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Estimation of China’s Investment in ICT Assets and Accumulated ICT Capital Stock

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Abstract

Despite the extraordinary impact of information and communication technologies (ICTs) on the Chinese economy, no systematic information is provided on ICT investment by Chinese official statistics. We make the first attempt to estimate such investment using China’s total investment in equipment by industry controlled by China’s national accounts, constructed by the CIP (China Industrial Productivity) Project, and the relationship between the ICT equipment investment and ICT service intermediate input, as observed in the Japanese economy. We show that over the entire period from 1978 to 2018, China’s investment in the ICT equipment grew by 21.8 percent per annum, which was nearly twice the investment in non-ICT equipment. The share of the ICT investment in China’s nominal GDP peaked in 2002 at 2.7 percent, then declined to approximately 1 percent in the recent years. Similarly, the ICT investment share in the nominal gross fixed capital formation (GFCF) peaked in 2002 at 7.7 percent and then declined to 2.4 percent in 2018, largely attributable to the government’s unprecedented investment in infrastructure to sustain growth. By 2018, China’s ICT intensity, measured as the share of the ICT equipment in the total equipment stock, had reached 10.6 percent, approximately 65 percent that of Japan (16.4 percent in 2015) and 71 percent that of the US (15.0 percent in 2017). In sectoral comparisons, we show that China’s service sector is more-ICT intensive (17.3) than its industrial sector (5.4), a pattern similar to, but with a narrower spread than that in Japan (25.8 vs. 4.5 in 2015), and the US (21.1 vs. 3.8 in 2017).

JEL classification: C82, E22, E24

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ESTIMATION OF CHINA'S INVESTMENT IN ICT ASSETS AND ACCUMULATED ICT CAPITAL STOCK*

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ABSTRACT

Despite the extraordinary impact of information and communication technologies (ICTs) on the Chinese economy, no systematic information is provided on ICT investment by Chinese official statistics. We make the first attempt to estimate such investment using China's total investment in equipment by industry controlled by China's national accounts, constructed by the CIP (China Industrial Productivity) Project, and the relationship between the ICT equipment investment and ICT service intermediate input, as observed in the Japanese economy. We show that over the entire period from 1978 to 2018, China's investment in the ICT equipment grew by 21.8 percent per annum, which was nearly twice the investment in non-ICT equipment. The share of the ICT investment in China's nominal GDP peaked in 2002 at 2.7 percent, then declined to approximately 1 percent in the recent years. Similarly, the ICT investment share in the nominal gross fixed capital formation (GFCF) peaked in 2002 at 7.7 percent and then declined to 2.4 percent in 2018, largely attributable to the government's unprecedented investment in infrastructure to sustain growth. By 2018, China's ICT intensity, measured as the share of the ICT equipment in the total equipment stock, had reached 10.6 percent, approximately 65 percent that of Japan (16.4 percent in 2015) and 71 percent that of the US (15.0 percent in 2017). In sectoral comparisons, we show that China's service sector is more-ICT intensive (17.3) than its industrial sector (5.4), a pattern similar to but with a narrower spread than that in Japan (25.8 vs. 4.5 in 2015), and the US (21.1 vs. 3.8 in 2017).

Keywords**:** information and communication technologies (ICTs); ICT investment; ICT capital stock; input-output tables.

***JEL* Classification:** C82, E22, E24

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1. INTRODUCTION

The exponential improvement in the efficiency of information and communication technologies (ICTs) as predicted by Moore's Law, and the precipitous decline in the prices of the ICT equipment have greatly benefited the growth of developing economies like China, which is not only ambitiously open to new technologies but also facilitated by the government's industrial policies that have led to a rapid expansion of manufacturing capacities. On the other side of the coin, China's entry into ICT manufacturing from the lower end of the technology and then gradually moved up along the global value chains of ICTs must also have significantly facilitated the world's ICT advancement, given China's comparative advantage in the mass production of standard, yet cheap ICT parts, and in turn furthered China's growth.

The logic of such an understanding of the role of ICTs in China's growth has not, however, been empirically examined with official statistics that allow any direct measures of the inputs and outputs of ICT manufacturers and productive users. China's growth performance has been impressive in terms of the output or value added by the ICT-related industries. As showed by the latest global manufacturing data from the United Nations Industrial and Development Organization (UNIDO), by 2018 China had overtaken the US as the world's largest manufacturer of ICT products (parts and equipment).

China's growth from an ICT perspective was first assessed by Wu and Liang (2017) in a Jorgensonian industry-origin growth accounting framework. Notwithstanding the absence of a direct measure of ICT assets, they identified Chinese ICT-producing and using industries based on observations of the US economy, as documented in Jorgenson (2001) and Jorgenson *et al*. (2005). Despite their high appraisal about the role of the so-defined ICT industries in China's growth and productivity performance, they were unable to acknowledge or measure the contribution of the ICT capital stock to the growth without a proper estimation of ICT investment by industry.

The significance of ICT capital in the growth and productivity performance has been well established in the literature. In one of the pioneering studies that account for the role of ICT in advanced economies, Jorgenson (2001) shows that the ICT capital services in the US showed a robust growth from 11.5 percent per annum over 1990–1995 to 19.4 percent per annum over 1995–1999, which was in a sharp contrast to the non-ICT capital services increasing merely from 1.7 percent to 2.9 percent over the same period. Particularly from 1995 to 1999, ICT products (both equipment and software) contributed 0.5 percentage points (ppts) out of the 0.75 percent annual total factor productivity (TFP) growth, accounting for nearly 67 percent of the aggregate TFP, despite the latter accounting for only 29 percent of the 4.08 percent annual GDP growth in the US.

In the case of Europe, O'Mahony and van Ark (2003) showed that in 15 European Union member states, the ICT-producing industries enjoyed a labor productivity growth of 7.5 percent per annum over 1995–2001, much higher than that of the overall economy (1.7 percent per annum). Focusing on the ICT investment and economic growth in nine OECD countries, Colecchia and Schreyer (2002) found that along with a significant decline in the prices of ICT capital goods over 1980–2000, these countries experienced a remarkable increase in the rate of investment in ICT equipment. On average, the ICT capital services contributed between 0.2 and 0.5 ppts to the annual economic growth ranging from 2.0 to 3.8 percent per annum. In the second half of the 1990s, the contribution rose to 0.3 to 0.9 ppts per year out of 1.0 to 5.6 percent annual output growth.

In a comparative study of Japan and South Korea, Fukao *et al.* (2009) found that the growth in the ICT investment in the two economies was phenomenal during the period from 1995 to 2005, at 13.1 percent and 15.5 percent per annum, respectively. However, it concludes that the aggregate TFP growth appears to be more attributable to ICT-producing industries than to ICT-using industries in both Japan and Korea.

In a recent study, Fukao, Kim and Kwon (2021) used the JIP and EU KLEMS databases to compare the ICT capital input between the US and Japan. Unexpectedly, the study finds that the US was not necessarily more ICT-intensive in its production activities than Japan during the period from 1995 to 2015. Moreover, in both countries, the ICT intensity, which is defined as the share of the ICT capital service in the total capital service, is higher in the non-manufacturing sector than that in the manufacturing sector. The intermediate ICT service share in value added in Japan is nearly twice as high as that in the US in the finance, wholesale, and retail sectors. The authors suggest that this could be attributable to the higher ICT assets and service prices in Japan. The growth rate of ICT capital stock is higher than that of the total capital stock in both countries. However, it is slower in Japan than in the US.

However, the lack of statistics on the ICT investment at the industry level has prevented us from directly identifying and measuring individual Chinese industries with a specific role and a level of importance in ICT. This paper is a preliminary attempt to construct the ICT tangible assets, computer and communication equipment, in China's capital stock. The study reported in this paper is heavily data-driven and measurement-oriented. First, we estimate China's ICT investment flows at the macro level through CIP/China KLEMS reconstructed input-output accounts in a time series. Then, the industry-level distribution of ICT investment spending is gauged using an econometric approach to explore the relationships between the change in ICT intensity and the change in intermediate input from the ICT service producers using the detailed industry level Japan Industrial Productivity (JIP) database 2015.

The remainder of this paper is organized as follows: Section 2 explains how the annual ICT investment flows are constructed for the aggregate economy and individual industries, respectively, and introduces the integration with the CIP capital account. Section 3 summarizes our estimates of the prices of ICT assets and net ICT capital stock by industry through the perpetual inventory method. Section 4 presents the estimated results and compares China with the US and Japan. Finally, Section 5 concludes the paper and discusses future research priorities.

2. Construction of Annual ICT Investment Flows

As there are no ICT equipment investment data reported in the Chinese official statistics, we need to estimate them using the information available from various sources and indirect approaches. This section presents the methodology used to estimate the flows of ICT equipment investment for the aggregate Chinese economy and in each industry from 1977 to 2018.

Deriving the macro-level annual ICT investment spending

First, we estimate the investment in information technology (IT) and communication technology (CT) equipment separately for the aggregate economy, which is consistent with the data in national accounts. The commodity flow method is the preferred approach to derive the annual ICT investment series when official statistics are unavailable (van Ark, 2002):

$$(2.1) \qquad I_{ICT,t} = \frac{I_{ICT,T}^{IO}}{(Y_{ICT,T}^{IO}+IM_{ICT,T}^{IO}-EX_{ICT,T}^{IO})}\left(Y_{ICT,t}+IM_{ICT,t}-EX_{ICT,t}\right)$$

where $I_{ICT,t}$ is the current gross fixed capital formation (GFCF) of ICT-producing industries in year t. Y is gross domestic output, IM imports, and EX exports. Superscript IO refers to input-output tables, and T is the benchmark year for the IO table. All other variables without superscript IO are time-series data obtained from the national accounts.

This supply-side method traces specific commodities from their domestic production and imports to their final demand, excluding exports. More precisely, commodity-based supply and use tables (SUTs) combined with production, import and export data for ICT equipment could serve our purpose. The SUTs show the domestic production (excluding exports) and imports destined to investment. While doing this, we exclude the ICT goods for household consumption use. We identify two manufacturing industries as ICT equipment producers in the CIP industry classification, electronic and telecommunication equipment (CIP code 21), and instruments and office equipment (CIP 22),which are in line with the international standard industrial classification (ISIC) revision 3 sector numbers 30, 32, and 33. In the CIP time-series SUTs,[1] the GFCF of these two ICT commodities: office machinery and computers as IT equipment; and radio, television, and communication equipment as CT equipment, from two ICT manufacturing producers are used to estimate the ICT equipment investment for the aggregate economy.

Estimating the industry-level ICT investment distributions

Estimating the industry-level ICT investment is a more challenging task because no statistics on ICT investment are directly available at the industry level. Therefore, the strategy we adopt to indirectly estimate the industry level distribution of ICT investment is to explore the relationship between the ICT investment and the relevant variables using an econometric approach. The IO tables could provide us with linkages across industries, particularly the intermediate matrix, which highlights the inter-industry relationships covering all sectors in the economy. We could access the time-series IO tables and detailed industry-level ICT investment statistics for Japan from the JIP database and time-series IO tables for China from the CIP database.

The basic idea of the empirical strategy is to explore the relationship between the ICT equipment investment and intermediate ICT service using the JIP database. Then, we apply the estimated coefficients of intermediate ICT service to Chinese data to predict the industry level distribution of ICT equipment investment in China. The IO tables show that the majority of industries receive the intermediate input from the ICT-producing service sector, which includes hardware and software consultancy, maintenance of computing equipment, data processing, and telecommunication services. According to the SNA and OECD (2009), the expenditure on assets will be capitalized only if a purchase has a “useful life of more than one year”. However, this does not take into account for all ICT investments. For instance, a firm’s purchase of a

[1] See Wu and Ito (2015) for details on construction of China’s supply-use and input-output accounts in time series.

software with a one-year license will be recorded as intermediate consumption. In general, these intermediate ICT services need to be delivered through the ICT equipment during the production activities. Hence, industry-level ICT hardware investments should be responsive to the changes in the intermediate ICT services.

To estimate the industry level distribution of ICT investment, we first investigate how ICT equipment investment intensity responds to the changes in the intermediate ICT service intensity. The panel data regression model is set as follows:

$$\widetilde{ICT}_{jt} = \alpha + \beta_1 \widetilde{MICTS}_{jt} + \beta_2 t + \beta_3 t^2 + \theta_j + \epsilon_{jt} \quad (2.1)$$

where the dependent variable is $\widetilde{ICT}_{jt}$, the deviation from the mean of ICT hardware investment intensity for industry j in year t; the main independent variable is $\widetilde{MICTS}_{jt}$, the deviation from the mean of intermediate ICT service intensity for industry j in year t; and other control variables include time trend t and its quadratic term t^2, and the industry dummy variable θ_j, which represents industry fixed effects, and will thus enable us to control for the industry-specific characteristics and avoid some criticism on omitted variables. Finally, ϵ_{jt} is the error term.

Some may argue that it is better to estimate the ICT investment function. However, some key variables such as ICT capital stock, user cost, and spillover effect of ICT assets and R&D capital stock are required to estimate the ICT investment function, similar to Miyagawa and Hamagata (2004). First, due to data unavailability, we could not obtain data on these key independent variables for such an estimation, including the ICT capital stock data to estimate the user cost of ICT assets. Then, the different purposes made us leave this estimation strategy to the future research to draw policy implications for ICT investment.

The data used to estimate the coefficients in the above regression model come from the JIP database 2015, which is compiled by the RIETI Asian Industrial Productivity Program and the IER at Hitotsubashi University.[2] This dataset covers 107 industries in the Japanese economy from 1970 to 2012 and provides time-series IO tables and data on ICT assets. From this dataset, we chose data on 106 industries over 1990–2012.[3] Telegraph and telephone services (JIP code 78), and information and Internet-based services (JIP 91) are distinguished from the JIP industry classification as CT- and IT-producing services, respectively, which produce intermediate ICT services for other sectors. Furthermore, according to the assets concordance between the JIP and EU KLEMS databases (see Table A2 for details), we identify the general equipment: asset type nos.14, 15, and 18 in the JIP investment matrix as IT equipment, and asset type nos. 19 and 20 as CT equipment.

ICT hardware investment intensity, $\widetilde{ICT}_{jt}$, is defined as the share of ICT equipment investment in the total equipment investment of industry j in year t and is measured as the deviation from the mean intensity of the aggregate economy, which means that it equals to one for industries with the same intensity as that of the aggregate economy and is greater or less

[2] The JIP database could provide us the most detailed industry information, asset types and relatively long time series data satisfying our purpose among the KLEMS-type data sets. See Fukao *et al.* (2007) for details.

[3] The housing sector with no ICT assets is removed from our sample. Given the rapid diffusion of ICT in production due to the swiftly falling semiconductor prices, we chose the sample data starting from the 1990s when a substantial acceleration in the development and deployment of ICT occurred in the major developed economies.

than one for industries with higher or lower intensity than that of the aggregate economy. As the IT and CT equipment have significant differences in price and depreciation processes, we estimate them separately. Three variables, dev_ict_ieqp, dev_it_ieqp and dev_ct_ieqp, are constructed to measure the ICT, IT and CT investment intensity of each industry:

$$dev\_ict\_ieqp_{jt} = \left(\frac{i\_ICT_{jt}}{i\_eqp_{jt}}\right) / \left(\frac{\sum_j i\_ICT_{jt}}{\sum_j i\_eqp_{jt}}\right) \tag{2.2a}$$

$$dev\_it\_ieqp_{jt} = \left(\frac{i\_IT_{jt}}{i\_eqp_{jt}}\right) / \left(\frac{\sum_j i\_IT_{jt}}{\sum_j i\_eqp_{jt}}\right) \tag{2.2b}$$

$$dev\_ct\_ieqp_{jt} = \left(\frac{i\_CT_{jt}}{i\_eqp_{jt}}\right) / \left(\frac{\sum_j i\_CT_{jt}}{\sum_j i\_eqp_{jt}}\right) \tag{2.2c}$$

where the variables i_ICT_{jt}, i_IT_{jt} and i_CT_{jt} are the investments in ICT, IT, and CT equipment, respectively, and the variable i_eqp_{jt} is the total equipment investment of industry j in year t.

Similarly, intermediate ICT service intensity, $\widetilde{MICTS}_{jt}$, is defined as the share of intermediate ICT service in the total intermediate input of industry j in year t and is measured as the deviation from the mean intensity of the aggregate economy. In addition, three variables, dev_micts_m, dev_mits_m and dev_mcts_m, are constructed to measure the intermediate ICT, IT, and CT service intensity of each industry:

$$dev\_micts\_m_{jt} = \left(\frac{m\_ICTS_{jt}}{m_{jt}}\right) / \left(\frac{\sum_j m\_ICTS_{jt}}{\sum_j m_{jt}}\right) \tag{2.3a}$$

$$dev\_mits\_m_{jt} = \left(\frac{m\_ITS_{jt}}{m_{jt}}\right) / \left(\frac{\sum_j m\_ITS_{jt}}{\sum_j m_{jt}}\right) \tag{2.3b}$$

$$dev\_mcts\_m_{jt} = \left(\frac{m\_CTS_{jt}}{m_{jt}}\right) / \left(\frac{\sum_j m\_CTS_{jt}}{\sum_j m_{jt}}\right) \tag{2.3c}$$

where the variables m_ICTS_{jt}, m_ITS_{jt} and m_CTS_{jt} are the intermediate ICT, IT, and CT services, and the variable m_{jt} is the total intermediate input of industry j in year t.Table 2.1 shows the descriptive statistics for the main variables.

TABLE 2.1
DESCRIPTIVE STATISTICS FOR THE MAIN VARIABLES

Variables	(1) Obs	(2) Mean	(3) Std. Dev.	(4) Min	(5) Max
dev_micts_m	2,438	0.915	1.191	0	11.24
dev_mits_m	2,438	0.996	1.174	0	6.411
dev_mcts_m	2,438	0.845	1.479	0	15.95
dev_ict_ieqp	2,438	0.687	0.791	0.00536	5.956
dev_it_ieqp	2,438	0.659	0.851	0	7.278
dev_ct_ieqp	2,438	0.722	1.321	0.000797	10.52
Number of industry	106	106	106	106	106

Source: Authors' elaborations of JIP database 2015.

Table 2.2 presents the regression results with ICT hardware investment intensity and individual IT and CT hardware investment intensities as dependent variables, with industry fixed effects included. From columns (1) to (3), the dependent variable is the ICT hardware investment intensity. The first column shows the result obtained by running the regression of this dependent variable on the intermediate ICT service intensity. Unfortunately, the coefficient of the intermediate ICT service intensity is insignificant and has a negative sign, which is inconsistent with our hypothesis. This result suggests that the intermediate IT and CT services together do not cause variability in the dependent variable; the latter is probably due to the distinctive capital accumulation patterns caused by their different prices and depreciation rates of IT and CT equipment. Therefore, we decided to explore the effect of individual intermediate IT and CT service intensities on the dependent variable, that is, the ICT hardware investment intensity, respectively.

Column (2) of Table 2.2 reports the result with only the intermediate IT service intensity as the independent variable and the same independent variable, ICT investment intensity. The coefficient of the intermediate IT service intensity is 0.1477, which is significant at the 1 percent level. Next, if we add the intermediate CT service intensity into the model as another independent variable, the result of column (3) is obtained. The coefficient of intermediate IT service intensity is still significantly positive and quite stable, but the coefficient of the intermediate CT service intensity is only significant at the 10 percent level and is negative. Thus, this result supports our hypothesis that the investment in IT equipment may be more responsive to changes in intermediate IT services due to its rapid price decline and a high replacement rate due to its relatively higher depreciation rate than that of other machinery. In contrast, the CT equipment is relatively abundant in Japan and less responsive to changes in intermediate CT services because of its slower price decline and lower depreciation rate.

Finally, we investigate individual IT and CT investment intensities as the dependent variables. Columns (4) and (5) of Table 2.2 present the results for models with IT investment intensity as the dependent variable. The coefficient of the intermediate IT service intensity is significant and positive in model (4). When the intermediate CT service intensity is added in, the coefficient of intermediate IT service intensity is still stable, but the coefficient of intermediate CT service is not significant. Similarly, if we examine the case of only the CT investment intensity as the dependent variable, columns (6) and (7) show insignificant results for the intermediate CT service intensity as the independent variable.

To achieve our goal, we adopt the coefficients of intermediate IT service intensity in models (2) and (4), in which both ICT investment intensity and IT investment intensity respond noticeably to the change in intermediate IT service. The different magnitudes of the coefficients of intermediate IT service intensity in these two models may indicate the impact on the change in CT investment. Therefore, we first apply the two estimated coefficients to the intermediate IT service intensity in China's data to predict the corresponding ICT investment intensity and IT investment intensity for the Chinese economy. Then, we obtain the CT investment intensity from the difference between the predicted ICT and IT investment intensities.

It is noteworthy that our estimation approach implicitly assumes that the response of ICT investment to the change in intermediate ICT services for each industry is similar in China and Japan. However, China has different intermediate ICT service intensity at the industry level and the ICT investment intensity at the aggregate level than those in Japan, which, to some extent, could control for the differences between the two countries.

To estimate the industry level distribution of ICT investment in China, the estimated coefficients β_1 and industry effects $\alpha + \theta_j$ from the above regression models using the JIP database are applied to the intermediate IT service intensity in China. The general coefficient α of the intercept term is used when the estimated industry effect is not significant. Before doing this, the 106 industries in the JIP database were merged into broader 33 sectors that could be mapped into the industry classification of the CIP database (see Table A3 for details). By using the nominal share of the intermediate IT service of each component industry in this broader sector as weight, we aggregate the industry effects of component industries for one broader sector. The adjusted coefficients of industry effects for 33 broader sectors and for the two models, ICT intensity model (2) and IT intensity model (4), are reported in Table A4.

Finally, after applying the estimated coefficients to the intermediate IT service intensity for each industry in the CIP database, we obtained the ICT investment intensity and IT investment intensity, both of which are measured as the deviation from the mean for the aggregate economy, defined as Eq. 2.2a and 2.2b. Then, by multiplying these two obtained intensities by the ICT investment share in total equipment investment $\frac{\sum_j i\_ICT_{jt}}{\sum_j i\_eqp_{jt}}$ and by the IT investment share in total equipment investment $\frac{\sum_j i\_IT_{jt}}{\sum_j i\_eqp_{jt}}$ of the aggregate economy in China respectively, we get the ICT investment share in total equipment investment $\frac{i\_ICT_{jt}}{i\_eqp_{jt}}$ and IT investment share in total equipment investment $\frac{i\_IT_{jt}}{i\_eqp_{jt}}$ for each industry j. Eventually, by multiplying the industry level total equipment investment from the CIP database, we can derive the IT and CT investment at the industry level for China.

The estimated ICT investment for the aggregate economy from the commodity flow method is taken as the "control total". We calculate the industry structure of ICT investment using the results estimated from the regression and then redistribute the "control total" to obtain our ultimately estimated industry-level ICT investment. Furthermore, to match 37 industries in the CIP database, we split the broader sector by the nominal investment share in the total equipment investment of each component industry.

Before the construction of the ICT capital stock described in the next section, the estimated ICT investment needs to be integrated with the capital account in the CIP database. We take the investment in total equipment from CIP as the "control total" and split it into ICT and non-ICT equipment investment. The non-ICT equipment capital stock was constructed following the procedures documented by Wu (2015).

TABLE 2.2
INTERMEDIATE ICT SERVICE INTENSITY AND ICT HARDWARE INVESTMENT INTENSITY

Model	ICT intensity			IT intensity		CT intensity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	*dev_ict_ieqp*	*dev_ict_ieqp*	*dev_ict_ieqp*	*dev_it_ieqp*	*dev_it_ieqp*	*dev_ct_ieqp*	*dev_ct_ieqp*
dev_micts_m	-0.0892						
	(-0.66)						
dev_mits_m		0.1477	0.1294	0.2182	0.2041		0.0780
		(2.94)***	(3.25)***	(2.05)**	(1.98)*		(1.89)*
dev_mcts_m			-0.1089		-0.0842	-0.0745	-0.0665
			(-1.71)*		(-1.31)	(-0.97)	(-0.90)
t	-0.0307	-0.0256	-0.0313	-0.0378	-0.0422	-0.0100	-0.0085
	(-5.11)***	(-6.94)***	(-6.21)***	(-6.83)***	(-6.57)***	(-1.51)	(-1.33)
t^2	0.0015	0.0013	0.0015	0.0017	0.0018	0.0008	0.0007
	(5.95)***	(8.43)***	(7.09)***	(7.00)***	(6.43)***	(3.02)***	(2.94)***
Constant	0.8615	0.6029	0.7475	0.5840	0.6958	0.7569	0.6636
	(5.81)***	(8.96)***	(9.87)***	(4.51)***	(5.35)***	(8.22)***	(7.24)***
Observations	2,438	2,438	2,438	2,438	2,438	2,438	2,438
R-squared	0.113	0.139	0.170	0.113	0.124	0.073	0.078
Number of industry	106	106	106	106	106	106	106
Industry FE	YES	YES	YES	YES	YES	YES	YES

Source: Authors' elaborations of JIP database 2015.
Notes: 1) Robust t-statistics in parentheses; 2) *** p<0.01, ** p<0.05, * p<0.1.

3. Estimation of ICT Net Capital Stock

Capital stock estimates can be derived either by using data based on the direct measurement of the stock or by using investment data and the perpetual inventory method. However, the direct measurement of ICT capital stock is not available in the official statistics on China. Therefore, the perpetual inventory method is adopted to estimate the ICT capital stock.

The perpetual inventory method

The perpetual inventory method (PIM) for estimating capital stock was developed by Goldsmith (1951). Following Hulten (1990), we can start by assuming that not the amount of capital stock itself, A_t, but the quantity of new capital added to the stock via investment in each year, I_t, can be observed. The problem is to develop a reasonable procedure for adding up the investment I into an estimate of capital stock A, recognizing that partial or all the past additions to the stock may have been retired from service and that the services obtained from older capital may be less productive.

The perpetual inventory method is an attempt to solve this problem. When this method is adopted to transform the data on ICT investment quantities into the estimates of the quantity of ICT capital stock, two key assumptions are required here. The first is the age-efficiency profile, which shows the relative productivity of ICT capital at different ages and is defined by a constant geometric rate. The second assumption is that all ICT investments are measured in constant quality efficiency units, which allows the investment of different vintages to be treated as perfect substitutes in production. Together, these two assumptions imply that the perpetual inventory method can be expressed as:

(3.1)
$$A_t = (1 - \delta_k)A_{t-1} + I_t$$

where A_t is the stock at the end of period t, and the efficiency of an asset is assumed to decline geometrically with age at the rate δ_k. Note that the rates of decline in efficiency, δ_k, are indexed only by asset k, which means that they are constant over time and that there are no differences in asset composition across industries. Finally, because all capital is measured in base-year efficiency units, the appropriate price for valuing ICT capital stock in all years is the economy-wide investment price deflator for ICT assets.

Thus, in order to be able to apply the perpetual inventory method to measure the ICT capital stock, we need a time series of ICT investment flow at constant price, information on the depreciation rates of the ICT assets, and information on the initial ICT capital stock at the time when the investment time series starts. Next, we use this process to estimate China’s ICT capital stock for the period 1977–2018.

ICT asset-specific deflators and rates of depreciation

As the perpetual inventory method requires the investment flows expressed in constant quality efficiency units, ICT price deflators are needed to convert investment data at nominal prices into a constant-price basis. In the case of ICT goods, the embodied technical changes are quick, and their prices decline rapidly. It is crucial to distinguish the *real* price change from the price change due to changes in *quality* to obtain the volume terms of ICT assets. Therefore, a constant quality price index is required to deflate ICT investment in the nominal term. The hedonic approach is used by several countries to estimate the ICT price index, which establishes a systematic relationship between the price and characteristics of computer models. The hedonic method cannot be applied to China because of the data constraints. Meanwhile, the conventional producer price index of the ICT manufacturing industry mixed with other non-ICT assets clearly understates the real price change of ICT assets. Thus, the measured rate of growth in investment volume will be slower under the producer price index than under the hedonic price index. Hence, we consider the US ICT price deflators, which are estimated based on the hedonic approach.

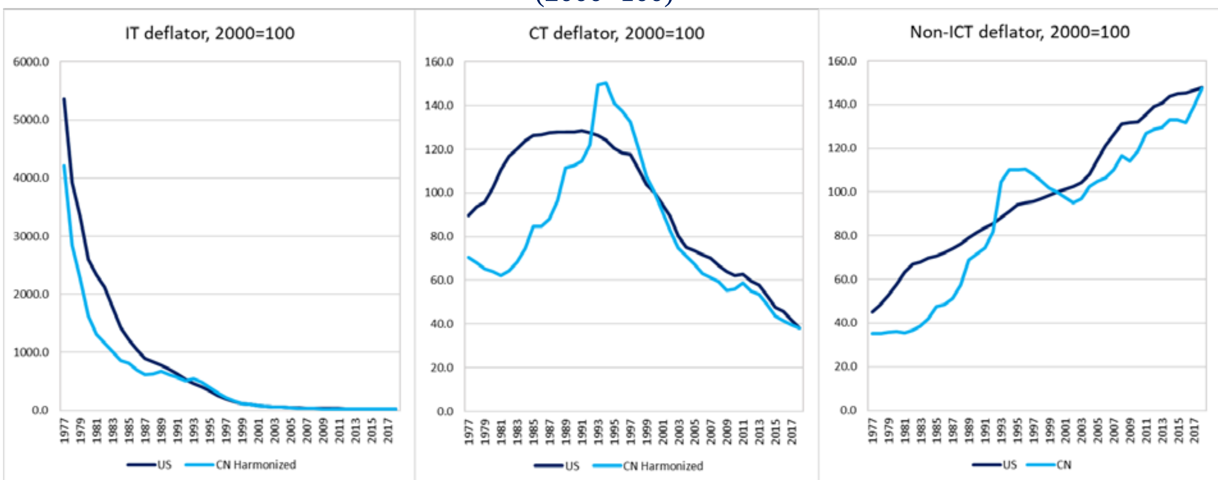
If we directly use the US ICT deflators, the underlying hypothesis is that the nominal prices of ICT products change at the same rate in the US as that in China. It is also assumed that there are no differences in the composition of ICT production or consumption, or in the market structure and competition. In addition, this assumes away that different countries may experience different changes in the general price level.

Therefore, we construct the "harmonized" ICT deflators (Schreyer, 2002) to control for domestic inflation. The following assumption is made: the relative price change in the ICT products is the same across countries. Specifically, we assume that the relative price change in ICT and non-ICT capital goods in China is the same as that in the US, which is given by:

(3.2) $$\Delta \ln(P_{ICT}^{CN}) = \Delta \ln P_{Non}^{CN} + (\Delta \ln P_{ICT}^{US} - \Delta \ln P_{Non}^{US})$$

where $\Delta \ln P_{ICT}^{CN}$ is the growth rate of ICT product price in China, $\Delta \ln P_{Non}^{CN}$ is the growth rate of non-ICT product price in China, and the other two terms are the growth rates of ICT and non-ICT product prices in the US. The ICT price deflators of the US and the "harmonized" ICT price deflators of China are depicted as follows.

FIGURE 3.1
ICT AND NON-ICT PRICE INDICES FOR THE US AND CHINA
(2000=100)



Sources: EU KLEMS database 2019, updated CIP database and authors' estimates.
Notes: For the US, non-ICT investment deflator is estimated as a weighted average of the prices of transportation equipment, general machinery and non-residential construction. Similarly, for China, it is estimated as a weighted average of the prices of equipment and non-residential construction. In both cases, the weight is the nominal investment share of each asset type.

As shown in Figure 3.1, there is a rapid decline in IT product price, which provides powerful economic incentives for the diffusion of information technology. Jorgenson, Ho, and Stiroh (2005) found that the substantial rate of the IT price decline triggered a burst of IT investment, which had become the foundation for the resurgence of the American economy since the mid-1990s. Although not falling as fast as IT price, CT price has also been falling since the 1990s in the US, in a sharp contrast to the rise in non-ICT price. Adjusted for the domestic inflation, a similar pattern could also be observed in the estimated ICT prices in China.

For depreciation rates, due to the lack of the survey data on service lives of ICT assets for China, we assume their service lives to be the same as those of the ICT assets in the US, and therefore, adopt the BEA (Bureau of Economic Analysis) depreciation rates of 31.5 percent for IT equipment and 11.5 percent for CT equipment.

The initial ICT capital stock

The estimation of the initial ICT capital stock follows the steady-state method of King and Levine (1994). Let us assume that the physical capital stock and the real output grow at the same rate φ^*, that is,

(3.3) $$\varphi_t^* = \frac{dA_t}{A_t} = \frac{dY_t}{Y_t}$$

where A_t is the ICT capital stock and Y_t is the real GDP at time t. As $dA_t = I_t - \delta_k A_t$, then $\frac{dA_t}{A_t} = \frac{I_t}{A_t} - \delta_k$, where I_t is the gross ICT investment and δ_k is the depreciation rate for asset type k. Hence, the initial ICT capital stock can be derived as follows:

(3.4) $$A_0 = \frac{I_0}{\varphi_0^* + \delta_k}$$

where the subscript 0 of the variables indicates the initial time.

To solve for A_0 in Eq. 3.4, we have already obtained ICT investment flows in 1977, which can be used for I_0, and depreciation rates δ_k are 31.5 percent and 11.5 percent for IT and CT equipment, respectively. For the initial-period GDP growth rate φ_0^*, in order to avoid fluctuations in GDP growth, an average growth rate is adopted for each industry for the period 1977–1981.

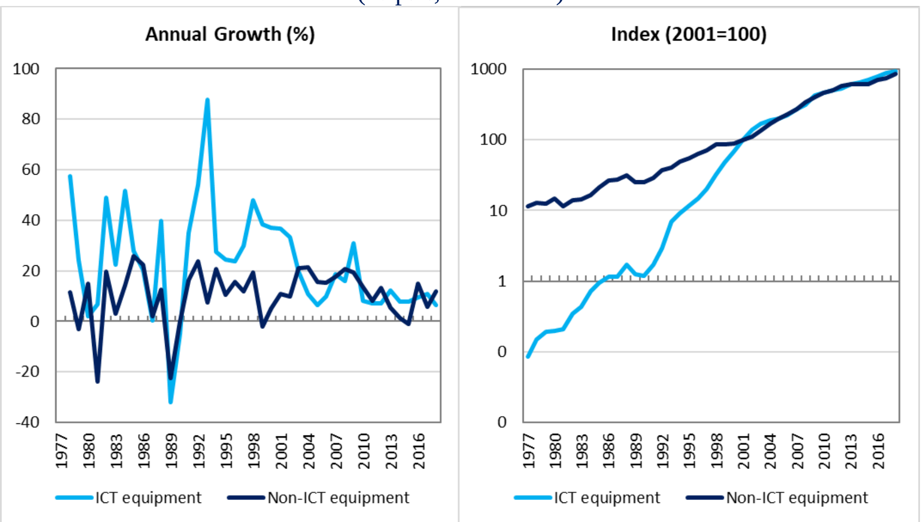
4. Results and Discussions

This section presents and discusses our estimates of ICT assets for the Chinese economy over the period 1977–2018. It is difficult to make a reasonable or acceptable assessment of such a data work when the primary information is missing. It is important to benchmark our estimates on policy regime changes in the domestic economy that are deemed to influence investment decisions and on proper international references, although subject to strong assumptions. In what follows, we first report and assess the estimates for ICT and non-ICT investment, and then report and discuss the estimates for ICT and non-ICT capital stock by asset type and by ICT-specific industry groups, respectively. Finally, we compare the key indicators with those of the US and Japan for their two major sectors, industrial and service, where comparable data were available.

China's ICT and non-ICT investment

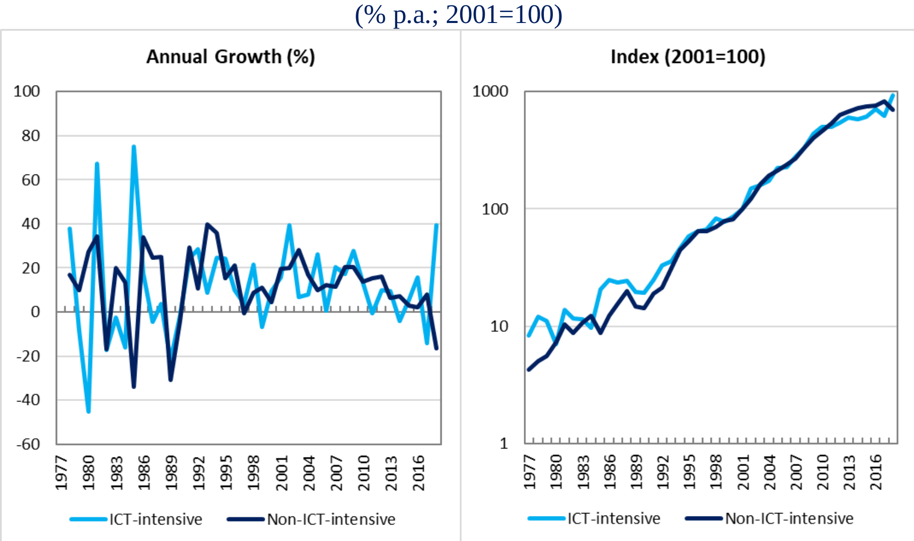
Serving as a useful background, let us examine the dynamics of China's ICT investment over the past four decades. Figure 4.1 demonstrates the changes in China's investment in ICT versus non-ICT equipment while Figure 4.2 shows changes in China's investment in ICT-intensive versus non-ICT-intensive industries, measured at the real annual growth rate (the left panel) and in the level effect of the real growth based on the estimate for 2001 (the right panel).

FIGURE 4.1
CHINA'S INVESTMENT IN ICT AND NON-ICT EQUIPMENT, 1977–2018
(% p.a.; 2001=100)



Source: Authors' estimation.
Note: ICT equipment is defined as computing equipment and communication equipment, see Section 2; in 2000 price.

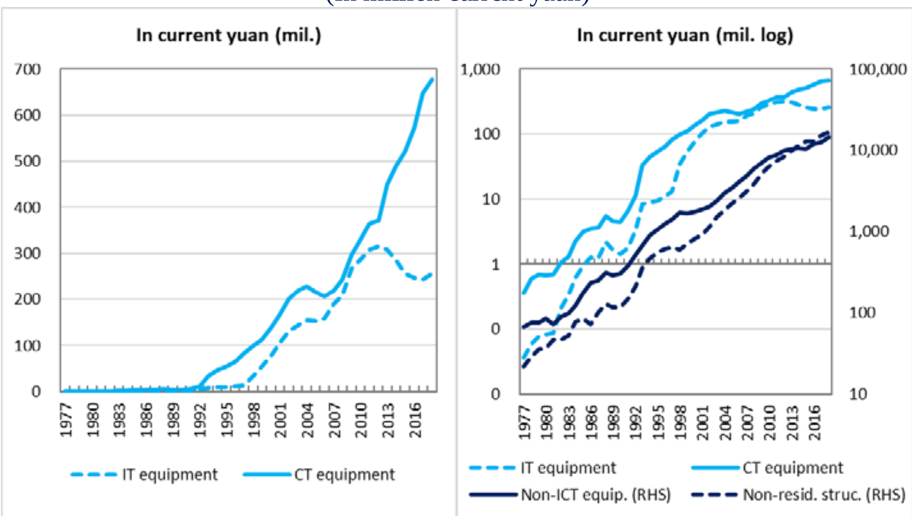
FIGURE 4.2
CHINA'S INVESTMENT IN ICT-INTENSIVE AND NON-ICT-INTENSIVE INDUSTRIES, 1977–2018
(% p.a.; 2001=100)



Source: Authors' estimation.
Note: ICT-intensive industry is defined as the intensity of ICT capital service which is above the median of the aggregate economy; in 2000 price.

From Figure 4.1, we can see a more rapid growth in the investment in ICT equipment compared to that in non-IT equipment, which resulted in a quick catch-up of the former with the latter. Since the early 2000s, in the wake of China's entrance to WTO, these two investments had followed a similar growth trend quickly, as shown in the right panel of Figure 4.1. Interestingly, from an industry perspective, as shown in Figure 4.2, despite a seemingly more volatile behavior, the faster growth in ICT investment did not induce a faster expansion of industries that produced ICT equipment or used ICT intensively compared to non-ICT-intensive industries particularly after the mid-1990s. This observation may suggest that China's catch-up through ICTs, notably the mature part of ICTs, was somewhat balanced across all industries following a more market-oriented reforms in the mid-1990s when the communist government adopted a "socialist market model".

FIGURE 4.3
CHINA'S INVESTMENT IN ICT AND NON-ICT ASSETS, 1977–2018
(In million current yuan)



Source: Authors' estimation.
Notes: Asset types include IT and CT equipment, non-ICT equipment and non-residential structure; The demonstration of the right panel is designed in logarithm scale to show the underlying growth trend though still in nominal terms.

To better understand such an investment dynamism, it is better to examine changes in China's investment in nominal terms because investments are motivated by relative costs between asset types in different industries. Figure 4.3 (the left panel) shows China's investment in IT and CT equipment in comparison with that in non-ICT assets in the current yuan denoted value. This further confirms that the significant increase in ICT investment in China began in the 1990s with the adoption of the "socialist market" model. By our estimation, in 2018 it amounted to 933.1 billion yuan, compared to 14.8 billion yuan in 1992. It is worth noting that the ICT investment surge in the 1990s was led by CT equipment rather than IT equipment, although the IT catch-up starting at the end of the 1990s experienced an even faster pace (the right panel). It may therefore be conjectured that the more consumer market-oriented CT development, such as mobile phones, played a key role in motivating the more producer market-oriented IT investment. This considers the nature of the "ICT-led revolution" that significantly increases market uncertainty, hence driving intense competition, because of the "Moore-speed" technical advancement and decline of ICT equipment prices at the same time. However, one may be puzzled: Why did the IT investment lose steam since the early 2010s, whereas investment in other assets, especially non-ICT, remained robust?

TABLE 4.1
SHARE OF THE ESTIMATED ICT INVESTMENT IN NOMINAL GDP BY ASSET TYPE AND SECTOR, 1977–2018
(Nominal GDP = 100)

	1978–1984	1984–1992	1992–1996	1996–2001	2001–2007	2007–2012	2012–2018	*1978–2018*
GFCF share in GDP (% p.a.)	***28.32***	***28.61***	***33.56***	***32.56***	***38.41***	***43.07***	***43.22***	***35.02***
	GFCF share decomposed by asset type (percentage points, ppts)							
ICT equipment	**0.23**	**0.43**	**1.10**	**1.84**	**2.15**	**1.43**	**1.14**	***1.13***
- IT equipment	0.04	0.11	0.18	0.58	0.89	0.66	0.37	*0.39*
- CT equipment	0.20	0.32	0.92	1.26	1.26	0.77	0.77	*0.74*
Non-ICT equipment	**16.99**	**19.02**	**17.96**	**18.10**	**17.90**	**19.05**	**16.20**	***17.91***
Non-residential structures	**9.03**	**7.56**	**9.32**	**7.85**	**11.24**	**14.61**	**18.04**	***11.00***
Dwellings	**2.07**	**1.60**	**5.18**	**4.77**	**7.12**	**7.97**	**7.84**	***4.99***
	GFCF share decomposed by sector (percentage points, ppts)							
Manufacturing	**10.51**	**12.71**	**13.47**	**8.99**	**11.22**	**11.02**	**4.45**	***10.32***
- ICT-related industries*	4.70	6.73	7.32	4.68	7.37	6.94	2.95	*5.78*
- Non-ICT-related industries	5.82	5.98	6.15	4.31	3.84	4.08	1.49	*4.53*
Services	**8.03**	**7.51**	**13.83**	**15.29**	**21.05**	**26.42**	**32.69**	***17.37***
- ICT related industries*	3.80	3.59	4.08	5.69	4.49	4.91	7.22	*4.78*
- Non-ICT-related industries	4.23	3.92	9.76	9.60	16.56	21.52	25.47	*12.59*
Other sectors	**9.78**	**8.39**	**6.26**	**8.28**	**6.14**	**5.62**	**6.09**	***7.34***

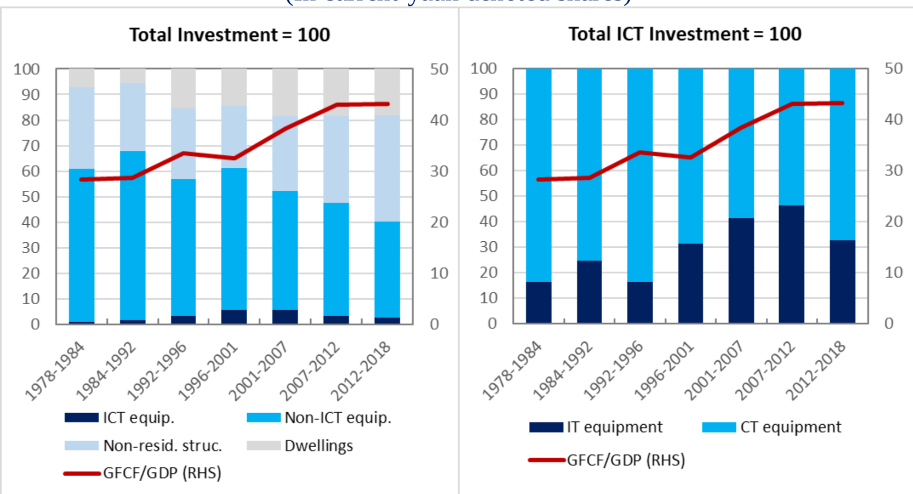
Sources: Authors' estimates.
Notes: *ICT-related industries include ICT producing and intensive-using industries that are defined by their intensity of ICT capital service which is above the median of the aggregate economy.

This puzzling observation can be better understood with the background of policy regime shifts. Considering that the rapid decline in ICT equipment prices has significantly changed the relative costs between investments in different assets across industries, in Table 4.1, we examine China's investment structure by asset type and by ICT-specific industry in nominal terms over seven sub-periods that are characterized by different reforms or macroeconomic conditions. In general, despite several rounds of pro-market reforms, government interventions in investment have remained strong in upstream industries, such as energy and important capital goods such as heavy input materials, which are considered strategically imperative to the national economy or the state interests, while leaving those industries close to the end market less controlled, hence subject to more market competition (Wu, 2019). However, macroeconomic policies to accelerate or to sustain the growth have had an important impact on investment. Figure 4.4, derived from Table 4.1, further helps our examination of the policy or institutional effect on the ICT investment and the change in the IT and CT patterns.

FIGURE 4.4

STRUCTURAL CHANGES OF CHINA'S INVESTMENT BY ASSET TYPE

(In current-yuan denoted shares)



Source: Table 4.1.

Notes: The left panel: Total investment is the sum of all asset types, which is equal to GFCF. The right panel: A zoom-in demonstration of the ICT equipment of the left panel with a decomposition of CT and IT investment.

From the left panel of Figure 4.4, we can see that the ICT share in the total investment or GFCF significantly accelerated in the wake of China's adoption of the "socialist market" model in 1992–1996 and deepening state-owned enterprises (SOE) reforms in 1996–2001. The right panel of the figure reveals that the 1992–1996 ICT investment surge was attributable to CT, but the further rise over 1996–2001 was mainly caused by a quick catch-up of IT. This implies that the earlier market expansion for CT investment now began to attract IT investment in production. Although the total ICT share in the GFCF appears to have remained unchanged in 2001–2007 despite China's accession to the WTO (the left panel), there was a substantial shift from CT to IT within the ICT investment (the right panel). While the government's industrial policy aiming at technological advancement played a key role in this shift, but it was also enhanced by the local governments competing for faster growth.[4]

[4] China's growth model considers the growth problem as the government's legitimacy problem, hence encouraging state agencies and local governments to compete for faster growth (Wu, 2019; Xu, 2011).

This shift continued nonetheless in the early post-global financial crisis period of 2007–2012. These noteworthy changes were accompanied by a rapid growth in investment in infrastructure and dwellings as a result of the central government's post-crisis policy to sustain growth (the left panel). In the late post-crisis period of 2012–2018, when the rising costs and persisting structural problems further reduced the room for manipulating macroeconomic policies and government interventions, the investment in CT resurged (the right panel). This is evidenced by the rapid expansion of mobile phones since 2012 following the emergence of Chinese smartphone brands such as Huawei, Xiaomi, Oppo, and Vivo.

Apart from the above policy-based interpretation of the ICT investment estimates, it is helpful to quantify the factors that might have caused the distinct rise in the share of ICT investment in GDP over the period 1977–2002, and the distinct decline in the share over the period 2002–2018 as shown in Table 4.1. We use a shift-share technique as expressed in Eq. 4.1 to examine whether the slowdown in the growth rate of this share for the Chinese economy is due to a shrinkage in the proportion of industries with higher growth rates of this share. The slowdown in the growth rate of ICT investment share in GDP of the aggregate economy, and those in the manufacturing sector, service sector, and other sectors can be decomposed into the following two effects:

$$\sum_j \bar{w}_{02,18,j}\Delta\lambda_{02,18,j} - \sum_j \bar{w}_{77,02,j}\Delta\lambda_{77,02,j} = \frac{1}{2}\sum_j\left(\bar{w}_{77,02,j} + \bar{w}_{02,18,j}\right)\left(\Delta\lambda_{02,18,j} - \Delta\lambda_{77,02,j}\right) + \frac{1}{2}\sum_j\left(\Delta\lambda_{02,18,j} + \Delta\lambda_{77,02,j}\right)\left(\bar{w}_{02,18,j} - \bar{w}_{77,02,j}\right) \quad (4.1)$$

where $\bar{w}_{77,02,j}$ and $\bar{w}_{02,18,j}$ are the average shares of the industry GDP in the aggregate GDP for the periods 1977–2002 and 2002–2018, respectively; $\Delta\lambda_{77,02,j}$ and $\Delta\lambda_{02,18,j}$ are the annual average growth rates of the ICT investment share in GDP for the two periods.

The first term on the right-hand side of the above equation is the "within industry effect" which explains that the slowdown in the growth rate of the share for aggregate economy stems from the slowdown at the industry level. The second term reflects the "structural change effect", which implies a shrinkage in the proportion of industries with relatively higher growth rates of the share.

TABLE 4.2
DECOMPOSITION OF THE SLOWDOWN IN ICT INVESTMENT SHARE IN GDP FROM 1977–2002 TO 2002–2018

Sector	The Slowdown of the Growth Rate	Within Industry Effect	Structural Change Effect
		Growth Rates (%)	
Aggregate Economy	**-788.2**	**-754.2**	**-34.0**
Manufacturing	-820.5	-782.8	-37.7
Services	-8.9	-10.2	1.3
Others	41.2	38.9	2.3
		Contributions (percentage points, ppts)	
Aggregate Economy	**100.0**	**95.7**	**4.3**
Manufacturing	100.0	95.4	4.6
Services	100.0	114.9	-14.9
Others	100.0	94.3	5.7

Source: Authors' calculation.
Notes: The manufacturing sector includes CIP industry 6–24; The service sector includes CIP 27–37; Others consist of all the remaining industries.

Table 4.2 shows the decomposition of the slowdown in the growth rate of ICT investment share in GDP from the period 1977–2002 to 2002–2018. For the aggregate economy, the structural change effect is -34 percent, indicating that changes in the weights of component industries lowered the growth rate of ICT investment share in GDP. However, this negative effect of the structural change is only 4.3 ppts which is quite small compared with the slowdown of the macroeconomy from the period 1977–2002 to 2002–2018.

The results for sectors presented different patterns. As for the manufacturing sector, the shrinkage in the proportion of industries with a higher growth rate reduced the growth rate of the ICT investment share in GDP. In contrast, the service sector had a positive structural change effect, albeit very small (14.9 ppts), which raised the growth rate of the share. This implies that in the service sector, the proportion of industries with higher growth rates of ICT investment shares is expanding. In the case of other sectors, the growth rate of ICT investment share in GDP is accelerating, which is mainly attributable to the within-industry effect.

In summary, these results suggest that the slowdown in the growth rate of ICT investment share in GDP since 2002 is not primarily due to the structural change effect, but mostly a result of the slowdown in the manufacturing and service sectors. As discussed earlier, this decomposition supports our view that the decline in ICT investment is associated with the expansion of the real estate sector after China's WTO entry and unprecedented infrastructure investment in the wake of the global financial crisis.

China's ICT and non-ICT capital stock

In Table 4.3, we report the estimated ICT and non-ICT capital stock for the Chinese economy for the entire period and its subperiods associated with significant policy regime shifts. The stock estimates are in the real and net terms, obtained by the standard perpetual inventory method (PIM), as expressed in Eq. 3.1. Additionally, in Table 4.4, we show the asset structure of the capital stock at constant 2000 prices for an examination of structural changes in the capital stock over the whole period and its subperiods.[5]

Based on the stock estimates, in Figure 4.5, we depict indices for all the major non-ICT assets and ICT assets, benchmarked to the year 2001, when China was granted with a WTO membership. We use a logarithmic scale to better examine the likely shifts in the underlying trends, turns, and shocks, which may help explore the institutional or policy impact on the buildup of China's capital stock, especially the changes between ICT and non-ICT capital stock, and between IT and CT within the ICT capital stock. The features of our ICT-specific capital stock estimates are summarized in the following three points.

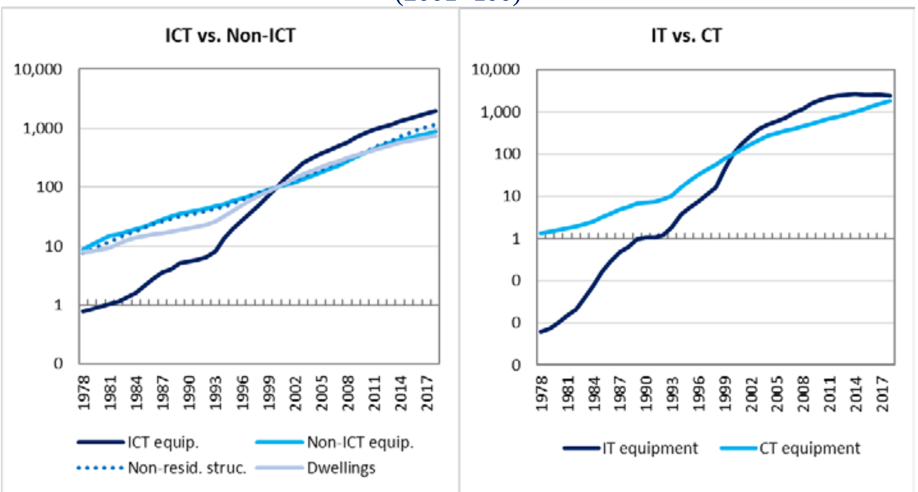
First, China's ICT capital stock grew more rapidly than the non-ICT capital stock through several important accelerations over the period in question. From the left panel of Figure 4.5, we see that China's ICT capital stock began to accelerate in the mid-1980s, as China launched its industrial reform. It appears that allowing the market to play a role at the margin (i.e., in addition to the planning assignment under the dual-track price scheme) stimulated the growth of ICT capital stock. The growth was obstructed by the Tiananmen shock in 1989 but

[5] Denoting structural changes at constant prices inevitably causes substitution bias especially at the time when ICT equipment experienced an extensive price decline. There is no widely acceptable approach to properly deal with the problem. Attempting to explore a solution is beyond the scope of the present study although we are open to any criticism and suggestion.

accelerated again at an even faster pace from 1992, following Deng's call for bolder reforms. However, the post-WTO entry period did not see a further surge but somewhat returned to its underlying trend of the 1980s before a global financial crisis-induced slowdown in the 2010s.

Second, as shown in the right panel of Figure 4.5, the growth of CT capital stock appears to be less volatile than that of IT capital stock. It was relatively steady despite the shock of the crisis. This suggests that the slight slowdown in the total ICT stock accumulation after the 2010s, as shown in the left panel, was largely attributable to the slowdown in the IT stock rather than CT stock. Such different performances of IT and CT stock appear to be consistent with our conjecture that, compared to the consumer market-oriented CT investment, the producer market-oriented IT investment is more exposed to government interventions and industrial policies, and hence more influenced by radical policy changes. This can be substantiated by the post-crisis shift in the ICT capital stock growth from the industrial sector to the service sector, and the greater concentration on the CT capital stock (Table 4.3).

FIGURE 4.5
INDICES OF CAPITAL STOCK BY ASSET TYPE IN CHINA
(2001=100)



Source: Table 4.3.
Notes: The right panel: A zoom-in demonstration of the ICT equipment of the left panel with a decomposition of CT and IT investment.

Third, despite external shocks and radical policy regime shifts, the growth of non-residential structures, mainly influenced by the government's persistent investment in infrastructure to sustain growth, was rather steady throughout the entire period. It should be emphasized that by separating the ICT capital stock from the non-ICT capital stock, and dwellings from other structures, the government's objective of using infrastructure investment as a policy instrument becomes much clearer. As a good example, observable in the left panel of Figure 4.5, during the late post-crisis period 2012–2018 when the growth of all other capital assets slowed down, except for the CT stock, the growth of non-residential structures remained strong or strongly path-dependent (Table 4.3) and its share in the total capital stock reached 35 percent, for the first time since the mid-1980s (Table 4.4).

TABLE 4.3

CHINA'S ANNUAL GROWTH OF NET CAPITAL STOCK BY SECTOR AND BY ASSET TYPE

(% change p.a.)

	1978–1984						1984–1992					
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K
Total	***51.7***	***13.0***	***11.4***	***14.4***	***10.1***	***12.2***	***30.0***	***14.9***	***10.0***	***8.9***	***6.8***	***9.4***
Manufacturing												
-- ICT*	44.0	12.0	5.9	10.4	0.0	7.3	43.3	21.7	10.8	10.0	0.0	10.7
-- Non-ICT	61.5	21.1	15.9	26.4	0.0	19.6	33.6	18.1	12.0	9.2	0.0	11.0
Services												
-- ICT**	49.5	8.7	9.2	8.9	0.0	9.1	27.9	13.2	7.7	8.0	0.0	8.0
-- Non-ICT	55.4	19.1	12.2	13.9	10.1	11.4	20.2	9.4	8.9	11.3	6.8	8.5
Agriculture	44.6	7.1	8.6	9.5	0.0	9.0	27.3	7.4	3.2	3.0	0.0	3.1
Mining	54.5	11.7	11.6	16.9	0.0	12.7	25.0	9.2	6.3	7.3	0.0	6.6
Energy	50.8	-31.9	18.3	27.0	0.0	19.9	28.7	17.5	11.7	9.4	0.0	11.2
Construction	58.8	19.8	11.3	11.8	0.0	11.4	21.0	7.8	4.1	6.9	0.0	4.9
	1992–1996						1996–2001					
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K
Total	***44.4***	***36.0***	***10.0***	***12.4***	***21.1***	***12.5***	***68.8***	***27.4***	***10.6***	***12.1***	***16.8***	***12.5***
Manufacturing												
-- ICT*	49.7	42.1	11.7	11.4	0.0	12.2	61.3	20.3	5.6	6.7	0.0	6.6
-- Non-ICT	47.5	41.8	12.7	10.0	0.0	12.0	58.3	19.3	7.8	4.1	0.0	7.1
Services												
-- ICT**	38.3	29.0	8.7	10.9	0.0	10.5	77.0	35.2	13.6	17.1	0.0	17.2
-- Non-ICT	33.5	28.7	14.0	21.3	21.1	20.4	68.6	26.0	14.2	18.4	16.8	17.2
Agriculture	45.2	39.6	6.0	5.1	0.0	5.7	72.1	22.7	12.0	7.4	0.0	10.0
Mining	52.7	43.0	4.2	6.8	0.0	5.2	55.1	13.5	3.5	2.3	0.0	3.5
Energy	41.5	39.7	7.1	9.0	0.0	7.6	83.9	35.6	16.7	9.7	0.0	15.9
Construction	77.2	63.2	13.2	10.1	0.0	13.4	66.1	23.2	10.8	6.4	0.0	11.0

Source: Authors' estimate.

Notes: 1) * ICT-producing and -intensive-using manufacturing; ** ICT-producing and -intensive-using services; 2) Capital stock is estimated in 2000 prices.

TABLE 4.3 (CONTINUED)
CHINA'S ANNUAL GROWTH OF NET CAPITAL STOCK BY SECTOR AND BY ASSET TYPE
(% change p.a.)

	2001–2007						2007–2012					
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K
Total	***28.1***	***18.6***	***12.8***	***13.8***	***14.1***	***13.5***	***18.9***	***12.8***	***15.2***	***14.6***	***11.0***	***13.8***
Manufacturing												
-- ICT*	34.2	24.2	15.8	13.3	0.0	15.6	13.5	11.1	15.1	11.4	0.0	13.7
-- Non-ICT	25.6	12.7	9.5	8.5	0.0	9.3	19.3	11.3	14.7	10.6	0.0	13.3
Services												
-- ICT**	21.9	13.2	11.0	10.0	0.0	10.8	22.9	11.7	18.5	10.3	0.0	13.7
-- Non-ICT	41.4	31.1	25.9	19.2	14.1	17.1	23.7	19.0	20.8	18.2	11.0	14.6
Agriculture	27.9	14.3	14.7	6.2	0.0	11.1	26.7	15.4	22.6	12.2	0.0	18.6
Mining	36.8	23.1	17.3	13.5	0.0	16.7	17.3	12.6	15.5	11.2	0.0	14.4
Energy	20.6	8.6	8.3	3.8	0.0	7.7	10.6	6.8	8.6	3.2	0.0	7.8
Construction	21.0	15.8	15.3	7.1	0.0	14.1	21.3	11.6	18.0	17.0	0.0	17.6
	2012–2018						1977–2018					
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	Total K
Total	***0.1***	***14.6***	***9.2***	***12.9***	***7.3***	***10.0***	***33.4***	***18.5***	***11.2***	***12.5***	***11.7***	***11.8***
Manufacturing												
-- ICT*	-10.0	4.6	2.0	5.7	0.0	3.3	33.2	18.6	9.5	9.8	0.0	9.8
-- Non-ICT	-19.4	0.6	-0.3	3.1	0.0	1.0	31.3	16.8	10.3	10.4	0.0	10.4
Services												
-- ICT**	6.0	19.2	17.6	12.2	0.0	14.8	33.5	17.6	12.1	10.8	0.0	11.7
-- Non-ICT	5.7	19.4	13.7	14.9	7.3	11.0	34.3	20.8	15.3	16.1	11.7	13.6
Agriculture	6.6	31.3	18.7	17.4	0.0	18.3	34.2	18.1	11.9	8.5	0.0	10.5
Mining	0.6	16.3	13.7	22.5	0.0	16.4	33.1	17.1	10.4	11.8	0.0	10.9
Energy	-13.9	3.9	6.4	4.7	0.0	6.1	30.3	9.9	11.2	9.7	0.0	11.0
Construction	-1.8	13.8	10.5	5.4	0.0	9.4	34.5	19.6	11.3	9.0	0.0	11.1

Source: Authors' estimate.
Notes: 1) * ICT-producing and -intensive-using manufacturing; ** ICT-producing and -intensive-using services; 2) Capital stock is estimated in 2000 prices.

TABLE 4.4
ESTIMATED ASSET STRUCTURE OF CHINA'S NET CAPITAL STOCK
(In 2000-yuan denoted shares; Total Stock=100)

	1978					1984				
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings
Total	***0.0***	***0.3***	***60.2***	***26.4***	***13.1***	***0.0***	***0.3***	***57.7***	***30.3***	***11.6***
Manufacturing										
-- ICT*	0.0	0.2	77.6	22.2	0.0	0.0	0.2	72.6	27.2	0.0
-- Non-ICT	0.0	0.1	75.2	24.7	0.0	0.0	0.2	61.9	38.0	0.0
Services										
-- ICT**	0.0	1.1	54.8	44.1	0.0	0.0	1.0	55.4	43.6	0.0
-- Non-ICT	0.0	0.2	12.4	21.0	66.5	0.0	0.3	13.1	24.6	62.0
Agriculture	0.0	0.0	50.5	49.4	0.0	0.0	0.0	49.1	50.8	0.0
Mining	0.0	0.1	85.2	14.7	0.0	0.0	0.1	80.8	19.1	0.0
Energy	0.0	-0.1	87.8	12.3	0.0	0.0	0.1	80.9	19.1	0.0
Construction	0.0	0.2	77.7	22.1	0.0	0.0	0.3	77.0	22.7	0.0
	1992					1996				
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings
Total	***0.0***	***0.5***	***60.9***	***29.1***	***9.5***	***0.1***	***1.2***	***55.8***	***29.4***	***13.6***
Manufacturing										
-- ICT	0.0	0.6	73.6	25.8	0.0	0.1	1.9	72.8	25.2	0.0
-- Non-ICT	0.0	0.3	67.0	32.7	0.0	0.1	0.9	69.0	30.1	0.0
Services										
-- ICT	0.0	1.6	54.4	43.9	0.0	0.1	3.4	51.3	45.2	0.0
-- Non-ICT	0.0	0.3	13.7	31.0	55.0	0.0	0.4	10.6	32.2	56.7
Agriculture	0.0	0.1	49.6	50.3	0.0	0.0	0.2	50.4	49.4	0.0
Mining	0.0	0.2	79.5	20.3	0.0	0.1	0.8	77.3	21.9	0.0
Energy	0.0	0.1	83.5	16.5	0.0	0.0	0.3	82.2	17.5	0.0
Construction	0.0	0.4	72.7	26.9	0.0	0.2	2.8	73.1	23.9	0.0

Source: Authors' estimate.
Notes: * ICT-producing and -intensive-using manufacturing; ** ICT-producing and -intensive-using services.

TABLE 4.4 (CONTINUED)

ESTIMATED ASSET STRUCTURE OF CHINA'S NET CAPITAL STOCK

(In 2000-yuan denoted shares; Total Stock=100)

	2001					2007				
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings
Total	***1.0***	***2.5***	***50.8***	***28.9***	***16.8***	***2.3***	***3.3***	***48.2***	***29.0***	***17.2***
Manufacturing										
-- ICT*	1.3	3.8	69.5	25.4	0.0	3.9	6.2	68.4	21.5	0.0
-- Non-ICT	0.8	1.6	71.7	25.9	0.0	2.1	2.0	71.6	24.4	0.0
Services										
-- ICT**	2.6	8.5	43.4	45.5	0.0	5.0	9.5	43.1	42.4	0.0
-- Non-ICT	0.2	0.7	9.1	34.3	55.7	0.9	1.5	15.0	37.6	45.0
Agriculture	0.5	0.5	55.7	43.3	0.0	1.3	0.5	67.0	31.2	0.0
Mining	0.7	1.3	77.3	20.7	0.0	2.3	1.8	79.0	16.9	0.0
Energy	0.8	0.9	85.5	12.8	0.0	1.7	0.9	87.4	10.0	0.0
Construction	2.9	5.3	72.8	19.1	0.0	4.3	5.8	77.5	12.4	0.0
	2012					2018				
Industry groups	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings	IT equip.	CT equip.	Non-ICT equip.	Non-resid. structures	Dwellings
Total	***2.9***	***3.1***	***50.2***	***29.3***	***14.5***	***1.6***	***4.0***	***47.5***	***34.6***	***12.3***
Manufacturing										
-- ICT	3.8	5.3	72.0	18.8	0.0	1.8	6.0	69.5	22.7	0.0
-- Non-ICT	2.7	1.7	74.7	20.8	0.0	0.8	1.8	72.6	24.8	0.0
Services										
-- ICT	7.4	8.0	51.1	33.5	0.0	4.2	10.1	58.2	27.5	0.0
-- Non-ICT	1.3	1.8	19.3	42.3	35.3	0.9	2.7	21.0	49.3	26.1
Agriculture	1.8	0.4	76.6	21.2	0.0	0.9	0.9	78.1	20.0	0.0
Mining	2.6	1.6	81.6	14.1	0.0	1.1	1.8	75.2	22.0	0.0
Energy	1.9	0.9	89.4	7.8	0.0	0.6	0.8	91.5	7.2	0.0
Construction	5.1	4.3	78.6	12.0	0.0	2.6	5.5	82.7	9.3	0.0

Source: Authors' estimate.

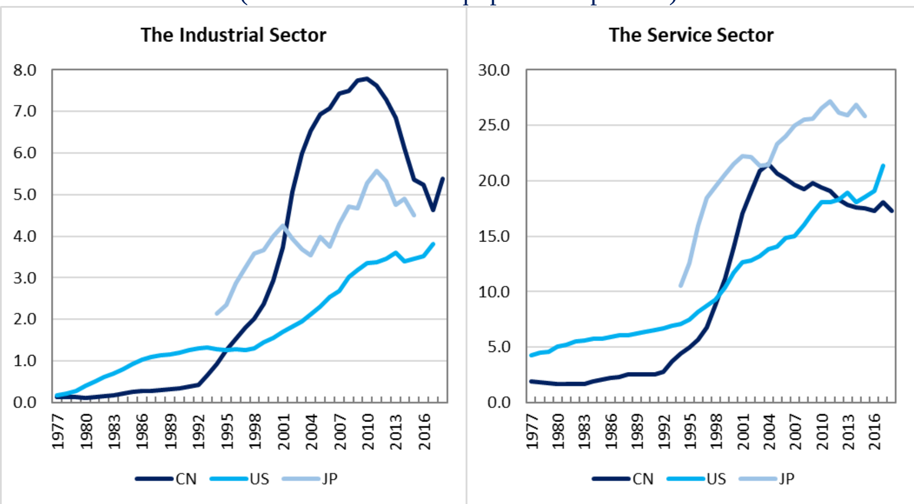
Notes: * ICT-producing and -intensive-using manufacturing; ** ICT-producing and -intensive-using services.

A comparison with the US and Japan

Given data deficiencies, it is challenging to compare our estimates for China with data for the other economies, especially in the case of ICT capital stock. It is difficult to control the stage of development with per capita GDP as a yardstick because of the rapid ICT advancement and simultaneous price decline, especially since the 1990s, making it difficult to have countries with comparable conditions in history. However, the nature of ICT development suggests that such a consideration may be unnecessary because huge uncertainties, and hence fierce competitions that are caused by unprecedentedly rapid changes in technologies and prices, make any administrative controls over ICT transfer costlier and therefore market integration across countries easier. Even so, one must bear in mind that China's ICT economy concentrates more on those industries using largely low-to-medium-range mature technologies, whereas the more advanced economies, such as the US and Japan that are to be compared in what follows, focus mainly on high-range technologies and innovations.

FIGURE 4.6

ICT INTENSITY OF THE INDUSTRIAL AND SERVICE SECTORS: CHINA VS. THE US AND JAPAN
(ICT share of total equipment in percent)



Source: Authors' estimate and EU KLMES 2019 database.

To assess our estimated ICT capital stock for the Chinese economy with the US and Japan as benchmarks, we use an indicator of ICT intensity, measured by the share of ICT equipment in the total equipment. We compare the industrial and the service sectors separately, as presented in the two panels of Figure 4.6. In the case of the industrial sector, despite a much lower initial level in the 1980s, China's ICT intensity exceeded that of the US in the late 1990s and Japan in the early 2000s. China reached its peak of 7.8 percent in 2010, a level that was surprisingly approximately 50 and 40 percent higher than that of the US in 2011 and Japan in 2017, respectively. China maintained the highest ICT intensity among the three economies, even after a sharp decline in the recent decade. Such a decline is difficult to explain considering the nature of the ICT development, as discussed earlier, and the trend of the US in particular. Other things being equal, one may argue that Chinese ICT industries, like non-ICT industries of the industrial sector, might have also suffered from a severe capacity surplus problem, although our earlier work shows that the former is more productive than the latter (Wu and Liang, 2017).

In the case of the service sector, shown in the right panel of Figure 4.6, all the three economies generally have a higher ICT intensity than that in the manufacturing sector. Among the three economies, Japan demonstrated the highest ICT intensity, ranging from 10.5 percent in 1994 to 25.8 percent in 2015. However, for the comparable period, the US was approximately 9 ppts below Japan but exhibited less volatility than Japan. China's service sector, like its industrial sector, had a fairly low ICT intensity before a sudden surge in the early 1990s. China's pace of the catch-up in the following decade was nothing but extraordinary, exceeding the rate in the US in 1999 and matching the rate in Japan in 2004. However, the year 2004 also marked the beginning of China's abrupt downturn and there was no sign of reversal by the end of the period of our comparison. In our view, any market mechanism-based opinion without a careful investigation of the underlying institutional problems may only provide a misleading conclusion. Based on our earlier work, Chinese ICT-intensive industries in the service sector were largely monopolized by the central government-controlled SOEs and less efficient than their counterparts in manufacturing (Wu and Liang, 2017).

5. CONCLUDING REMARKS

In the era of ICT-led growth and productivity enhancement, any growth analysis, especially for an economy of the size and pace of expansion like China's, is by no means complete without an explicit account of the role of ICT capital assets and the role of the industries making and intensively using ICTs. However, the lack of primary and systematic information for ICT activities in official statistics has been a major obstacle to such an analysis. This study has made the first ever attempt to bridge this gap by following the standard capital theory in a national account framework.

Based on the reconstructed time series input-output accounts in the CIP/China KLEMS database, we first estimate macro-level IT and CT investment flows and distribute the aggregate flows among 37 Chinese industries using an econometric approach that explores the relationship between the level of ICT investment intensity and the intermediate inputs from ICT-producing service industries using the JIP database. We then follow the PIM model to establish IT and CT capital stock series for each of the 37 industries that coherently integrate with the CIP capital account for 1977–2018.

Our results show that over the entire period 1978–2018 China's investment in ICT equipment grew by 21.8 percent per annum, which was approximately twice that of non-ICT equipment. The share of ICT investment in China's nominal GDP peaked in 2002 at 2.7 percent, yet declined to approximately 1 percent in the recent years. Similarly, the ICT investment share in the nominal GFCF peaked in 2002 at 7.7 percent, and then declined to 2.4 percent in 2018, largely attributable to the government's unprecedented investment in infrastructure to sustain growth. Despite such a relative decline in this share, by 2018, China's ICT intensity, measured as the share of the ICT equipment in the total equipment stock, reached 10.6 percent, which was approximately 65 percent that of Japan (16.4 percent in 2015), and 71 percent that of the US (15.0 percent in 2017). In sectoral comparisons, we show that China's service sector is more-ICT intensive (17.3) than its industrial sector (5.4), a pattern similar to, but with a narrower spread than that in Japan (25.8 vs. 4.5 in 2015), and the US (21.1 vs. 3.8 in 2017). China's catch-up in ICTs is obvious despite the competing policy objectives and a distorted market environment; however, remaining data problems, such as the lack of software and price problems, may still challenge the reliability of our estimates, upon which our findings are based.

APPENDIX

TABLE A1

CIP/CHINA KLEMS INDUSTRIAL CLASSIFICATION AND GROUPING

CIP Code	EU-KLEMS	Grouping	Industry	
01	AtB	Agriculture	Agriculture, Forestry, Animal Husbandry and Fishery	AGR
02	10	Mining	Coal mining	CLM
03	11	Energy	Oil and gas extraction	PTM
04	13	Mining	Metal mining	MEM
05	14	Mining	Non-metallic minerals mining	NMM
06	15	Non-ICT M	Food and kindred products	F&B
07	16	Non-ICT M	Tobacco products	TBC
08	17	Non-ICT M	Textile mill products	TEX
09	18	Non-ICT M	Apparel and other textile products	WEA
10	19	Non-ICT M	Leather and leather products	LEA
11	20	Non-ICT M	Saw mill products, furniture, fixtures	W&F
12	21t22	ICT M	Paper products, printing & publishing	P&P
13	23	Non-ICT M	Petroleum and coal products	PET
14	24	ICT M	Chemicals and allied products	CHE
15	25	Non-ICT M	Rubber and plastics products	R&P
16	26	Non-ICT M	Stone, clay, and glass products	BUI
17	27t28	ICT M	Primary & fabricated metal industries	MET
18	27t28	Non-ICT M	Metal products (excl. rolling products)	MEP
19	29	ICT M	Industrial machinery and equipment	MCH
20	31	ICT M	Electric equipment	ELE
21	32	ICT M	Electronic and telecommunication equipment	ICT
22	30t33	ICT M	Instruments and office equipment	INS
23	34t35	ICT M	Motor vehicles & other transportation equipment	TRS
24	36t37	ICT M	Miscellaneous manufacturing industries	OTH
25	E	Energy	Power, steam, gas and tap water supply	UTL
26	F	Construction	Construction	CON
27	G	ICT S	Wholesale and Retail Trades	SAL
28	H	Non-ICT S	Hotels and Restaurants	HOT
29	I	ICT S	Transport and Storage	T&S
30	64	ICT S	Information & Computer Services	P&T
31	J	ICT S	Financial Intermediation	FIN
32	K	Non-ICT S	Real Estate Activities	REA
33	71t74	ICT S	Leasing, Technical, Science & Business Services	BUS
34	L	Non-ICT S	Public Administration and Defense	ADM
35	M	Non-ICT S	Education	EDU
36	N	Non-ICT S	Health and Social Security	HEA
37	O&P	Non-ICT S	Other Services	SER

Source: See Wu and Ito (2015) for CIP classification.

Notes: 1) Based on authors' estimation, ICT intensive using industries are defined as the intensity of ICT capital service which is above the median of the aggregate economy; 2) ICT M: ICT-producing and intensive using manufacturing; non-ICT M: non-ICT intensive using manufacturing; ICT S: ICT-producing and intensive using service; non-ICT S: non-ICT intensive using service.

TABLE A2
ASSET CONCORDANCE FOR JIP AND EU KLEMS ASSETS

JIP Code	JIP Asset	KLEMS Asset	KLEMS Description
1	Farm	OCon	Total non-residential construction
2	Other furniture	OMach	Other machinery and equipment
3	Nuclear fuel	OCon	Total non-residential construction
4	Household appliances	OMach	Other machinery and equipment
5	Other fabricated metal products	OMach	Other machinery and equipment
6	Steam engines and turbines	OMach	Other machinery and equipment
7	General industrial machinery, including materials handling equipment	OMach	Other machinery and equipment
8	Instruments	OMach	Other machinery and equipment
9	Mining and oil field machinery	OMach	Other machinery and equipment
10	Chemical machinery	OMach	Other machinery and equipment
11	Metalworking machines	OMach	Other machinery and equipment
12	Agricultural machinery, except tractors	OMach	Other machinery and equipment
13	Special industrial machinery	OMach	Other machinery and equipment
14	Photocopiers and related equipment	IT	Computing equipment
15	Office computing, and accounting machinery	IT	Computing equipment
16	Service industry machinery	OMach	Other machinery and equipment
17	Household electric appliances (excluding VTRs and applied electronic equipment)	OMach	Other machinery and equipment
18	Computers and peripheral equipment	IT	Computing equipment
19	Communications equipments for business purpose	CT	Communications equipment
20	VTRs and applied electronic equipment	CT	Communications equipment
21	Electricity transmission and distribution apparatus	OMach	Other machinery and equipment
22	Electric lighting fixtures and apparatus	OMach	Other machinery and equipment
23	Passenger cars	TraEq	Transport equipment
24	Trucks, buses, and truck trailers	TraEq	Transport equipment
25	Motorcycles and bicycles	TraEq	Transport equipment
26	Other transport equipment	TraEq	Transport equipment
27	Ships and boats	TraEq	Transport equipment
28	Internal combustion engines	OMach	Other machinery and equipment
29	Railroad equipment	TraEq	Transport equipment
30	Aircraft	TraEq	Transport equipment
31	Other equipments	OMach	Other machinery and equipment
32	Residential construction	RStruc	Residential structures
33	Non-residential construction	OCon	Total non-residential construction
34	Other (private non-residential structures)	OCon	Total non-residential construction
35	Railroad replacement tracks	OCon	Total non-residential construction
36	Construction of electric plants	OCon	Total non-residential construction
37	Construction for electronic communication	OCon	Total non-residential construction
38	Custom software	Soft	Software
39	Other business services	Other	Other assets

Source: Gouma and Timmer (2012).

TABLE A3
INDUSTRY CONCORDANCE FOR JIP AND CIP DATABASE

JIP Code	JIP Description	CIP Code	CIP Description
1	Rice, wheat production	1	Agriculture, forestry and fishing
2	Miscellaneous crop farming	1	Agriculture, forestry and fishing
3	Livestock and sericulture farming	1	Agriculture, forestry and fishing
4	Agricultural services	1	Agriculture, forestry and fishing
5	Forestry	1	Agriculture, forestry and fishing
6	Fisheries	1	Agriculture, forestry and fishing
7	Mining	2,3,4,5	Mining and quarrying
8	Livestock products	6	Food and kindred products
9	Seafood products	6	Food and kindred products
10	Flour and grain mill products	6	Food and kindred products
11	Miscellaneous foods and related products	6	Food and kindred products
12	Prepared animal foods and organic fertilizers	6	Food and kindred products
13	Beverages	6	Food and kindred products
14	Tobacco	7	Tobacco products
15	Textile products	8,9	Textile and apparel products
16	Lumber and wood products	11	Saw mill products, furniture, fixtures
17	Furniture and fixtures	11	Saw mill products, furniture, fixtures
18	Pulp, paper, and coated and glazed paper	12	Paper, printing & publishing
19	Paper products	12	Paper, printing & publishing
20	Printing, plate making for printing and bookbinding	12	Paper, printing & publishing
21	Leather and leather products	10	Leather and leather products
22	Rubber products	15	Rubber and plastics products
23	Chemical fertilizers	14	Chemicals and allied products
24	Basic inorganic chemicals	14	Chemicals and allied products
25	Basic organic chemicals	14	Chemicals and allied products
26	Organic chemicals	14	Chemicals and allied products
27	Chemical fibers	14	Chemicals and allied products
28	Miscellaneous chemical products	14	Chemicals and allied products
29	Pharmaceutical products	14	Chemicals and allied products
30	Petroleum products	13	Petroleum and coal products
31	Coal products	13	Petroleum and coal products
32	Glass and its products	16	Stone, clay, and glass products
33	Cement and its products	16	Stone, clay, and glass products
34	Pottery	16	Stone, clay, and glass products
35	Miscellaneous ceramic, stone and clay products	16	Stone, clay, and glass products
36	Pig iron and crude steel	17	Primary & fabricated metal
37	Miscellaneous iron and steel	17	Primary & fabricated metal
38	Smelting and refining of non-ferrous metals	17	Primary & fabricated metal
39	Non-ferrous metal products	18	Metal products (excl. rolling prod.)

Source: JIP database 2015 and CIP database 3.0.

TABLE A3 (CONTINUED)
INDUSTRY CONCORDANCE FOR JIP AND CIP DATABASE

JIP Code	JIP Description	CIP Code	CIP Description
40	Fabricated constructional and architectural metal products	18	Metal products (excl. rolling prod.)
41	Miscellaneous fabricated metal products	18	Metal products (excl. rolling prod.)
42	General industry machinery	19	Industrial machinery and equipment
43	Special industry machinery	19	Industrial machinery and equipment
44	Miscellaneous machinery	19	Industrial machinery and equipment
45	Office and service industry machines	22	Instruments and office equipment
46	Electrical generating, transmission, distribution and industrial apparatus	20	Electric equipment
47	Household electric appliances	20	Electric equipment
48	Electronic data processing machines, digital and analog computer equipment and accessories	21	Electronic and telecom. equip.
49	Communication equipment	21	Electronic and telecom. equip.
50	Electronic equipment and electric measuring instruments	21	Electronic and telecom. equip.
51	Semiconductor devices and integrated circuits	21	Electronic and telecom. equip.
52	Electronic parts	21	Electronic and telecom. equip.
53	Miscellaneous electrical machinery equipment	20	Electric equipment
54	Motor vehicles	23	Motor vehicles, other trans. equip.
55	Motor vehicle parts and accessories	23	Motor vehicles, other trans. equip.
56	Other transportation equipment	23	Motor vehicles, other trans. equip.
57	Precision machinery & equipment	22	Instruments and office equipment
58	Plastic products	15	Rubber and plastics products
59	Miscellaneous manufacturing industries	24	Miscellaneous manu. industries
60	Construction	26	Construction
61	Civil engineering	26	Construction
62	Electricity	25	Power, steam, gas and water supply
63	Gas, heat supply	25	Power, steam, gas and water supply
64	Waterworks	25	Power, steam, gas and water supply
65	Water supply for industrial use	25	Power, steam, gas and water supply
66	Waste disposal	25	Power, steam, gas and water supply
67	Wholesale	27	Wholesale and Retail Trades
68	Retail	27	Wholesale and Retail Trades
69	Finance	31	Financial Intermediation
70	Insurance	31	Financial Intermediation
71	Real estate	32	Real Estate Activities
72	Housing	32	Real Estate Activities
73	Railway	29	Transport, Storage & post
74	Road transportation	29	Transport, Storage & post
75	Water transportation	29	Transport, Storage & post
76	Air transportation	29	Transport, Storage & post
77	Other transportation and packing	29	Transport, Storage & post
78	Telegraph and telephone	30	Information & computer services

Source: JIP database 2015 and CIP database 3.0.

TABLE A3 (CONTINUED)

INDUSTRY CONCORDANCE FOR JIP AND CIP DATABASE

JIP Code	JIP Description	CIP Code	CIP Description
79	Mail	30	Information & computer services
80	Education (private and non-profit)	35	Education
81	Research (private)	33	Leasing, Tech, Science & Business
82	Medical (private)	36	Health and Social Security
83	Hygiene (private and non-profit)	36	Health and Social Security
84	Other public services	37	Other Services
85	Advertising	33	Leasing, Tech, Science & Business
86	Rental of office equipment and goods	33	Leasing, Tech, Science & Business
87	Automobile maintenance services	27	Wholesale and Retail Trades
88	Other services for businesses	33	Leasing, Tech, Science & Business
89	Entertainment	37	Other Services
90	Broadcasting	37	Other Services
91	Information services and internet-based services	30	Information & computer services
92	Publishing	37	Other Services
93	Video picture, sound information, character information production and distribution	37	Other Services
94	Eating and drinking places	28	Hotels and Restaurants
95	Accommodation	28	Hotels and Restaurants
96	Laundry, beauty and bath services	37	Other Services
97	Other services for individuals	37	Other Services
98	Education (public)	35	Education
99	Research (public)	33	Leasing, Tech, Science & Business
100	Medical (public)	36	Health and Social Security
101	Hygiene (public)	36	Health and Social Security
102	Social insurance and social welfare (public)	36	Health and Social Security
103	Public administration	34	Public Administration and Defense
104	Medical (non-profit)	36	Health and Social Security
105	Social insurance and social welfare (non-profit)	36	Health and Social Security
106	Research (non-profit)	33	Leasing, Tech, Science & Business
107	Other (non-profit)	37	Other Services

Source: JIP database 2015 and CIP database 3.0.

TABLE A4
THE ESTIMATED COEFFICIENTS OF INDUSTRY EFFECTS

Code	Industry	ICT Intensity Model (2)	IT Intensity Model (4)
1	Agriculture, Forestry, Animal Husbandry and Fishery	0.120	0.214
2	Mining and quarrying	0.185	0.255
3	Food and kindred products	0.285	0.449
4	Tobacco products	0.556	0.717
5	Textile mill products, Apparel and other textile products	0.247	0.350
6	Leather and leather products	0.180	0.195
7	Saw mill products, furniture, fixtures	0.255	0.290
8	Paper products, printing & publishing	0.702	1.022
9	Petroleum and coal products	0.275	0.451
10	Chemicals and allied products	0.258	0.287
11	Rubber and plastics products	0.216	0.164
12	Stone, clay, and glass products	0.204	0.292
13	Primary & fabricated metal industries	0.399	0.486
14	Metal products (excl. rolling products)	0.246	0.314
15	Industrial machinery and equipment	0.617	0.139
16	Electric equipment	0.769	0.731
17	Electronic and telecommunication equipment	1.329	1.121
18	Instruments and office equipment	0.790	0.722
19	Motor vehicles & other transportation equipment	0.400	0.372
20	Miscellaneous manufacturing industries	0.592	0.729
21	Power, steam, gas and tap water supply	0.028	0.085
22	Construction	0.444	0.551
23	Wholesale and Retail Trades	0.723	0.945
24	Hotels and Restaurants	0.101	0.175
25	Transport, Storage & post	0.355	0.211
26	Information & computer services	2.791	1.319
27	Financial Intermediation	2.152	3.704
28	Real Estate Activities	0.266	0.281
29	Leasing, Technical, Science & Business Services	0.869	1.225
30	Public Administration and Defense	1.172	0.879
31	Education	0.382	0.263
32	Health and Social Security	0.986	0.305
33	Other Services	0.338	0.391

Source: Authors' estimate. See text in Section 2.

TABLE A5–1
GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 1978–1984 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	9.0	10.3	9.0
2	CLM	Coal mining	9.9	13.8	9.9
3	PTM	Oil and gas extraction	24.9	-203.5	24.8
4	MTM	Metal mining	15.9	14.8	15.9
5	NMM	Non-metallic minerals mining	15.1	22.3	15.1
6	FDB	Food and kindred products	22.4	46.5	22.3
7	TBC	Tobacco products	35.3	23.7	35.4
8	TEX	Textile mill products	21.5	23.9	21.5
9	WEA	Apparel and other textile products	26.6	39.2	26.6
10	LEA	Leather and leather products	24.7	34.1	24.7
11	WDF	Saw mill products, furniture, fixtures	9.7	15.8	9.7
12	PAP	Paper products, printing & publishing	13.4	29.2	13.4
13	PET	Petroleum and coal products	19.5	15.0	19.5
14	CHE	Chemicals and allied products	8.8	23.3	8.8
15	RBP	Rubber and plastics products	19.5	34.3	19.4
16	BUI	Stone, clay, and glass products	16.2	22.4	16.2
17	MSP	Primary & fabricated metal industries	7.6	4.3	7.6
18	MPD	Metal products (excl. rolling products)	9.6	34.1	9.6
19	MCH	Industrial machinery and equipment	4.1	21.4	4.1
20	ELE	Electric equipment	8.7	29.1	8.7
21	ICT	Electronic and telecomminucation equipment	6.9	33.8	6.7
22	INS	Instruments and office equipment	7.7	15.0	7.5
23	TRS	Motor vehicles & other transportation equipment	3.8	17.4	3.8
24	OTH	Miscellaneous manufacturing industries	59.2	-136.0	54.5
25	UTL	Power, steam, gas and tap water supply	17.2	31.6	17.2
26	CON	Construction	11.4	22.8	11.4
27	SAL	Wholesale and Retail Trades	1.9	36.3	1.9
28	HOT	Hotels and Restaurants	14.1	25.6	14.1
29	T&S	Transport, Storage & post	12.0	1.4	12.1
30	P&T	Information & computer services	7.6	0.4	8.1
31	FIN	Financial Intermediation	24.2	19.0	24.7
32	REA	Real Estate Activities	10.5	37.6	10.5
33	BUS	Leasing, Technical, Science & Business Services	16.6	41.2	16.3
34	ADM	Public Administration and Defense	11.4	21.0	11.2
35	EDU	Education	15.1	23.7	15.0
36	HEA	Health and Social Security	17.1	28.7	17.0
37	SER	Other Services	16.7	21.0	16.7

Source: Authors' estimate.
Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

TABLE A5–2
GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 1984–1992 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	3.1	11.2	3.1
2	CLM	Coal mining	7.7	14.1	7.7
3	PTM	Oil and gas extraction	11.1	21.6	11.1
4	MTM	Metal mining	4.6	7.3	4.6
5	NMM	Non-metallic minerals mining	8.1	17.9	8.1
6	FDB	Food and kindred products	9.3	15.9	9.2
7	TBC	Tobacco products	14.1	26.9	14.0
8	TEX	Textile mill products	9.9	18.9	9.9
9	WEA	Apparel and other textile products	14.4	21.8	14.3
10	LEA	Leather and leather products	11.7	19.4	11.7
11	WDF	Saw mill products, furniture, fixtures	10.4	20.4	10.4
12	PAP	Paper products, printing & publishing	11.3	22.4	11.2
13	PET	Petroleum and coal products	12.3	21.7	12.2
14	CHE	Chemicals and allied products	11.1	22.6	11.0
15	RBP	Rubber and plastics products	11.8	21.5	11.8
16	BUI	Stone, clay, and glass products	9.3	17.2	9.3
17	MSP	Primary & fabricated metal industries	10.7	16.9	10.7
18	MPD	Metal products (excl. rolling products)	11.6	22.7	11.5
19	MCH	Industrial machinery and equipment	7.5	22.9	7.4
20	ELE	Electric equipment	14.6	31.5	14.5
21	ICT	Electronic and telecomminucation equipment	14.3	28.7	14.0
22	INS	Instruments and office equipment	11.0	14.8	10.9
23	TRS	Motor vehicles & other transportation equipment	10.1	24.5	10.1
24	OTH	Miscellaneous manufacturing industries	16.4	-1.5	15.9
25	UTL	Power, steam, gas and tap water supply	11.3	16.0	11.3
26	CON	Construction	4.9	9.6	4.8
27	SAL	Wholesale and Retail Trades	4.7	19.9	4.6
28	HOT	Hotels and Restaurants	5.9	13.5	5.9
29	T&S	Transport, Storage & post	10.0	11.3	10.0
30	P&T	Information & computer services	15.3	20.9	15.0
31	FIN	Financial Intermediation	1.8	9.7	1.0
32	REA	Real Estate Activities	8.8	27.3	8.7
33	BUS	Leasing, Technical, Science & Business Services	4.6	8.1	4.6
34	ADM	Public Administration and Defense	5.8	9.2	5.7
35	EDU	Education	10.1	9.3	10.1
36	HEA	Health and Social Security	10.3	17.8	10.2
37	SER	Other Services	9.7	19.8	9.6

Source: Authors' estimate.
Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

TABLE A5–3

GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 1992–1996 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	5.7	40.8	5.6
2	CLM	Coal mining	6.1	46.8	5.8
3	PTM	Oil and gas extraction	2.2	28.1	2.0
4	MTM	Metal mining	2.5	38.2	2.3
5	NMM	Non-metallic minerals mining	8.5	49.3	8.2
6	FDB	Food and kindred products	15.0	46.9	14.7
7	TBC	Tobacco products	7.9	31.6	7.4
8	TEX	Textile mill products	9.6	44.9	9.4
9	WEA	Apparel and other textile products	16.4	43.4	16.2
10	LEA	Leather and leather products	13.0	44.6	12.8
11	WDF	Saw mill products, furniture, fixtures	13.6	51.6	13.3
12	PAP	Paper products, printing & publishing	12.2	42.7	11.6
13	PET	Petroleum and coal products	6.9	35.7	6.6
14	CHE	Chemicals and allied products	11.5	45.1	11.1
15	RBP	Rubber and plastics products	12.9	42.8	12.6
16	BUI	Stone, clay, and glass products	16.3	53.8	16.0
17	MSP	Primary & fabricated metal industries	12.7	42.0	12.3
18	MPD	Metal products (excl. rolling products)	15.7	60.1	15.1
19	MCH	Industrial machinery and equipment	7.8	39.0	7.2
20	ELE	Electric equipment	13.1	43.0	12.3
21	ICT	Electronic and telecomminucation equipment	12.9	39.0	11.6
22	INS	Instruments and office equipment	9.2	36.7	8.6
23	TRS	Motor vehicles & other transportation equipment	14.7	50.6	14.2
24	OTH	Miscellaneous manufacturing industries	27.2	68.2	26.2
25	UTL	Power, steam, gas and tap water supply	10.8	65.9	10.7
26	CON	Construction	13.4	65.4	12.3
27	SAL	Wholesale and Retail Trades	7.8	44.0	7.2
28	HOT	Hotels and Restaurants	8.5	44.8	8.4
29	T&S	Transport, Storage & post	17.9	50.4	17.5
30	P&T	Information & computer services	4.5	24.6	2.8
31	FIN	Financial Intermediation	5.8	23.4	3.4
32	REA	Real Estate Activities	23.6	57.3	23.5
33	BUS	Leasing, Technical, Science & Business Services	0.3	28.6	-0.5
34	ADM	Public Administration and Defense	12.3	18.3	12.1
35	EDU	Education	8.1	29.6	8.0
36	HEA	Health and Social Security	5.8	32.5	5.2
37	SER	Other Services	6.9	35.9	6.6

Source: Authors' estimate.

Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

TABLE A5–4
GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 1996–2001 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	10.0	36.9	9.8
2	CLM	Coal mining	4.0	22.0	3.8
3	PTM	Oil and gas extraction	16.5	50.4	15.9
4	MTM	Metal mining	-0.6	13.5	-0.7
5	NMM	Non-metallic minerals mining	9.1	30.5	8.8
6	FDB	Food and kindred products	3.0	17.2	2.8
7	TBC	Tobacco products	18.5	36.1	17.8
8	TEX	Textile mill products	0.1	13.7	0.0
9	WEA	Apparel and other textile products	4.6	26.9	4.4
10	LEA	Leather and leather products	3.2	21.2	3.0
11	WDF	Saw mill products, furniture, fixtures	11.1	30.8	10.7
12	PAP	Paper products, printing & publishing	12.4	34.3	11.4
13	PET	Petroleum and coal products	14.7	40.4	14.3
14	CHE	Chemicals and allied products	6.3	23.3	6.0
15	RBP	Rubber and plastics products	7.3	26.0	7.0
16	BUI	Stone, clay, and glass products	-1.1	6.2	-1.2
17	MSP	Primary & fabricated metal industries	5.6	22.1	5.1
18	MPD	Metal products (excl. rolling products)	3.8	16.6	3.5
19	MCH	Industrial machinery and equipment	-0.2	11.1	-0.6
20	ELE	Electric equipment	8.5	26.8	7.6
21	ICT	Electronic and telecomminucation equipment	16.7	38.0	14.3
22	INS	Instruments and office equipment	-1.2	-48.3	1.1
23	TRS	Motor vehicles & other transportation equipment	6.3	22.0	5.8
24	OTH	Miscellaneous manufacturing industries	2.4	16.2	1.8
25	UTL	Power, steam, gas and tap water supply	15.7	45.6	15.5
26	CON	Construction	11.0	31.6	9.8
27	SAL	Wholesale and Retail Trades	13.1	42.4	11.5
28	HOT	Hotels and Restaurants	15.7	39.8	15.6
29	T&S	Transport, Storage & post	18.9	37.2	18.5
30	P&T	Information & computer services	20.4	45.6	14.8
31	FIN	Financial Intermediation	7.5	27.6	2.0
32	REA	Real Estate Activities	17.3	33.8	17.3
33	BUS	Leasing, Technical, Science & Business Services	12.2	39.1	10.2
34	ADM	Public Administration and Defense	17.6	25.2	17.3
35	EDU	Education	16.1	38.5	15.7
36	HEA	Health and Social Security	14.5	36.5	13.1
37	SER	Other Services	12.1	29.2	11.7

Source: Authors' estimate.

Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

TABLE A5–5
GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 2001–2007 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	11.1	21.6	11.0
2	CLM	Coal mining	16.7	28.3	16.4
3	PTM	Oil and gas extraction	1.9	3.6	1.9
4	MTM	Metal mining	19.6	36.2	19.3
5	NMM	Non-metallic minerals mining	11.0	17.7	10.9
6	FDB	Food and kindred products	13.8	28.2	13.5
7	TBC	Tobacco products	-4.9	-9.2	-4.8
8	TEX	Textile mill products	12.9	29.8	12.6
9	WEA	Apparel and other textile products	13.3	26.9	13.0
10	LEA	Leather and leather products	14.7	28.4	14.5
11	WDF	Saw mill products, furniture, fixtures	18.1	28.5	17.8
12	PAP	Paper products, printing & publishing	14.1	21.4	13.6
13	PET	Petroleum and coal products	-1.0	2.4	-1.1
14	CHE	Chemicals and allied products	14.1	25.6	13.8
15	RBP	Rubber and plastics products	14.2	22.8	14.0
16	BUI	Stone, clay, and glass products	14.0	31.9	13.7
17	MSP	Primary & fabricated metal industries	17.5	29.8	17.0
18	MPD	Metal products (excl. rolling products)	14.0	25.6	13.7
19	MCH	Industrial machinery and equipment	16.3	31.4	15.4
20	ELE	Electric equipment	13.6	22.8	12.9
21	ICT	Electronic and telecomminucation equipment	20.0	27.4	18.5
22	INS	Instruments and office equipment	24.1	42.0	22.7
23	TRS	Motor vehicles & other transportation equipment	10.8	19.0	10.5
24	OTH	Miscellaneous manufacturing industries	12.4	-43.5	9.0
25	UTL	Power, steam, gas and tap water supply	9.9	23.1	9.8
26	CON	Construction	14.1	17.6	13.7
27	SAL	Wholesale and Retail Trades	9.7	14.4	9.2
28	HOT	Hotels and Restaurants	15.4	27.3	15.3
29	T&S	Transport, Storage & post	12.9	20.8	12.7
30	P&T	Information & computer services	6.2	14.2	3.1
31	FIN	Financial Intermediation	-0.5	7.9	-4.1
32	REA	Real Estate Activities	16.1	32.1	16.1
33	BUS	Leasing, Technical, Science & Business Services	10.4	16.4	9.7
34	ADM	Public Administration and Defense	26.9	40.1	26.3
35	EDU	Education	14.2	24.5	14.0
36	HEA	Health and Social Security	16.3	26.7	15.2
37	SER	Other Services	31.6	42.7	31.2

Source: Authors' estimate.
Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

TABLE A5–6
GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 2007–2012 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	18.6	22.5	18.6
2	CLM	Coal mining	16.1	16.2	16.1
3	PTM	Oil and gas extraction	4.2	4.6	4.2
4	MTM	Metal mining	12.4	12.5	12.4
5	NMM	Non-metallic minerals mining	11.7	11.9	11.7
6	FDB	Food and kindred products	17.2	17.3	17.2
7	TBC	Tobacco products	-0.6	0.9	-0.7
8	TEX	Textile mill products	8.2	8.2	8.2
9	WEA	Apparel and other textile products	14.3	17.3	14.2
10	LEA	Leather and leather products	14.2	17.8	14.1
11	WDF	Saw mill products, furniture, fixtures	13.4	12.3	13.4
12	PAP	Paper products, printing & publishing	8.8	7.4	8.8
13	PET	Petroleum and coal products	8.5	11.8	8.5
14	CHE	Chemicals and allied products	14.9	13.4	14.9
15	RBP	Rubber and plastics products	10.2	10.2	10.2
16	BUI	Stone, clay, and glass products	16.6	21.7	16.6
17	MSP	Primary & fabricated metal industries	14.6	14.5	14.6
18	MPD	Metal products (excl. rolling products)	19.8	19.3	19.8
19	MCH	Industrial machinery and equipment	15.8	16.5	15.7
20	ELE	Electric equipment	18.3	19.0	18.2
21	ICT	Electronic and telecomminucation equipment	9.5	7.2	9.8
22	INS	Instruments and office equipment	3.9	1.8	4.1
23	TRS	Motor vehicles & other transportation equipment	14.9	13.1	15.0
24	OTH	Miscellaneous manufacturing industries	9.7	9.8	9.7
25	UTL	Power, steam, gas and tap water supply	8.8	10.6	8.8
26	CON	Construction	17.6	14.8	17.8
27	SAL	Wholesale and Retail Trades	17.4	19.3	17.3
28	HOT	Hotels and Restaurants	21.6	23.0	21.6
29	T&S	Transport, Storage & post	13.1	14.5	13.0
30	P&T	Information & computer services	5.5	11.2	3.3
31	FIN	Financial Intermediation	12.1	14.8	11.2
32	REA	Real Estate Activities	13.4	18.4	13.4
33	BUS	Leasing, Technical, Science & Business Services	25.9	29.2	25.6
34	ADM	Public Administration and Defense	21.7	22.8	21.6
35	EDU	Education	10.1	8.7	10.2
36	HEA	Health and Social Security	18.5	18.8	18.5
37	SER	Other Services	22.8	31.1	22.7

Source: Authors' estimate.
Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

TABLE A5–7
GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 2012–2018 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	18.3	17.8	18.3
2	CLM	Coal mining	1.6	-8.1	1.7
3	PTM	Oil and gas extraction	2.2	-2.9	2.3
4	MTM	Metal mining	28.7	27.1	28.8
5	NMM	Non-metallic minerals mining	17.4	12.6	17.5
6	FDB	Food and kindred products	4.3	-2.8	4.4
7	TBC	Tobacco products	-0.5	-4.8	-0.4
8	TEX	Textile mill products	-3.1	-13.1	-3.0
9	WEA	Apparel and other textile products	8.9	3.4	8.9
10	LEA	Leather and leather products	-2.4	-13.8	-2.3
11	WDF	Saw mill products, furniture, fixtures	2.0	-5.6	2.1
12	PAP	Paper products, printing & publishing	-3.8	-14.2	-3.5
13	PET	Petroleum and coal products	2.3	-3.6	2.4
14	CHE	Chemicals and allied products	-0.8	-9.3	-0.7
15	RBP	Rubber and plastics products	-1.4	-7.0	-1.3
16	BUI	Stone, clay, and glass products	-9.3	-25.2	-9.2
17	MSP	Primary & fabricated metal industries	-2.2	-9.1	-2.1
18	MPD	Metal products (excl. rolling products)	6.6	-0.7	6.7
19	MCH	Industrial machinery and equipment	2.4	-2.4	2.6
20	ELE	Electric equipment	9.2	6.1	9.4
21	ICT	Electronic and telecomminucation equipment	10.7	8.1	10.9
22	INS	Instruments and office equipment	17.0	-11.4	18.0
23	TRS	Motor vehicles & other transportation equipment	5.6	0.6	5.7
24	OTH	Miscellaneous manufacturing industries	11.9	6.0	12.2
25	UTL	Power, steam, gas and tap water supply	7.0	-4.3	7.0
26	CON	Construction	9.4	8.9	9.5
27	SAL	Wholesale and Retail Trades	15.4	15.5	15.4
28	HOT	Hotels and Restaurants	10.8	10.3	10.9
29	T&S	Transport, Storage & post	13.0	15.9	12.9
30	P&T	Information & computer services	12.2	12.7	12.0
31	FIN	Financial Intermediation	12.8	7.4	14.1
32	REA	Real Estate Activities	9.2	12.9	9.2
33	BUS	Leasing, Technical, Science & Business Services	25.4	25.2	25.4
34	ADM	Public Administration and Defense	18.4	18.1	18.4
35	EDU	Education	12.6	13.2	12.5
36	HEA	Health and Social Security	17.9	16.4	18.0
37	SER	Other Services	15.2	13.2	15.2

Source: Authors' estimate.
Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

TABLE A5–8
GROWTH RATES OF TOTAL, ICT, AND NON-ICT CAPITAL STOCK, 1978–2018 (%)

Code	Abbr.	Industry	Total	ICT	non-ICT
1	AGR	Agriculture, Forestry, Animal Husbandry and Fishery	10.5	21.2	10.5
2	CLM	Coal mining	8.9	17.4	8.8
3	PTM	Oil and gas extraction	9.4	-16.4	9.3
4	MTM	Metal mining	12.3	20.2	12.2
5	NMM	Non-metallic minerals mining	11.6	21.7	11.5
6	FDB	Food and kindred products	11.9	23.0	11.8
7	TBC	Tobacco products	10.3	14.6	10.2
8	TEX	Textile mill products	8.7	17.1	8.6
9	WEA	Apparel and other textile products	14.2	24.6	14.1
10	LEA	Leather and leather products	11.4	20.5	11.3
11	WDF	Saw mill products, furniture, fixtures	11.0	20.4	10.9
12	PAP	Paper products, printing & publishing	9.7	19.4	9.4
13	PET	Petroleum and coal products	9.2	16.5	9.1
14	CHE	Chemicals and allied products	9.3	19.6	9.2
15	RBP	Rubber and plastics products	10.7	20.6	10.6
16	BUI	Stone, clay, and glass products	8.6	16.7	8.5
17	MSP	Primary & fabricated metal industries	9.4	15.9	9.2
18	MPD	Metal products (excl. rolling products)	11.4	23.9	11.2
19	MCH	Industrial machinery and equipment	7.6	19.5	7.4
20	ELE	Electric equipment	12.3	25.0	12.0
21	ICT	Electronic and telecomminucation equipment	13.0	25.7	12.4
22	INS	Instruments and office equipment	10.8	7.7	10.9
23	TRS	Motor vehicles & other transportation equipment	9.2	19.9	9.0
24	OTH	Miscellaneous manufacturing industries	20.0	-16.3	18.6
25	UTL	Power, steam, gas and tap water supply	11.5	24.4	11.5
26	CON	Construction	11.1	21.6	10.8
27	SAL	Wholesale and Retail Trades	9.6	26.0	9.2
28	HOT	Hotels and Restaurants	12.7	24.5	12.7
29	T&S	Transport, Storage & post	13.5	19.5	13.3
30	P&T	Information & computer services	10.7	17.8	9.0
31	FIN	Financial Intermediation	8.9	14.7	7.4
32	REA	Real Estate Activities	13.3	30.1	13.3
33	BUS	Leasing, Technical, Science & Business Services	13.6	25.4	13.0
34	ADM	Public Administration and Defense	15.8	21.5	15.6
35	EDU	Education	12.4	19.9	12.3
36	HEA	Health and Social Security	14.4	24.5	14.0
37	SER	Other Services	16.5	26.6	16.4

Source: Authors' estimate.
Notes: The growth rate of capital stock for each asset category is estimated based on the Törnqvist aggregation of components.

REFERENCES

van Ark, Bart, 2002. "*ICT investments and growth accounts for the European Union*". s.n.

Colecchia, Alessandra and Paul Schreyer, 2002. "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries", *Review of Economic Dynamics*, Vol. 5, pp. 408–442.

Fukao, Kyoji, Sumio Hamagata, Tomohiko Inui, Keiko Ito, Hyeog Ug Kwon, Tatsuji Makino, Tsutomu Miyagawa, Yasuo Nakanishi, and Joji Tokui. 2007. "Estimation Procedure and TFP Analysis of the JIP Database 2006 (revised)". *RIETI Discussion Papers*, 07-E-003.

Fukao, Kyoji, Tsutomu Miyagawa, Hak K. Pyo and Keun H. Rhee, 2009. "Estimates of Multifactor Productivity, ICT Contributions and Resource Reallocation Effects in Japan and Korea", *RIETI Discussion Papers*, 09-E-021.

Fukao, Kyoji, Young Gak Kim, and Hyeog Ug Kwon, 2021. "The Causes of Japan's Economic Slowdown: An Analysis Based on the Japan Industrial Productivity Database." *International Productivity Monitor* (40), pp. 56ç88.

Goldsmith, R.W., 1951, "A perpetual inventory of national wealth", in M.R. Gainsburgh (ed.) *Studies in Income and Wealth*, Vol.14, Princeton.

Gouma, Reitze, and Marcel Timmer, 2012. "EU KLEMS Growth and Productivity Accounts. 2012 release." *Description of methodology and country notes for Japan*.

Hall, Robert E. and Dale W. Jorgenson, 1967, "Tax Policy and Investment Behaviour", *American Economic Review*, 57: 391–414.

Hulten, Charles R., 1990, "The Measurement of Capital," in Berndt, Ernst R. and Jack E. Triplette, eds. *Fifty Years of Economic Measurement: The Jubilee*, NBER, Studies in Income and Wealth, No. 54, University of Chicago Press, 1991.

Jorgenson, Dale W., 1963, "Capital Theory and Investment Behavior", *American Economic Review*, 53 (2): 247–59.

Jorgenson, Dale W., 2001. "Information Technology and the U.S. Economy", *American Economic Review*, Vol. 91 (1), pp. 1–32.

Jorgenson, Dale W. and Griliches, Z., 1967. "The explanation of productivity change", *Review of Economic Studies*, vol. 34 (3), pp. 249–83.

Jorgenson, Dale W., Mun S. Ho and Kevin J. Stiroh, 2005. *Information Technology and the American Growth Resurgence, Productivity Volume 3*. Cambridge, MA: MIT Press.

King, Robert J. and Ross Levine, 1994. "Capital Fundamentalism Economic Development and Economic Growth." *Carnegie-Rochester Conference Series on Public Policy* 40 (June): 259–292.

Miyagawa, Tsutomu and Sumio Hamagata, 2004. “Wagakuni IT Toshi no Kaseika Yoin – JIP database wo Riyo shita Kokusai Hikaku to Jissho Bunseki”, *Keizai Kenkyu (Economic Research)*, Vol. 55 (3), pp. 245–260.

OECD, 2009. *Handbook on Deriving Capital Measures of Intellectual Property Products*, OECD Publishing, Paris, https://www.oecd.org/sdd/na/44312350.pdf.

O’Mahony, M. and Bart van Ark, eds., 2003. EU Productivity and Competitiveness: An Industry Perspective. Can Europe Resume the Catching-up Process?, DG Enterprise, European Union, Luxembourg (http://www.ggdc.net/pub/EU_productivity_and_competitiveness.pdf).

Schreyer, P. 2002. “Computer Price Indices and International Growth and Productivity Comparisons”, *Review of Income and Wealth*, 48 (1), pp. 15–31.

Wu, Harry X. 2015. “Constructing China’s Net Capital Stock and Measuring Capital Service in China”, *RIETI Discussion Papers*, 15-E-006.

Wu, Harry X. 2019. “In Quest of Institutional Interpretation of TFP Change—The Case of China.” *Man and the Economy*, 6 (2).

Wu, Harry X. and David T. Liang, 2017. “Accounting for the Role of Information and Communication Technology in China’s Productivity Growth”, *RIETI Discussion Papers*, 17-E-111.

Wu, Harry X. and Keiko Ito, 2015. Reconstruction of China’s National Output and Income Accounts and Supply-Use and Input-Output Accounts in Time Series, *RIETI Discussion Papers*, 15-E-004.

Xu, Chenggang. 2011. “The Fundamental Institutions of China's Reforms and Development.” *Journal of Economic Literature* 49(4): 1076–51.