Has the ICT sector become the engine of China's economic growth?

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Abstract: This study examines the key drivers of the information and communication technology (ICT) sector's growth and the dynamics of its sectoral links in the Chinese economy, about which little is known, by using four updated and harmonized input-output tables for the period 2002-2017. The decomposition analysis shows that the ICT sector's growth was mainly driven by expansion of export and domestic demand in the 2002-2007 period, and by domestic demand expansion in the 2007-2012 and 2012-2017 periods. Furthermore, causative matrix analysis demonstrates that the ICT sector was consistently externalized throughout the study period, regardless of whether it received limited feedback from non-ICT sectors' final demand in the 2002-2007 and 2012-2017 periods, or substantial feedback in the 2007-2012 period. Finally, linkage analysis reveals that the ICT sector has had profound inter-sectoral linkages with both supply- and demand-side effects in the economy. We conclude that the ICT sector has been the engine of economic growth in China, and that stimulating its growth is a key tool for economic development.

Key words: ICT sector; Input–Output analysis; Structural decomposition analysis; Causative matrix; information intensity; Linkage analysis.

JEL: D57, D83.

1. Introduction

China is transforming into an innovation-driven economy, with information and communication technology (ICT) playing an increasingly important role as a driver of growth and competitiveness (Zhang & Chen, 2019; Li & Wu, 2018). The shifts toward an innovation-driven economy are attributable to a variety of factors. In the early 2000s, the Chinese government declared "informatization[1]" as its national strategy, and it viewed ICT as both a cutting-edge sector and a general-purpose technology (GPT)[2] for China's transition from manufacturing to a knowledge-based innovation-driven economy (Atkinson, 2014). Furthermore, China's WTO accession in 2001, followed by the International Technological Agreement in 2002, decisively contributed to the rapid upgrading of information technology, as well as to the creation of enormous demand for Chinese ICT products in international markets (Hong, 2008). China's ICT market is one of the leading ICT markets in the world, valued at RMB 18 trillion (US$2.68 trillion) in 2017. The total fixed investment in the ICT sector—defined as purchases of newly produced fixed capital—increased more than fourfold from RMB 116 billion in 2003 to RMB 699 billion in 2017. At the same time, the value-added of the ICT sector increased rapidly from RMB 476 billion in 2003 to RMB 2640 billion in 2017 (China Statistics Yearbook, 2019). What is more, the rapid integration of the ICT sector with traditional sectors has accelerated China's digital transformation. According to the China Academy of Information and Communication Technology (2017), the size of its digital economy reached 33% of China's GDP in 2017, up from 14% in 2005. The service sector has the highest level of digitalization, with a 33% contribution of ICT to its value-added, followed by the industrial and agricultural sectors, which account for 17% and 7%, respectively.

The remarkable technological evolution of the last two decades, combined with the rapid development and application of new technologies in production activities, has increased productivity in a

[1] The term "informatization" refers to the extent to which an economy or society is becoming information-intensive (adoption of ICT in an economy).

[2] Bresnahan and Trajtenberg (1995) highlighted three basic characteristics of a GPT that distinguish it from other technologies: 1) *Pervasiveness* – a GPT spreads to a wide range of sectors; 2) *Innovation spawning* –a GPT facilitates invention, the production of new products, and improvements in current production processes or products; 3) *Improvement* –a GPT improves over time and continues to lower the cost of its users.

variety of economic sectors in China, resulting in significant structural changes. Such transformations are apt to have altered the inter-sectoral links between the ICT sector and non-ICT sectors (Savulescu, 2015; Heo & Lee, 2019). Given the widely recognized dynamic nature of the ICT sector and its significance in knowledge creation and diffusion, it is policy relevant to determine the degree to which the Chinese economy has been informatized and to measure the major determinants of the output of the ICT sector, as well as the structural changes that have occurred in its inter-sectoral linkage relationship with the rest of the economic sectors. This would enable policymakers to gain a better understanding of the ICT sector's evolving role and thereby design effective policies to promote economic growth, while also promoting informatization and digitalization.

We aim to offer a reference piece on the movements in the sectoral links of the Chinese ICT sector, about which little is known, by pursuing four objectives. First, a quantification and decomposition of China's major growth drivers of the ICT sector aims to determine how the sector's sources of growth have changed over time. Our second objective is to determine the degree to which the Chinese economy has been informatized, as well as to assess the changes that have occurred in the inter-sectoral feedback between the ICT sector and non-ICT sectors. Our third objective is to assess the ICT sector's inter-sectoral linkages (supply- and demand-side effects), and to measure the information intensities of various sectors and their variations from 2002 to 2017. Finally, we aim to identify the most information-intensive Chinese manufacturing and service sectors.

Recent literature on economic growth and productivity has increasingly recognized knowledge as a productive asset. Countries can accelerate economic growth through knowledge creation and diffusion (Corrado et al., 2017). The role of ICT in transforming knowledge-based economies and in boosting productivity growth has become imperative (Cardona et al., 2013; Niebel, 2018). Theoretical literature suggests that the impact of ICT on productivity occurs through three main channels (Schreyer, 2002). First, investment in ICT capital as an input into the productive process directly contributes to productivity growth. ICT-related capital deepening boosts productivity by raising capital stock per worker, thereby lowering the marginal cost of capital, and bringing new ICT products. It improves the efficiency of knowledge creation, utilization and distribution in the economy (Roller & Waverman, 2001). To the extent that it substitutes for other forms of inputs (labor and capital), ICT frees productive resources to expand the productive capacity; to the extent that it supplements labor and capital, ICT improves the productivity of existing capital and labor stocks (Zhen-Wei & Alexander, 2004). Second, the emergence of new ICT-producing sectors directly contributes to the total value-added generated in an economy. ICT producing sectors with features of rapid technological progress and high total factor productivity (TFP) growth contribute to an economy's overall TFP (Cardona et al., 2013; Toh & Thangavelu, 2013). Finally, ICT contributes to productivity growth through its spillover effects, both within the ICT producing sectors and across ICT-using sectors (Cai & Zhang, 2015). The spillover effect of ICT is caused by the technology's network characteristics and by knowledge dissemination, and it occurs when the use of ICT in one sector affects the productivity of other sectors (Moshiri, 2016).

Given the importance of the ICT sector in the Chinese economy, some empirical work has been conducted to investigate its impact (Li & Wu, 2018; Cai & Zhang, 2015; Sun et al., 2012; Khuong, 2006). Several studies have confirmed the existence of a positive contribution of ICT to China's economic growth and productivity (Cai & Zhang, 2015; Heshmati & Yang, 2006; Zhang & Chen, 2019). For instance, Zhang and Chen (2019) discovered a strong correlation between the digital economy's growth and that of TFP. They further concluded that a unit increase in the overall digitalization of the economy results in a 0.3 percentage point increase in GDP growth. Likewise, other studies have found that ICT-intensive sectors have experienced rapid growth in value-added (Li & Wu, 2018; Li & Wu, 2019). In addition, several researchers have used Input-Output (I-O) analysis to examine the role of the ICT sector in the Chinese economy. For example, Yang and Zhou (2017) highlighted that intangible capital has an imperative role in transforming China into knowledge-based economy. They further argued that growth in intangible capital accounted for 20% of TFP growth in China from 1997 to 2012. Li et al. (2019) find that the Chinese ICT sector has a greater industrial impact and competitive advantage than do non-ICT sectors.

However, in this diverse empirical literature, little attention has been paid to the measurement of the determinants of growth in the ICT sector, as well as the extent to which rapid technological development and growth in the ICT sector may have altered its inter-sectoral relationship with non-ICT sectors. In addition, the supply- and demand-side effects of China's ICT sector, as well as the information intensities of various economic sectors, have gone unnoticed. To this end, we attempt to provide a more comprehensive analysis of the Chinese ICT sector, using four Chinese I-O tables (2002, 2007, 2012, and 2017).

We employ structural decomposition analysis (SDA) to examine how the major drivers of growth of the ICT sector have changed intertemporally. Furthermore, we employ the causative matrix approach to investigate the extent of informatization in the Chinese economy, as well as the inter-sectoral relationship of the ICT sector with non-ICT sectors. This approach enables us to detect structural changes as well as the changing nature of the ICT sector's feedback relationship with non-ICT sectors. Next, normalized backward and forward linkages, along with Rasmussen indices and the Leontief matrix, are used to gauge the inter-sectoral linkages (supply- and demand-side impacts) of the ICT sector and information intensities of the entire economy. This analysis allows us to determine whether the ICT sector has become the engine of China's economic growth, as well as how the information intensity of various sectors changes over time.

Our analysis yields four main results. First, we document that growth in the ICT sector was driven primarily by both export and domestic demand expansions in the period 2002-2007. However, in the subsequent two periods (2007-2012 and 2012-2017), domestic demand expansion contributed significantly (more than half) to the ICT sector's growth, whereas the other two factors, namely export and import substitution, accounted for the majority of the remaining growth. Second, we discover that the ICT sector's inter-sectoral relationship with non-ICT sectors has undergone significant structural changes. The notable aspect is the consistent externalization of the ICT sector over the study period, regardless of whether it received less feedback from non-ICT sectors' final demand in the periods 2002-2007 and 2012-2017, or more feedback from non-ICT sectors in the period 2007-2012. Third, our findings show that the Chinese ICT sector was a 'key' sector in the economy, having both strong supply- and demand-side effects on non-ICT sectors. Finally, we document that information intensities, of both technology-intensive manufacturing and service sectors, have increased in the Chinese economy. To sum up, our findings demonstrate that the ICT sector has been an engine of economic growth in China, with deep inter-sectoral linkages and supply- and demand-side effects.

Our analysis makes a four-fold contribution. First, we use the latest available I-O table of 2017, along with three consecutive official published I-O tables, which enables us to provide more comprehensive and updated estimates of the ICT sector's contribution to China's economy. Second, to the best of our knowledge, we offer one of the first decomposition analyses, similar to Roy et al. (2002), to assess changes in the major drivers of the ICT sector's growth. Third, we present the first application of the causative matrix approach to study the extent of informatization of the Chinese economy, and to identify the structural changes in the relationship of the ICT sector with non-ICT sectors. Finally, we employ comprehensive linkage indices to measure the inter-sectoral linkages—supply- and demand-side effects—of the Chinese ICT sector, as well as the economy's overall information intensities.

The remainder of the study is structured as follows: Section 2 offers an overview of China's ICT sector while Section 3 outlines methodology and sheds light on data. Section 4 reports and discusses the main results, while the last section contains our conclusions.

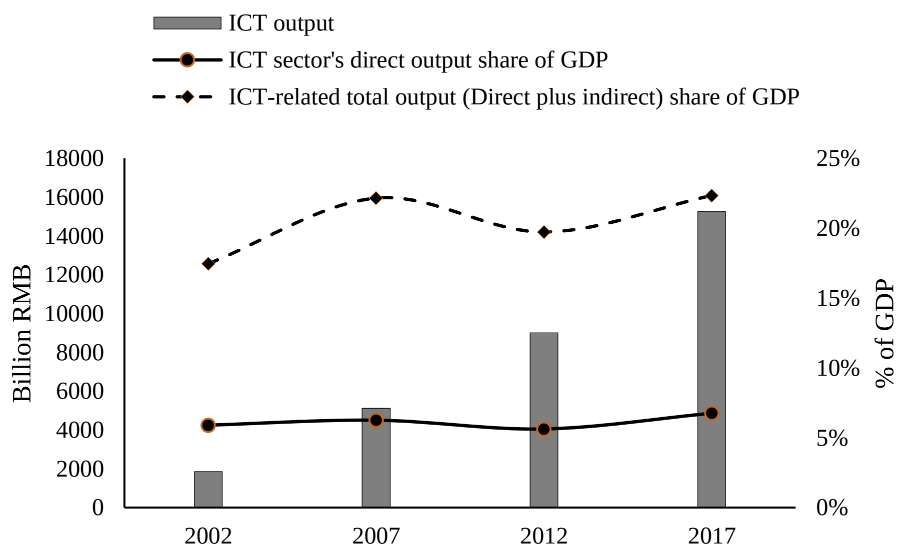
2. Macroeconomic Effects of the ICT sector in China

Here we assess the direct macroeconomic impacts of the Chinese ICT sector, as well as its economic characteristics, by using a series of indicators derived from the national I-O table of China from 2002 to 2017. We begin by examining the ICT sector's contribution to China's gross domestic products (GDP) and gross national income (GNI). Furthermore, we calculate the ICT sector's share of household final consumption (HFC), gross fixed capital formation (GFCF), and gross compensation of employees (GCE), which will help us to understand the ICT sector's impact on domestic consumption, production and employment.

Table 1 reports the contribution of the ICT sector to different indicators, as well as their rankings, from 2002 to 2017. The contribution of the ICT sector to China's GDP increased eightfold from 2002 to

2017 (Figure 1). It increased from RMB 1849 billion in 2002, representing 5.9% of China's GDP (fourth place), to RMB 5122 billion in 2007 and RMB 9010 billion in 2012, representing 6.26% and 5.63% of its GDP, respectively. It peaked in 2017, when it contributed RMB 15245 billion, or 6.75% of GDP (second place). The ICT sector makes both direct output contributions in the economy and indirect contributions to total output through its linkages with the upstream and downstream sectors. Over the study period, total (direct and indirect) ICT-related output remained significantly higher than its direct output effect—nearly three times the direct effect. For instance, in 2002, total ICT-related output accounted for 17.5% of the national economy; by 2017, that figure had risen to 22.3% (Figure 1). The underlying reason for such a stronger indirect impact is that the ICT sector plays a significant role, first in creating demand and then in meeting those demands. These findings show that the ICT sector's role in the Chinese economy is growing, with significant direct and indirect effects and strong sectoral links.

Figure 1. Contribution of China’s ICT sector to the national output



Source: Calculated by the authors.

Furthermore, the ICT sector's share of China's GNI was 5.02% in 2002 (ranked fifth), whereupon it declined, reaching its lowest level in 2012, with a share of 4.3% (ranked eight). However, its trend reversed and reached a peak in 2017, with a share of 5.5% and a contribution of RMB 4522.30 billion (ranked seventh). In addition, the share of the ICT sector in the total HFC of the national economy ranged between 4.14% and 5.1%. Overall, its share in HFC peaked in 2007, after which it began to decline. The share of the ICT sector in the GFCF of China fell significantly from 7.1% in 2002 to 5.1% in 2007. However, it has been steadily increasing since 2007, reaching a peak in 2017 with a share of 7.7% (ranked fourth) and a contribution of RMB 2802.76 billion. Finally, the share of the ICT sector in the total national GCE has steadily increased, from 2.8% in 2002 to 4.7% in 2017, while its ranking has improved from 10 in 2002 to 7 in 2017. This discussion demonstrates that China's ICT sector has a significant impact on production, consumption and employment.

Table 1. The contribution of the ICT sector to China's national economy

Year	**Share in GDP**	**Rank**	**Share in GNI**	**Rank**	**Share in HFC**	**Rank**	**Share in GFCF**	**Rank**	**Share in GCE**	**Rank**
2002	5.90	4	5.02	5	4.14	9	7.10	3	2.80	10
2007	6.26	4	4.82	6	5.09	7	5.13	4	3.17	9
2012	5.63	4	4.26	8	4.83	8	5.76	4	3.63	8
2017	6.75	2	5.49	7	4.58	9	7.69	4	4.71	7

Source: Calculated by the authors.

3. Methods and Data

3.1 Structural Decomposition Analysis

A sector's growth can be decomposed into changes in its various determinants, such as intermediate input, imports, along with domestic and foreign demands. Structural Decomposition Analysis (SDA), developed by Chenery (1960), has been a widely used approach in the I-O framework to unravel a sector's aggregate growth; part by part, from intermediate and final demands, and from domestic and international sources. A significant amount of literature on SDA methodology and its applications has been developed in recent years; see, for example, Dietzenbacher and Los (2000), Jacobsen (2000), Roy et al. (2002), and Huang et al. (2021).

This study has adopted the SDA based model of Roy et al. (2002) to explore the ICT sector's sources of growth. In an open Leontief system, the basic material balance between supply and demand is given as:

$$x_i = u_i(d_i + w_i) + e_i \qquad (1)$$

where x_i, u_i,d_i, w_i,and e_i are the vectors of domestic production, domestic supply ratio, domestic final demand, intermediate demand, and exports of sector i, respectively. The domestic supply ratio which is the proportion of intermediate and final demand produced domestically in sector i, is given as:

$$u_i = (x_i - e_i)/(d_i + w_i) \qquad (2)$$

Equation (2) can be rewritten as:

$$x_i = u_i d_i + u_i w_i + e_i \qquad (3)$$

Intermediate demand is the product of technical coefficients and output of sector, $w = A\text{x}$, (where A is the matrix of technical coefficients). The above equation in matrix notation is given as:

$$x = \hat{u}d + \hat{u}Ax + e \qquad (4)$$

$$x = (I - \hat{u}A)^{-1}(\hat{u}d + e) \qquad (5)$$

Let $R = (I - \hat{u}A)^{-1}$, then

$$x = R(\hat{u}d + e) \qquad (6)$$

where, û is the diagonal matrix of a sector's domestic supply ratio.

Equation 6 can be further transformed into an ICT balance equation from the basic material balance equation as follows: $\hat{g}x = \hat{g}[R(\hat{u}d + e)]$ (7)

where ĝ is the diagonal matrix with ones and zeros. To select the ICT sector row from the I-O table, the row corresponding to the ICT sector is set to one while the other diagonal elements are set to zero. Following Roy et al. (2002), the change in output between two periods, X_1 and X_0, can be decomposed using equation (9) and its hierarchical structure is listed in Table 2.

$$\Delta(\hat{g}x) = \hat{g}(x_1 - x_0) \qquad (8)$$

$$\Delta(\hat{g}x) = \hat{g}[R_1(\hat{u}_1 d_1 + e_1) - R_0(\hat{u}_0 d_0 + e_0)] \qquad (9)$$

Table 2. SDA of change in the ICT sector output

Factor	**Equation**
Change in ICT sector output	$\hat{g}(x_1 - x_0) = \hat{g}[R_1(\hat{u}_1 d_1 + e_1) - R_0(\hat{u}_0 d_0 + e_0)]$
(1) Domestic final demand effect	$\hat{g}R_1\hat{u}_1(d_1 - d_0)$
(a) Mixed effect	$\hat{g}R_1\hat{u}_1(d_1 - \lambda d_0)$
(b) Growth effect	$\hat{g}R_1\hat{u}_1(\lambda - 1)d_0$
(2) Exports effect	$\hat{g}R_1(e_1 - e_0)$
(3) Imports substitution effect	$\hat{g}R_1(\hat{u}_1 - \hat{u}_0)(d_0 + w_0)$
(4) Technical coefficient effect	$\hat{g}R_1\hat{u}_1(A_1 - A_0)x_0$
(a) ICT sector input coefficient	$\hat{g}R_1\hat{u}_1(A_1^I - A_0^I)x_0$
(b) Non-ICT sector input coefficient	$\hat{g}R_1\hat{u}_1(A_1^N - A_0^N)x_0$
Notes: x_t is the vector of output and R_t is the Leontief inverse matrix at time t; t = 0, 1. λ is a scalar that represents the domestic final ratio between two periods. In the decomposition equation, the import substitution effect is based on the assumption that imported goods are perfect substitutes for	

Factor	Equation
domestic goods, and a negative value of change in domestic supply ratio $(\hat{u}_1 - \hat{u}_0)$ in import substitution effect reflects that (the ICT) sector has high dependence on imported goods, and that substitution of imports with domestic production is not achieved by that sector. On the other hand, a positive value of change in domestic supply ratio in the import substitution effect indicates that import substitution with domestic production occurred. A^I is a matrix of technical coefficients with all entries equal to zero except for the ICT sector rows, whereas A^N is a matrix of technical coefficients with zero entries for the ICT sector row only.	

3.2 Structural change and the Causative Matrix

We use the Causative matrix model in an I-O framework to analyze the extent of informatization in the Chinese economy and the linkage structure of the ICT sector. This framework is chosen because it uniquely represents the economic structure[3]. Lipstein's (1968) model specifies the Causative matrix (C) as follow:

$$P_{t+1} = C \cdot P_t \qquad (10)$$

$$\rightarrow C = P_{t+1} P_t^{-1} \qquad (10^*)$$

where P_{t+1} and P_t are the transition probability matrices for periods t+1 and t, respectively, and its element, that is, p_{ij}, describes the transition probability of sector *i* to sector *j*, and the P matrix's row sum equal 1. However, Plane and Rogerson (1986) substituted the Leontief inverse matrix (L) for P in the causative matrix model to make the matrix applicable to the I-O analysis.

According to Jackson et al. (1990), each column of the matrix is normalized using the respective column sums of Leontief inverse (which yield matrix L). This procedure standardizes magnitude changes in output multipliers (OMs), with an emphasis on the relative impact of one sector (for example, ICT sector) on other (non-ICT) sectors, and vice versa. The column sums of transitional matrices are always equal to unity. The standardized OM of sector *j* is given as:

$$OM_j = l_{1j} + l_{2j} + \ldots\ldots + l_{nj} = 1 \qquad (11)$$

where l_{ij} is the $i-j$ element of matrix L. Following Equation (10), the model is given as:

$$L_{t+1} = C \cdot L_t \qquad (12)$$

where C denotes the left causal matrix, which is preferred for interpreting backward linkage changes. Thereby, the interaction between the transition matrices over two time periods is captured. A typical element of L_{t+1} is given as:

$$l_{ij}^{t+1} = c_{i1}.l_{1j}^{t} + c_{i2}l_{2j}^{t} + \ldots\ldots + l_{nj}^{t} \qquad (13)$$

where c_{ik} is the effect of sector *k* on sector *i*'s ability to influence the OM of other sectors, while a negative value of c_{ik} indicates a decline in sector's *i* impact on the OM of sector *j* in the presence of sector *k*.

Owing to the $n \times n$ dimensions of matrix C, it is difficult to evaluate all elements in the causative matrix, which contains n^2 elements. We inferred the results from the matrix C using the simplified method proposed by Jackson et al. (1990), which focuses on two aspects of the matrix: diagonal elements and sums of their respective off-diagonal row elements (ODE). In their proposed classifications, the diagonal elements are compared with unity, while the sums of their respective ODE are compared with zero (Table 3) as follows: (a) A diagonal element (c_{ii}) with a value greater than one reflects that the final demand of targeted (ICT) sector influences its own output, and is becoming more internalized within the sector. In contrast, a value of less than one for the diagonal element (c_{ii}) indicates that the targeted sector's (ICT sector)

[3] Traditional structural change methods are based on unidimensional measures, for example, sectoral employment concentrations or the impact of a single sector on the overall economy (Jackson et al., 1990). However, these conventional approaches have ignored the economy's inter-sectoral relationships. Lipstein (1968) proposed the causative matrix approach to address this issue, which complements conventional approaches of structural change by quantifying the inter-sectoral component of system-wide structural changes. This method provides a detailed picture of the inter-sectoral component of economic structure changes (Rogerson & Plane, 1984).

final demand is externalizing and influencing the output of other (non-ICT) sectors. b) The positive (negative) deviation of the respective sums of their respective ODE from zero indicates that the relative contribution of other (non-ICT) sectors' final demand to the output of the targeted (ICT) sector has increased (decreased).

Table 3. Inference of Causative matrix

	Sum of ODE<0 Decreased output impacts caused by the final demand of other sectors	*Sum of ODE>0* Increased output impacts caused by the final demand of other sectors
C_{ii}>1 Increased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**Type IV** Sectors are becoming increasingly endogenized, and receiving less feedback from other sectors	**Type I** Sectors are becoming increasingly endogenized, with more feedback from other sectors
C_{ii}<1 Decreased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**Type III** Sectors are becoming more externalized, with less feedback from other sectors	**Type II** Sectors are becoming more externalized, with more feedback from other sectors.

Source: Jackson et al. (1990).

Additionally, the Causative matrix's row sums are interpretable. A row sum greater than one indicates a greater contribution to OM. In this case, the (ICT) sector experienced a greater output effect as a result of changes in overall final demand. In contrast, rows sum value below unity suggests that changes in overall final demand of rest of the (non-ICT) sectors have a weaker effect on the output of the (ICT) sector (Jackson et al., 1990).

3.3 Linkage analysis and information intensities

3.3.1 Linkage analysis and identification of the Key sectors

In an I-O framework, the Leontief and Ghosh inverses can be used to analyze the inter-sectoral linkages. The Leontief (Ghosh) inverse is constructed using the direct input (output) coefficient matrix A (matrix B). If l_{ij} and g_{ij} is the element of $n \times n$ matrix of the Leontief inverse $(I - A_t)^{-1}$, and Ghosh inverse $(I - B_t)^{-1}$, respectively, then the total backward linkage $(B(t)_{.j})$ of sector j and total forward linkage $(FL(t)_{i.})$ of sector i is given in Equation (14) and (15), respectively.

$$B(t)._j = \sum_{i=1}^{n} l_{ij} \qquad (14)$$

$$FL(t)_i. = \sum_{j=1}^{n} g_{ij} \qquad (15)$$

Various definitions for the identification of 'the key sectors' and linkage indices have been proposed in literature (Rasmussen, 1957; Hirschman, 1958; Hewings, 1982; Miller & Blair, 2009). There are two type of indices on the basis of entries in the Leontief and Ghosh inverses. First, the normalized backward linkage (NBL_j) is given as:

$$NBL_j = \frac{\sum_{i=1}^{n} l_{ij}}{\frac{1}{n}\sum_{i}^{n}\sum_{j}^{n} l_{ij}} \qquad (16)$$

Second, the normalized forward linkages (NFL_i) is given as:

$$NFL_i = \frac{\sum_{j=1}^{n} g_{ij}}{\frac{1}{n}\sum_{i}^{n}\sum_{j}^{n} g_{ij}} \qquad (17)$$

In both cases, the linkage of a sector is divided by the average of all linkages.

Rasmussen (1957) has proposed two types of indices based on Leontief inverse entries. First, the power of dispersion for the backward linkage BL_j is given as:

$$BL_j = \frac{\sum_{i=1}^{n} l_{ij}}{\frac{1}{n}\sum_{i}^{n}\sum_{j}^{n} l_{ij}} \qquad (18)$$

Second, the indices of the sensitivity of dispersion for forward linkages FL_i is given as:

$$FL_i = \frac{\sum_{j=1}^{n} l_{ij}}{\frac{1}{n}\sum_{i}^{n}\sum_{j}^{n} l_{ij}} \qquad (19)$$

In both cases, the linkage of a sector is divided by the average of all linkages.

The above-mentioned indices can be interpreted as follow: the power of dispersion (NBL_j) of a sector measures the increase in total output of the entire economy to meet a unit increase in final demand of sector j. The sensitivity of dispersion (NFL_i) measures the change in output of sector i caused by a unit change in the final demand of the entire system of sectors (Rasmussen, 1957). Furthermore, a sector with both power of dispersion (NBL) index and sensitivity of dispersion (NFL) index greater than one is considered to be a "key" sector, or one that is closely linked to the entire system of sectors and generates more economic activity.

3.3.2 Information Intensity

The study further quantifies the degree to which various sectors of the Chinese economy are information intensive, as well as their changes from 2002 to 2007, 2007 to 2012, and 2012 to 2017. Such analysis is based on the disaggregated microeconomic foundation. In this regard, an I-O framework is most appropriate and offers a solid foundation. There are two basic types of information intensities computed for a given sector: (a) Direct information intensity, which is denoted as h_i, is the ratio of information used to total sectoral output; (b) The direct demand coefficient can be used to calculate the second type of intensity h_i^* which takes into account the total (direct and indirect) information intensities of different sectors (Bhowmik, 2003; Roy et al., 2002). The matrix form of these intensities is given as:

$$h^{*\prime} = h'(I - A)^{-1} \qquad (20)$$

where $h^{*\prime}$ and h' are the row vectors consisting of element h_i^* and h_i, respectively, while $(I - A)^{-1}$ is the Leontief inverse matrix.

3.4 Data Description

This study makes use of basic data from the national I-O table of China for four years (2002, 2007, 2012, and 2017), which is compiled and published every five years by the National Bureau of Statistics [4]. Despite the fact that each of the three I-O tables (2002, 2007, and 2012) contains 42 sectors, we discovered several inaccuracies in these I-O tables' sectoral classifications and order, which have significant impacts on the results (see Supplementary Section 1 for the explanation of these tables and their comparability). To overcome and correct significant biases, we revised the I-O tables in accordance with China's Classification of National Economic Industries, and constructed 39 sectors tables that are consistent in terms of industry definitions (see Supplementary Table 1A). Thereafter, we also revised the newly published 149 sectors I-O table of 2017 into 39 sectors. Furthermore, in order to eliminate the effects of price fluctuations across years, we used the RAS procedure to adjust the I-O tables to 2002 constant price.

According to China's current industrial classification, there are two sectors that belongs to the ICT sector: Communication equipment, computer and other electronic equipment manufacturing (19) and Information Transmission, Computer Service and Software (28). To investigate the spillover effect of the ICT sector, we first combined the aforementioned sectors (19 and 28) into a new sector, ICT (40), while keeping the remaining sectors' codes (39 sector aggregation) unchanged. Afterwards, we divided the

[4] Prior to the 2002 I-O table, the 1997 I-O table contained 33 sectors, while there are 42 sectors in I-O tables of 2002, 2007, and 2012, and 149 sectors in 2017 I-O table. Therefore, this study has chosen 2002, 2007, 2012, and 2017 for the analysis.

revised I-O table of 39 sectors into two categories: the ICT sector and non-ICT sectors. Supplementary Table 1B contains a description of the sectors as well as their codes.

4. Results and Discussions

4.1 Growth sources of ICT sector

Table 4 reports the decomposition results for various growth sources of China's ICT sector during the study period. The change of the ICT sector's output nearly doubled in 15 years, rising from RMB 3272.975 billion in the period 2002-2007 to RMB 6235.47 billion in the period 2012-2017. The export and domestic-demand effects were the most important contributors to the ICT sector's overall growth in the period 2002-2007. Exports, in particular, made a significant contribution of RMB 2088.665 billion (63.84%) to its growth. This reflects China's outward-looking approach to develop its ICT sector, with a greater emphasis on the strength of ICT exports. However, the periods 2007-2012 and 2012-2017 give very different results. There were few noticeable changes in sources of growth of the ICT sector in these two periods. Domestic demand, for example, has increased more than two-fold, from RMB 1497.96 billion (45.8%) in the period 2002-2007 to RMB 3517.99 billion (56.4%) in the period 2012-2017, making it a major contributor to the change in the ICT sector's output, whereas, the contribution of exports declined to RMB 1201.304 billion (30.9%) in the period 2007-2012 and to RMB 1742.47 billion (27.9%) in the period 2012-2017.

Table 4. The growth sources of China's ICT sector from 2002 to 2017

	2002-2007	**2007-2012**	**2012-2017**
	Billion (¥) (%)	Billion (¥) (%)	Billion (¥) (%)
Change in the ICT output	3272.975 (100)	3887.59 (100)	6235.47 (100)
（1）**Effect of growth in domestic final demand**	1497.96 (45.8)	1956.37 (50.32)	3517.99 (56.42)
(a) the growth effect	1037.14 (31.69)	2489.53 (64.03)	2687.84 (43.11)
(b) the mixed effect	460.823 (14.08)	-533.158 (-13.731)	830.16 (13.31)
(2) **Effect of the change in exports**	2088.665 (63.8)	1201.304 (30.89)	1742.47 (27.94)
(3) **Effect of the import substitution**	-357.50 (-10.9)	664.803 (17.10)	813.21 (13.04)
(4) **Technical effect**	43.84 (1.30)	65.11 (1.675)	161.80 (2.59)
(a) ICT sector	-37.15 (-1.10)	-153.88 (-4.01)	12.73 (0.20)
(b) non-ICT sector	81.001 (2.47)	219 (5.61)	149.07 (2.39)

Source: Calculated by the authors.

Moreover, import substitution, which had a negative effect in the period 2002-2007 and a positive one in the periods 2007-2012 and 2012-2017, has had a mixed impact on the ICT sector. On the one hand, the negative import substitution effect in the period 2002-2007 suggests that China imported ICT products from other countries and that import substitution by domestic production in the ICT sector was not achieved. The underlying reason is that China's ICT products were unable to meet the (domestic) production requirements of certain sectors. On the other hand, the import substitution effect was positive in the periods 2007-2012 and 2012-2017, pointing to the fact that import substitution with domestic production occurred in China's ICT sector. Furthermore, the technological change had a positive effect throughout the study period, implying that China needs to improve the technological level of other (non-ICT) sectors in order to increase the output of its ICT sector. In addition, the non-ICT portion is responsible for the majority of the technical change during the study period. By contrast, ICT, which had negative contributions in the periods 2002-2007 and 2007-2012, showed a positive marginal impact in the period 2012-2017.

The decomposition analysis shows that China's ICT sector is highly influenced by exports and domestic final demand, which are closely related to the country's population, GDP, and size of the economy. More importantly, China's WTO accession has opened up more opportunities and foreign investment in the ICT sector, as well as a larger market for foreign firms. Furthermore, the relocation of production from developed economies and regions to China has the effect of diffusing foreign advanced technologies to domestic Chinese enterprises. In addition, China's elimination of import tariffs on ICT products following the International Technological Agreement (ITA) in 2002 and 2005 has had a significant impact on the ICT sector's output.

4.2 Results of Causative matrix

We assess China's structural changes using the Causative matrix, and relevant statistics extracted from the matrix for three time periods are presented in Table 5. Both, the diagonal element ($C_{40,40}$) and the row sum corresponding to the ICT sector are under unity in the study period. This implies that changes in the final demand of non-ICT sectors have a smaller effect on the ICT sector's output. On the one hand, diagonal element below one demonstrates that, relative to the impact on its own output, the Chinese ICT sector's final demand was externalized, resulting in an increase in non-ICT sectors' output. Hence, China's ICT sector has become more competitive in supplying total (direct and indirect) requirements of other sectors in the economy. On the other hand, row sum values less than one imply that changes in the final demand of non-ICT sectors have a weaker output effect on the ICT sector. The underlying reason for non-ICT sectors' weaker output effect is that a smaller share of the ICT sector's output is used as final demand by non-ICT sectors, compared with a large share of its output being used as final demand by household, private, and government consumption.

Table 5. Causative matrix

	Period	Row sum of ICT sector	diagonal element $C_{(40, 40)}$
ICT sector	2002-2007	0.72	0.96
	2007-2012	0.99	0.98
	2012-2017	0.07	0.52

Source: Calculated by the authors.

We classified all sectors from the causative matrix in Table 6 using the criteria outlined in Table 3 for the periods 2002-2002, 2007-2012 and 2012-2017. The ICT sector (40) falls into Type III in two periods, 2002-2007 and 2012-2017, indicating that the ICT sector was more externalized and that the entire system of (non-ICT) sectors has a smaller impact on the ICT sector's output. However, the ICT sector falls into Type II, in the period 2007-2012, implying that the ICT sector remained externalized and that non-ICT sectors' final demand increasingly stimulated the ICT sector's output and, at the same time, non-ICT sectors' final demand has stimulated the ICT sector's output. These findings imply that the growing linkages of the ICT sector have been accompanied by significant structural changes from 2002 to 2017. The results of the Causative matrix therefore reveal that the ICT sector has emerged as an important sector in the economy, and that the Chinese government's emphasis on information technologies has led to informatization of the Chinese economy.

Table 6. A typology of structural change based on the left causative matrix method (In code)

2002-2007		
	Sum of ODE<0 Decreased output impacts caused by the final demand of other sectors	Sum of ODE>0 Increased output impacts caused by the final demand of other sectors
Cii>1 Increased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**IV** 29, 31, 32	**I** 23
C_{ii}<1 Decreased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**III** 2, 25, 26, 27, **40**	**II** 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 24, 30, 33, 34, 35, 36, 37, 38, 39
2007-2012		
	ODE<0 Decreased output impacts caused by the final demand of other sectors	ODE>0 Increased output impacts caused by the final demand of other sectors

$C_{ii}>1$ Increased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**IV** 3, 4, 9, 11, 12, 13, 14, 18, 20, 23, 25, 30, 35, 36, 37, 38	**I** 2, 6, 7, 26, 27, 29, 33, 39
$C_{ii}<1$ Decreased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**III** 1, 8, 10, 15, 16, 17, 21, 22, 24	**II** 5, 31, 32, 34, **40**
2012-2017		
	ODE<0 Decreased output impacts caused by the final demand of other sectors	ODE>0 Increased output impacts caused by the final demand of other sectors
$C_{ii}>1$ Increased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**IV** 2, 3, 4, 5, 7, 8, 10, 15, 35, 36	**I** 9, 20, 21, 22, 24, 25, 30, 37, 38
$C_{ii}<1$ Decreased relative endogenization of sector *i*'s impacts in comparison to the rest of the sectors	**III** 1, 6, 11, 12, 14, 16, 17, 18, 23, 26, 29, 31, 33, 34, 39, **40**	**II** 13, 27, 32

Source: Calculated by the authors.

4.3 Linkage analysis and Information intensities

4.3.1 Linkage analysis

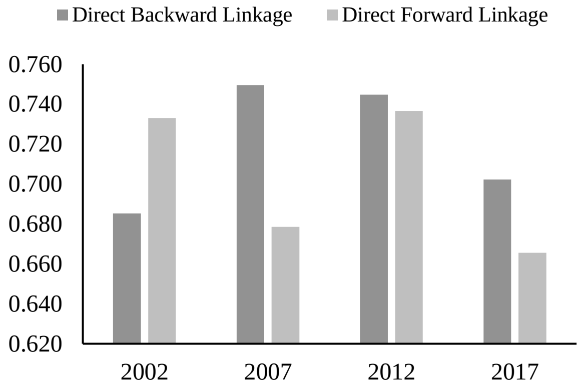
We utilize forward and backward linkage indicators to measure the push and pull effects of the ICT sector in the Chinese economy. Forward linkage is a measure of a sector's supply-side (push) effects in the economy, as well as its consumption structure, or how its output is consumed by other sectors. Backward linkage, on the other hand, measures a sector's demand-side (pull) effects—intermediate input demand for other sectors' production—as well as industrialization and technological level of that sector.

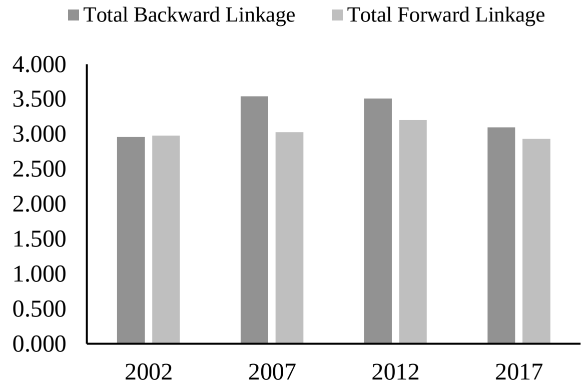
Figure 2a shows direct forward and backward linkages of the ICT sector from 2002 to 2017. The coefficients of direct forward linkage follow a rough S-shaped pattern in the study period. Initially, with a higher coefficient value of 0.733 in 2002, the ICT sector's direct forward linkage dropped to 0.67 in 2007. However, after reaching a high of 0.736 in 2012, it fell back to 0.66 in 2017. In contrast, its direct backward linkage was 0.73 in 2002 (lower than forward linkage) but increased to 0.749 in 2007 and to 0.744 in 2012. However, in 2017, its coefficient fell to 0.70. With the exception of 2002, the ICT sector's direct backward linkage has consistently been higher than its forward linkage. Likewise, the total backward linkage of the ICT sector was greater than its total forward linkage in the study period except for 2002 (Figure 2b). Another notable feature of the ICT sector's total forward linkage values, when compared with direct (forward and backward) linkages, is that the long-term trend shows a narrowing gap between forward and backward linkage.

The linkage analysis reveals that the backward linkage has consistently been higher than the forward linkage. The underlying reason for stronger backward linkage is that the ICT sector stimulates output growth in non-ICT sectors by utilizing their output in its production process. It reflects that the pull effects of the ICT sector are stronger than its push effects, and the sector pulls China's economic growth through the process of demand creation. At the same time, the ICT sector's higher backward linkage values reflect the sector's high industrialization and technological level. Also, the higher total backward and forward linkage values demonstrate that the Chinese ICT sector has both supply- and demand-side effects.

Figure 2. Backward and forward linkages of Chinese ICT sector

a) Direct Backward and Forward Linkages b) Total Backward and Forward Linkages





Source: Calculated by the authors.

We further investigate the ICT sector's linkages (supply- and demand-side impacts) using several linkage measures described in subsection 3.3.1, as well as whether the ICT sector is a 'key' sector in the Chinese economy. The NBL and NFL results are presented in Supplementary Table 2A, while the Rasmussen indices are presented in Supplementary Table 2B. The results show that the NFL and NBL indices, as well as the Rasmussen indices for the ICT sector (40), all exceeded unity in the study period. As, the ICT sector's (normalized) forward linkage value exceeds unity, this suggests that this sector has stronger supply-side effects on overall industrial growth in the economy, and it provides important intermediate inputs to non-ICT sectors. Simultaneously, the fact that its (normalized) backward linkage values exceed one over the entire study period imply that the ICT sector has strong demand-side effects, with more input requirements (demand) from non-ICT sectors. Hence there is evidence that an increase in the ICT sector's demand would result in above-average (demand-side) economic activity expansion in the Chinese economy.

Error! Reference source not found. displays different classifications of sectors in the Chinese economy. The linkage analysis reveals that the ICT sector (40) was continuously a 'key sector' in the study period. Thus, being a key sector, it stimulated greater economic activity and was closely linked to entire system of sectors in the economy. These results manifest that the ICT sector has profound supply- and demand-side effects on non-ICT sectors. An important implication of these results is that stimulating the growth of the ICT sector, which has strong push and pull effects, would be an effective tool for developing the national economy.

Table 1. Sector's classifications in the Chinese economy (In code)

China's Sectors' classification on the basis of Normalized linkage measures in 2002, 2007, 2012, and 2017				
Year	**Backward oriented**	**Forward oriented**	**Key Sector**	**Non-key sector**
2002	6, 7, 8, 9, 13, 17, 21, 24, 26, 35	2, 3, 5, 22, 23, 25, 27, 31	4, 10, 11, 12, 14, 15, 16, 18, 20, 33, **40**	1, 29, 30, 32, 34, 36, 37, 38, 39
2007	6, 7, 8, 9, 13, 16, 17, 18, 21, 26, 33, 37	2, 3, 22, 25, 31, 33	4, 5, 10, 11, 12, 14, 15, 20, 23, 24, **40**	1, 27, 29, 30, 35, 36, 39
2012	6, 7, 8, 9, 13, 15, 16, 17, 18, 21, 24, 26, 34, 37	2, 3, 5, 22, 27, 31	4, 10, 11, 12, 14, 20, 23, 33, **40**	1, 25, 29, 30, 32, 35, 36, 39
2017	6, 7, 8, 9, 10, 16, 17, 18, 21, 27, 34	2, 3, 4, 5, 11, 22, 37	12, 13, 14, 15, 20, 23, 33, **40**	1, 24, 25, 26, 29, 30, 31, 32, 35, 36, 38, 39
China's Sectors' classification on the basis of Rasmussen indices measures in 2002, 2007, 2012, and 2017				
Year	**Backward oriented**	**Forward oriented**	**Key Sector**	**Non-key sector**
2002	4, 6, 8,9, 13, 15, 20, 21, 24, 26, 33	1, 2, 3, 23, 27, 29, 31	7, 10, 11, 12, 14, 16, 17, 18, **40**	5, 22, 25, 30, 32, 34, 36, 37, 38, 39
2007	4,5,8,9,13,15, 20, 21, 24, 26, 33, 37	1, 3, 27, 31	6, 7,10, 11, 12, 14, 16, 17, 18, 23, **40**	2, 22, 25, 28, 30, 32, 34,35, 36, 38, 39

2012	4, 8, 9, 10, 13, 15, 17, 18, 20, 21, 24, 26, 34, 37	1,2,3, 27, 29, 31	6, 7, 11, 12, 14, 16, 23, 33, **40**	5, 22, 25, 30, 32,35, 36, 38, 39
2017	3, 8, 9, 10, 17, 20, 21, 34, 37	1, 29, 31	6, 7, 12, 13, 14, 15, 16, 18, 23, 27, 33, **40**	2, 4, 5, 11, 22, 24, 25, 26, 30, 32, 35, 36, 38, 39

Source: Calculated by the authors.

4.3.2 Information intensities of Chinese economy

Using Equation (20), we calculate direct and total (direct plus indirect) sectoral information intensities of the Chinese economy along with their variations (Table 8). The results indicate that information intensities varied significantly at sectoral level in the entire study period[5]. In terms of both direct and total information intensities, the ICT sector (40) was at the top of the list in the study period. The underlying reason for the ICT sector's higher information intensities is that it is a knowledge-intensive sector shaped by rapid innovation and production cycles, and more importantly, a sector's demand for its own output is obvious. Another reason for increased information intensities in the ICT sector is the improvement of existing technologies and the emergence of new technologies and their applications, which have caused significant demand shifts in ICT and ICT-enabled goods and services.

The top five non-ICT sectors in terms of direct and total information intensities were stable in the study period, while others showed significant variation. The manufacturing of instruments, cultural items, and office machinery (20) was at the top of the list in terms of both direct and total information intensities in the study period. Other sectors, such as Electrical machinery and equipment manufacturing (18) and General and special equipment manufacturing (16) have significantly increased their information intensities in recent years. This is primarily because modern manufacturing and testing are becoming more automated and technology-driven. The use of computer-based precision engineering, as well as virtualized systems and computer simulation, assists manufacturers in producing more efficiently, effectively, and robustly. Furthermore, new technologies have significantly reduced manufacturing costs and processing times. Manufacturers can optimize their operations, improve quality, and increase productivity by using ICT, which includes cloud services, the Internet of Things, physical robotics, artificial intelligence, and machine learning. Connecting specialized (for example, medical) equipment to the internet, in conjunction with cloud technologies, accelerates innovation and creates new business opportunities.

Likewise, Financial Intermediation (31), Leasing, Business Services and tourism (33) and Scientific research, technical services and Comprehensive technology services (34) have high (direct and total) information intensities. However, the third place, sector (33), and fifth place, sector (31) in 2002 and 2007, lost ground in terms of consumption of their direct and total information usage in 2012 and 2017, respectively, while sector (34) remained in fourth place throughout the study period. The underlying reason for such high information intensities in these service sectors (31, 32, and 33) is that ICT applications have grown at a rapid pace in these industries, changing the way businesses operate across industries. For example, ICT diffusion in financial institutions has fueled the rise of financial technology, which has significantly restructured the financial system and increased its efficiency. ICT technologies have helped finance and leasing companies in the development of new business models, reducing information asymmetry between buyers and sellers, improving internal risk management and lowering data processing costs. More importantly, they can use big data to evaluate new market opportunities, develop new products and gain a better understanding of customers' demand.

[5] For example, direct information intensities in 2002 varied from 36% for the ICT sector (40) to a low of 0.2% for Agriculture, Forestry, Animal Husbandry and Fishing (1), while, it ranged from 42% for the ICT sector (40) to a low of 0.06% for Oil processing, coking and nuclear fuel processing industry (11) in 2017. Similarly, total information intensities varied significantly across sectors between 2002 and 2017. In the study period, it ranged from 62.3% to 86.4% for the ICT sector (40) to a low of 0 and 0.6% for Waste scrap (22). In addition, several sectors have a decreasing (increasing) trend in their direct information intensity, while other sectors have reversed their positive (negative) demand for the information input to negative (positive) demand.

Table 8. Information intensities of various sectors

	Direct Information intensities								Total Information intensities						
Code	**2002**	**2007**	**2012**	**2017**	**2002-2007**	**2007-2012**	**2012-2017**	**Code**	**2002**	**2007**	**2012**	**2017**	**2002-2007**	**2007-2012**	**2012-2017**
1	0.002	0.004	0.001	0.002	0.002	-0.003	0.001	**1**	0.027	0.027	0.019	0.022	0.000	-0.008	0.002
2	0.013	0.005	0.005	0.002	-0.008	0.000	-0.002	**2**	0.058	0.055	0.050	0.038	-0.003	-0.005	-0.012
3	0.010	0.004	0.002	0.001	-0.006	-0.002	-0.001	**3**	0.045	0.047	0.043	0.031	0.001	-0.003	-0.013
4	0.007	0.003	0.005	0.004	-0.003	0.001	-0.001	**4**	0.055	0.058	0.061	0.045	0.003	0.003	-0.016
5	0.030	0.004	0.004	0.004	-0.027	0.000	0.000	**5**	0.094	0.052	0.063	0.052	-0.042	0.011	-0.011
6	0.005	0.002	0.001	0.003	-0.003	-0.001	0.002	**6**	0.046	0.036	0.027	0.032	-0.009	-0.009	0.005
7	0.008	0.003	0.001	0.002	-0.005	-0.002	0.001	**7**	0.061	0.046	0.033	0.039	-0.015	-0.013	0.006
8	0.014	0.005	0.002	0.004	-0.009	-0.003	0.001	**8**	0.080	0.051	0.038	0.045	-0.029	-0.014	0.008
9	0.011	0.004	0.002	0.002	-0.007	-0.001	0.000	**9**	0.070	0.049	0.045	0.041	-0.021	-0.004	-0.004
10	0.014	0.012	0.006	0.009	-0.002	-0.006	0.003	**10**	0.073	0.073	0.054	0.057	-0.001	-0.019	0.004
11	0.007	0.004	0.002	0.001	-0.002	-0.003	-0.001	**11**	0.058	0.053	0.044	0.031	-0.005	-0.009	-0.013
12	0.010	0.004	0.002	0.004	-0.006	-0.002	0.002	**12**	0.073	0.059	0.050	0.048	-0.013	-0.009	-0.002
13	0.013	0.003	0.003	0.003	-0.011	0.000	0.000	**13**	0.077	0.052	0.058	0.048	-0.025	0.006	-0.010
14	0.008	0.009	0.001	0.002	0.002	-0.008	0.001	**14**	0.063	0.072	0.053	0.041	0.008	-0.019	-0.012
15	0.025	0.004	0.031	0.004	-0.021	0.027	-0.027	**15**	0.098	0.065	0.118	0.050	-0.033	0.053	-0.068
16	0.033	0.026	0.075	0.055	-0.007	0.049	-0.020	**16**	0.119	0.122	0.237	0.180	0.003	0.115	-0.057
17	0.017	0.013	0.046	0.022	-0.004	0.033	-0.025	**17**	0.099	0.108	0.195	0.114	0.009	0.087	-0.081
18	0.049	0.064	0.079	0.069	0.015	0.015	-0.009	**18**	0.146	0.196	0.228	0.193	0.050	0.032	-0.035
20	0.203	0.260	0.215	0.186	0.057	-0.045	-0.029	**20**	0.398	0.582	0.511	0.437	0.184	-0.071	-0.075
21	0.018	0.008	0.017	0.021	-0.009	0.009	0.004	**21**	0.082	0.060	0.082	0.081	-0.021	0.021	-0.001
22	0.000	0.000	0.001	0.001	0.000	0.001	0.000	**22**	0.000	0.006	0.019	0.007	0.006	0.013	-0.012
23	0.009	0.006	0.004	0.007	-0.003	-0.003	0.003	**23**	0.059	0.082	0.075	0.073	0.023	-0.007	-0.002
24	0.018	0.002	0.002	0.004	-0.016	0.000	0.001	**24**	0.086	0.050	0.045	0.038	-0.036	-0.006	-0.007
25	0.028	0.005	0.009	0.007	-0.023	0.004	-0.002	**25**	0.086	0.055	0.061	0.051	-0.031	0.006	-0.009
26	0.042	0.018	0.014	0.022	-0.025	-0.004	0.008	**26**	0.132	0.090	0.083	0.079	-0.042	-0.007	-0.004
27	0.013	0.012	0.011	0.016	-0.001	-0.002	0.005	**27**	0.063	0.060	0.070	0.083	-0.003	0.010	0.013
29	0.039	0.017	0.008	0.011	-0.022	-0.009	0.003	**29**	0.106	0.067	0.042	0.046	-0.038	-0.025	0.004
30	0.009	0.005	0.005	0.009	-0.004	0.000	0.004	**30**	0.052	0.039	0.029	0.042	-0.013	-0.010	0.012
31	0.055	0.026	0.028	0.034	-0.029	0.002	0.006	**31**	0.123	0.076	0.081	0.089	-0.047	0.005	0.008
32	0.006	0.006	0.005	0.006	-0.001	-0.001	0.001	**32**	0.045	0.027	0.030	0.031	-0.018	0.003	0.001
33	0.159	0.081	0.049	0.034	-0.078	-0.033	-0.014	**33**	0.304	0.209	0.145	0.108	-0.095	-0.064	-0.037
34	0.062	0.051	0.072	0.059	-0.011	0.021	-0.013	**34**	0.144	0.156	0.206	0.169	0.012	0.050	-0.037
35	0.025	0.034	0.037	0.040	0.009	0.003	0.002	**35**	0.088	0.110	0.108	0.103	0.022	-0.002	-0.005
36	0.021	0.021	0.016	0.017	0.000	-0.005	0.001	**36**	0.069	0.084	0.050	0.050	0.015	-0.035	0.001
37	0.010	0.015	0.014	0.018	0.005	-0.001	0.004	**37**	0.058	0.074	0.062	0.068	0.017	-0.013	0.006
38	0.046	0.020	0.014	0.018	-0.025	-0.006	0.004	**38**	0.117	0.080	0.054	0.061	-0.037	-0.026	0.007
39	0.036	0.035	0.031	0.047	-0.001	-0.004	0.016	**39**	0.095	0.096	0.083	0.108	0.001	-0.013	0.025
40	0.361	0.447	0.433	0.421	0.086	-0.014	-0.012	**40**	0.623	0.864	0.825	0.772	0.241	-0.039	-0.053

Source: Calculated by the authors.

5. Conclusion

This study has measured the economic impacts of the Chinese ICT sector by using the Chinese I-O tables from 2002 to 2017. In doing so, it restructured these tables to ensure data consistency through suitable aggregation. We employed the SDA to disentangle the changes in ICT sector's sources of growth from 2002 to 2017. In addition, we analyzed the changes in intersectoral relationship of the ICT sector with non-ICT sectors by using the causative matrix model. Furthermore, we used linkage analysis to calculate the supply- and demand-side impacts of the Chinese ICT sector, as well as the information intensities of various sectors. The findings demonstrate that the ICT sector has become the engine of China's economic growth.

The decomposition exercise revealedthat the ICT sector's output growth was mainly driven by export and domestic-demand effects in the period 2002-2007. There were signs that China looked outward when it came to develop its ICT sector, as evidenced by its increased emphasis on strengthening ICT exports. Here, the domestic-demand effect replaced the export effect, and became the dominant source of output growth of the ICT sector in the periods 2007-2012 and 2012-2017. In addition, the effect of import substitution on the ICT output growth changed from negative (during 2002-2007) to positive (during 2007-2012 and 2012-2017), signifying that import substitution with domestic production occurred in China's ICT sector. More importantly, the combined export and import substitution made a secondary contribution to the ICT's sector's output growth in the periods 2007-2012 and 2012-2017. Furthermore, the non-ICT portion was responsible for the bulk of technical change. The positive technological-change effect suggests that the Chinese ICT sector contributied significantly to non-ICT sectors by supporting their production process.

We discovered that the intersectoral relationship between the ICT and non-ICT sectors underwent significant structural changes. The most significant aspect of these changes was that the ICT sector was consistently externalized in the period examined, regardless of whether the ICT sector received little feedback from final demand of non-ICT sectors in the 2002-2007 and 2012-2017 periods, or received increased feedback from final demand of non-ICT sectors in the period 2007-2012.

In addition, linkage analysis revealed that the ICT sector had profound backward and forward links with the rest of the sectors, and this sector was consistently a 'key' sector in the Chinese economy. Our findings show that stimulating the ICT sector, which has significant supply- and demand-side effects on non-ICT sectors, would have a significant impact on the national economy. It was also found that technology-intensive manufacturing and service sectors topped the list of non-ICT sectors, with the highest information intensities. In particular, demand for information products grew faster in both manufacturing and service sectors. Summing up, the ICT sector has emerged as one of the most significant economic sectors in China, and the government's emphasis on ICT has resulted in the informatization of the Chinese economy.

The comprehensive analysis of this study should help policymakers and researchers in better understanding the links between the ICT and non-ICT sectors, and the effect of internal and structural changes in China's economy. Because the ICT sector is characterized by rapid technological changes, it requires constant upgrading of infrastructure, hence necessitating continued government investment. The government should prioritize the development of infrastructure networks and an environment conducive to innovation. The differences in the various sectors' "informationization" also needs to consider and the government should seek to increase co-operation among different sectors. Thus, the government could use ICT to refine its industrial structure, so as to accelerate economic growth. It should also encourage ICT education in higher education institutes and vocational schools.

Supporting information

Supplementary Section 1. Adjustments made to sectors over time in the Input-Output tables.
Supplementary Table 1. Codes of sectors and their description.
Supplementary Table 2. Linkage analysis.

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