exchange, leading to the rapid development of digital economy.

Table 2 Regression analysis results of Models 1 and 2.

Variable	Model 1 (2011–2015)	Model 2 (2016–2020)
Explained variable	T_s	T_s
Explaining variable	D_t	C_p
TTB	1.1785***	0.0874***
Capital	0.1797***	0.6587***
Labor	0.0761***	0.2645**
Intercept term	–	–
Sample capacity	155	155

Table 3 Regression analysis results of Models 3 and 4.

Variable	Model 3 (2016–2020)	Model 4 (2020)
Explained variable	GDP	GDP
Explaining variable	D_t	C_p
DT	0.0767***	–
CPDI	–	0. 6196***
Capital	0.8415***	0.4769***
Labor	0.1550***	0.2012***
Intercept term	−1.5615***	1.3695***
Sample capacity	155	31

According to measurement results in Section 4.1, the current national economic development is closely related to key indicators of TTB, DT, and CPDI. From 2011 to 2015, the correlation coefficient between TTB and GDP was 0.912, inferring that they are highly correlated and promoted mutually. However, that decreased to 0.694 from 2016 to 2020. The decline reasons of the correlation coefficient between TTB and GDP are comprehensively complex, which have been analyzed and summarized as follows. From the perspective of economic development, the correlation coefficient between TTB and GDP have been calculated for 31 provinces (municipalities or autonomous regions) in China from 2016 to 2020 in Table 4, indicating that the growth rates of TTB significantly exceeded those of GDP in this period. Since the global industrial production processes slowed down, international trade stayed relatively in a depression status with a fluctuating financial market. Therefore, China's economic development was also influenced to a certain extent. Meanwhile, China implemented the "speed and fee reduction" policy, the abolition of roaming fees, and the "broadband & dedicated line tariff reduction" policy, which further promoted the development of telecommunications industries during this period. According to the official data released by the Ministry of Industry and Information Technology, although the growth of telecommunications business revenue decreased, TTB increased significantly, showing its important contribution to telecommunications industries. New-emerging industries based on novel ICTs, such as big data, cloud computing and IoT, were strengthening forward and backward promotions on other industries, gradually showing the supporting effect on GDP. From the perspective of technology development, as one of

Table 4 Correlation coefficient of TTB and GDP for 31 provinces (municipalities or autonomous regions) in China from 2016 to 2020.

Province	CAGR of TTB	CAGR of GDP
Anhui	0.793 892	0.068 828
Beijing	0.550 545	0.051 478
Fujian	0.606 692	0.067 543
Gansu	0.823 817	0.048 924
Guangdong	0.660 274	0.056 805
Guangxi	0.876 558	0.058 915
Guizhou	0.972 781	0.080 034
Hainan	0.738 605	0.055 173
Hebei	0.769 520	0.058 929
Henan	0.814 245	0.057 884
Heilongjiang	0.598 924	0.038 333
Hubei	0.690 505	0.042 154
Hunan	0.787 084	0.067 856
Jilin	0.687 663	0.037 187
Jiangsu	0.664 753	0.058 664
Jiangxi	0.739 506	0.072 801
Liaoning	0.607 526	0.039 303
Inner Mongolia	0.804 436	0.036 294
Ningxia	0.768 480	0.061 167
Qinghai	0.877 466	0.054 487
Shandong	0.705 327	0.055 906
Shanxi	0.752 896	0.057 671
Shaanxi	0.730 439	0.059 727
Shanghai	0.545 128	0.053 526
Sichuan	0.802 363	0.068 102
Tianjing	0.733 429	0.032 428
Tibet	0.899 143	0.086 966
Xinjiang	0.871 568	0.058 140
Yunnan	0.832 385	0.076 032
Zhejiang	0.656 126	0.063 126
Chongqing	0.742 712	0.063 576

Note: CAGR represents the compound annual growth rate.

crucial hardware carriers for the information society, the development of advanced process technologies of Integrated Circuits (ICs) is becoming extremely difficult. Performance improvements and cost reductions based on Moore’s Law tended to get saturated. Consequently, the economic promotion effect produced by progress technologies of ICs and optimization of traditional ICTs, was going to shrink down, but that of the new generation of ICTs is becoming more prominent. From 2016 to 2020, the correlation coefficient between DT and GDP was 0.769, indicating that DT has been widely transmitted and used in social production. As an important digital production factor, DT plays an important role in socio-economic development. As digital technologies are continuously penetrating into more industrial fields, statistics from the private network (including Intranet) may be included into DT, together with mobile as well as fixed Internet access traffic in the future. In this case, it is expected that DT will show a stronger positive correlation with GDP. According to the cross-sectional analysis results of CP statistics, the correlation coefficient between the CPDI and GDP of China in 2020 was 0.8336. That is, with the increasing scale of DT, CP reflects national data processing capacity of industrial data and development potential, and also as an emerging production factor, it has a significant positive effect on promoting the digital economy development. Overall, there is a strong correlation between ICT industries and GDP, and the new generation of ICTs effectively enhances the operation of national economy.

(2) Under the background of the comprehensive development of digital economy, the key indicators of the new generation of ICTs have made significant positive contributions to national economic development.

Based on the mechanism analysis, in the era of digital economy, the new generation of ICTs promotes the digital transformation of various industries. In general, TTB reflects the development of digital services and the activity of digital business; DT characterizes the transmission and utilization of data production factors in socio-economic development; CPDI indicates the digital market scale and digital economic development potential shown by the capability of massive data processing and transaction.

According to the regression analysis results of panel data, the regression coefficient of $\ln(T_s)$ is 1.1785 in Model 1, which is significant at 1% level, indicating that GDP increases by 1.18% for every 1% up in TTB from 2011 to 2015; in Model 2, the regression coefficient of $\ln(T_s)$ is 0.0874 at the same significance level, indicating that GDP increases by 0.09% for every 1% up in TTB from 2016 to 2020; in Model 3, the regression coefficient of $\ln(D_t)$ is 0.0767 at 1% level of significance, indicating that GDP increases by 0.08% for every 1% up in DT from 2016 to 2020; in Model 4, the regression coefficient of $\ln(C_p)$ is 0.6196 at 1% level of significance, indicating that GDP increases by 0.6% for every 1% up in CPDI in 2020. To sum up, from 2016 to 2020, the growth rate of TTB and DT exceeds 20%, driving an average annual GDP growth of about 1.6 percentage points.

(3) The proposed indicators are supposed to get involved in the national economic analysis framework, to fully reflect economic development in the new era.

As shown in the context, this paper have analyzed the promotion influence of the new generation of ICTs on national economic development from the spillover effects of key indicators, based on theoretical analysis and empirical validations. At present, the influence of TTB has been recognized nationwide, and incorporated into regional economic accounting. Although DT and CPDI have not been directly incorporated into economic accounting at the regional or national level, their important supporting role has been generally recognized as prominent production factors in the digital economy era. Under this trend, the proposed key indicators of TTB, DT, and CPDI can be involved into the national economic analysis framework to strengthen the positive feedback effect between ICTs and national economic development, which is important for exploring the dividends of data resources and computing capability. Furthermore, the development of digital economy, as well as the comprehensive national power, will be improved.

5 Conclusion

With the deepening digital transformation of industries and the accelerating digital industrialization, ICTs have played a more and more significant role in the development of national economy. In order to comprehensively study the influence relationship between ICT industries and national economic development, this paper has selected TTB, DT, and CPDI as key indicators to comprehensively and qualitatively analyze the promotion mechanism of the new generation of ICTs on social and economic growth. Actually, TTB reflects the development of digital services, the activeness of digital business, and the achievement of enabling tertiary industries; DT describes both transmission and utilization of data production factors; and CPDI shows the level of aggregation, processing, and transaction of massive industrial data. Within the given framework, this paper has quantitatively analyzed the positive effect of ICTs on national economic growth by using correlation coefficient analysis and data regression analysis. Based on statistics of 31 provinces (municipalities or autonomous regions) in China from 2011 to 2020, empirical validations have been performed to verify the proposed conclusions.

In the future, more indicators of ICT industries will be continuously involved to improve comprehensiveness and accuracy. Besides statistics from mobile Internet, fixed broadband, and cloud computing, DT and CP from private networks (including Intranet) and MEC will be also considered to enable digital industries, further enhancing its explanation of economic growth.

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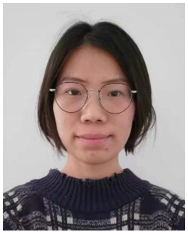

Songyan Xie received the master degree of finance from Tianjin University of Finance and Economics, Tianjin, China in 2017. She is currently a researcher at China Academy of Information and Communications Technology (CAICT). Her current research interest is information and communications technology.

Rongyi Yan received the BEng degree in automation from Shandong University, Jinan, China in 2010, and the PhD degree from Tsinghua University, Beijing, China in 2017. He is currently a senior engineer at CAICT. His current research interests include information and communication industry analysis and integrated circuit industry analysis.

Kairui Zuo received the PhD degree in innovation management from University of Chinese Academy of Sciences, China in 2014. He is currently a senior engineer at CAICT. His current research interests include 5G/6G, AI, and future industries.

Xiaojie Tu received the BEng and PhD degrees in communication and information system from Beihang University, Beijing, China in 2008 and 2014, respectively. He is currently a senior engineer at CAICT, Beijing, China. He was the final judge of ASEAN ICT Awards in 2019 and 2021. His current research is focused on the development of information and communication industry, integrated circuit industry, and other strategic emerging industries.

Zhuofang Li received the MEng degree in telecommunication and information system from China Academy of Telecommunication Technology (CATT), Beijing, China in 2007. She is currently a chief engineer at CAICT. Her current research is focused on the standardization, technical trial, and industrial research of mobile communication and wireless access technologies. She received the First Prize of Business Science and Technology Progress Award of China General Chamber of Commerce in 2016.