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ACCOUNTING FOR THE ROLE OF INFORMATION AND COMMUNICATION TECHNOLOGY IN CHINA'S PRODUCTIVITY GROWTH*

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ABSTRACT

Applying the Jorgensonian aggregate production possibility frontier (APPF) model to the China Industrial Productivity (CIP) data set constructed in the principle of KLEMS, we scrutinize the role of information and communication technology (ICT) industries in China's post-reform growth from 1981 to 2012. In the absence of a direct measure of ICT assets, we group Chinese industries into ICT-specific groups following the criteria used in the U.S. case (Jorgenson et al. 2005a), and apply the APPF industry origin of productivity framework, incorporating Domar weights for industry aggregation, to the grouped CIP industry data. This allows us to decompose China's productivity growth into the contribution of the ICT-specific groups and the factor reallocation effect across the groups. Our preliminary results show that Chinese ICT-producing and ICT-using manufacturing industries appear to be the most important driver of China's productivity growth over the entire period in question. While sharing 29% of China's 9.38% annual value added growth, these industries contributed 149% to China's 0.83% annual aggregate total factor productivity (TFP) growth. This, together with a strong gain from the labor reallocation effect across industries, has enabled the economy to compensate for its heavy productivity losses by non-ICT services and the economy-wide misallocation of capital resources.

Keywords: Information and communication technology (ICT), Aggregate production possibility function (APPF), Domar weights, Total factor productivity (TFP).

***JEL* Classification**: C82, E22, E24, O47

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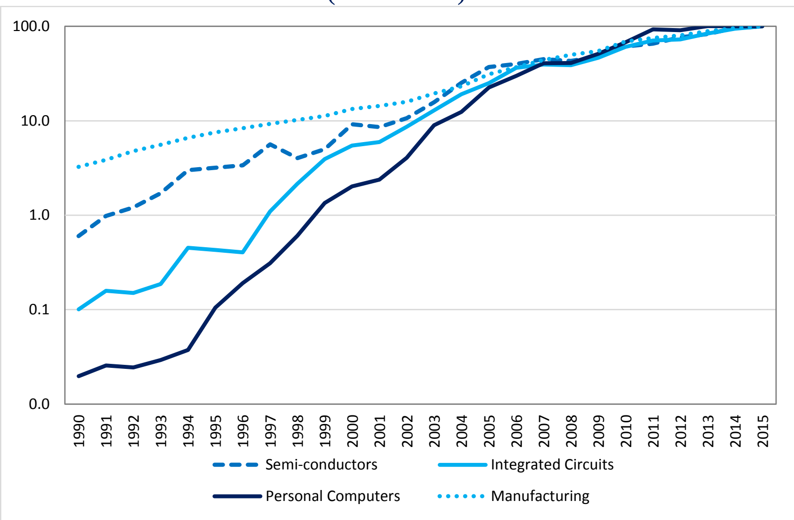
1. Introduction

Since the 1990s, the world economy has been driven by two most important and mutually enhancing engines, that is, globalization through trade and direct investment, thanks to the market-oriented reforms in emerging economies especially China, and information and communication technologies (ICT) that have been quickly maturing for the majority of manufacturing industries as a result of the rapid decline in the prices of ICT equipment. Figure 1 shows a time profile of China's dynamic production growth of personal computers, integrated circuits and semi-conductors vis-à-vis the gross output of manufacturing industries as a whole over the period 1990-2015. The annual compound growth rate of these ICT products is indeed very impressive as 40.7, 31.8 and 22.7 percent respectively, compared to 14.7 percent of the manufacturing sector as a whole. China's rapid emergence as the world largest manufacturing powerhouse cannot be appropriately assessed without understanding the role of ICT in China's output and productivity growth.

FIGURE 1
CHINA'S PRODUCTION OF ICT PRODUCTS VIS-À-VIS GROSS OUTPUT OF MANUFACTURING
(2015 = 100)



Sources: Authors' calculation based on official data in physical units (NBS 2013: 515, updated). Manufacturing gross output data are measured at 1990 prices, based on CIP 3.0.

In one of pioneer studies that account for the role of ICT in advanced economies, Jorgenson (2001) shows that the growth of ICT capital services in the US jumped from 11.5 percent per annum over the period 1990-1995 to 19.4 percent over the period 1995-1999, which was in a sharp contrast to the growth of non-ICT capital services increasing merely from 1.7 to 2.9 percent. Particularly over the period 1995-1999, ICT products (both equipment and software) contributed 0.5 percentage points (ppts) out of 0.75-percent annual TFP growth, accounting for nearly 67 percent of the aggregate TFP, despite it only accounted for 29 percent of the US 4.08-percent annual GDP growth.

In the case of Europe, O'Mahony and van Ark (2003) show that for 15 EU member states during the period 1995-2001, ICT-producing industries enjoyed a labor productivity growth of 7.5 percent per annum, much faster than that of the total economy of 1.7 percent per annum. Focusing on ICT investment and economic growth in nine OECD countries, Colecchia and Schreyer (2002) also find that along with a significant decline in the prices of ICT capital goods over the period 1980-2000, all these countries experienced a remarkable increase in the rate of investment in ICT equipment. On average, ICT capital contributed between 0.2 and 0.5 ppts to annual economic growth, ranging from 2.0 to 3.8 percent per annum. Particularly for the second half of the 1990s, this 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 between Japan and South Korea, Fukao et al. (2009) also find that the growth of ICT investment in the two economies was phenomenal during the period 1995-2005 by 13.1 and 15.5 percent per annum respectively. However, it concludes that aggregate TFP appears to be more attributable to ICT-producing industries than to ICT-using industries for both Japan and Korea.

However, lack of statistics on ICT investment at industry level has prevented us from directly identifying and measuring individual Chinese industries with a specific role and a level of importance in ICT. We therefore adopt an indirect approach to bypass this problem by reclassifying all the 37 industries in the CIP data set into ICT-specific groups using the ICT-making and asset-based ICT-using criteria in the US case (Jorgenson et al. 2005a). Obviously, in doing so we arbitrarily assume that the extent to which individual industries are exposed to the impact of ICT, either producing or using, is the same in China as in the US. This is by no means an ideal solution to the ICT data problem, but it provides an important perspective for examining the role of ICT in the Chinese economy.

We examine the so-grouped CIP data in a growth accounting model *a la* Jorgenson (Jorgenson 2001, Jorgenson et al. 2005a) that specifies the role of individual industries in an aggregate production possibility frontier (APPF) framework and also incorporates Domar aggregation to account for the interactions of individual industries within the system. This model allows us to decompose China's productivity growth into the contribution of ICT-specific groups and the factor reallocation effect across the groups. Our preliminary results have shown that ICT-producing and using manufacturing industries appear to be the most important driver of China's productivity growth over the entire period 1981-2012. While sharing 29 percent of China's 9.38-percent annual value added growth, these industries contributed 149 percent to China's 0.83-percent annual aggregate TFP growth.

The rest of the paper is organized as follows. Section 2 introduces the aggregate production possibility frontier framework incorporating Domar weights for industry aggregation, especially designed for ICT-specific grouping. Section 3 explains the updated and revised CIP data and the ICT-specific industry grouping in this study. Section 4 reports and interprets the growth accounting results. Section 5 concludes this study with prioritized tasks for future research.

2. Accounting for the Industry Origin of TFP[1]

The role of ICT in an economy can be more possibly examined by Jorgenson's aggregate production possibility frontier (APPF) framework that incorporates Domar weights for industry aggregation to account for the industry origin of growth and productivity. The widely used aggregate production function (APF) approach to TFP analysis is implicitly subject to very stringent assumptions that for all (underlying) industries "value-added functions exist and are identical across industries up to a scalar multiple" and "the aggregation of heterogeneous types of capital and labor must receive the same price in each industry" (Jorgenson, Ho and Stiroh 2005a). Given heavy government interventions and institutional set-ups that cause

[1] Adopted mainly from Wu (2016).

market imperfections in China, the APF approach is undoubtedly inappropriate for the growth accounting exercise of the economy, especially when the performances of specified industries are to be compared economy wide.

The APPF approach in growth accounting relaxes the strong assumption that all industries are subject to the same value-added production function to account for the industry origin of aggregate growth (Jorgenson 1966). The Domar weights-based aggregation was introduced into the APPF framework in Jorgenson, Gollop and Fraumeni (1987) to exercise direct aggregation across industries to account for the role of American industries in the changes of aggregate inputs. This approach has been used in Jorgenson and Stiroh (2000), Jorgenson (2001) and Jorgenson, Ho and Stiroh (2005a, 2005b) to quantify the role of information technology (IT)-producing and IT-using industries in the US economy.

To illustrate this aggregation methodology, let us begin with a production function where industry gross output is a function of capital, labour, intermediate inputs and technology indexed by time. We use individual industries as building blocks which allow us to explicitly trace the sources of the aggregate productivity growth and input accumulation to the underlying industries. Focusing on an industry-level gross output production function given by equation (1), each industry, denoted by a subscript *j*, purchases distinct intermediate inputs, capital and labour services to produce a set of products:

(1) $$Y_j = f_j(K_j, L_j, X_j, T)$$

where *Y* is output, *K* is an index of capital service flows, *L* is an index of labour service flows and *X* is an index of intermediate inputs including energy, materials and services, purchased from domestic and/or international markets. Note that all input variables are indexed by time but this is suppressed for notational convenience.

Under the assumptions of competitive factor markets, full input utilization and constant returns to scale, the growth of output can be expressed in the cost-weighted growth of inputs and technological change:

(2) $$\Delta \ln Y_j = \bar{v}_j^K \Delta \ln K_j + \bar{v}_{jt}^L \Delta \ln L_j + \bar{v}_j^X \Delta \ln X_j + v_j^T$$

where $\bar{v}_j^K$, $\bar{v}_j^L$ and $\bar{v}_j^X$ are two-period averages of nominal weights of input $v_j^K = \frac{P_j^K K_j}{P_j^Y Y_j}$, $v_j^L = \frac{P_j^L L_j}{P_j^Y Y_j}$ and $v_j^X = \frac{P_j^X X_j}{P_j^Y Y_j}$, respectively. Note that under constant returns to scale $v_j^K + v_j^L + v_j^X = 1$, which is controlled by the industry production accounts in nominal terms. Each element in the right-hand side of equation (2) indicates the proportion of output growth accounted for respectively by the growth of capital services ($\bar{v}_j^K \Delta \ln K_j$), labour services ($\bar{v}_j^L \Delta \ln L_j$), intermediate materials ($\bar{v}_j^X \Delta \ln X_j$) and total factor productivity (v_j^T).

Clearly, equation (2) requires a proper measure of input services by different types of each input. For example, it requires a measure for labor services provided by different types of labor with specific demographic, educational and industrial attributes, as discussed in pioneering studies by Griliches (1960), Denison (1962) and Jorgenson and Griliches (1967). In doing so, it relaxes the usual strong assumption that treats numbers employed or hours worked as if they are homogenous. The growth of total labor input is hence defined as a Törnqvist quantity index of individual labour types as follows:

(3a) $$\Delta \ln L_j = \sum_h \bar{v}_{h,j} \Delta \ln H_{h,j}$$

where $\Delta \ln H_{h,j}$ indicates the growth of hours worked by each labour type *h* (with specific gender, age and educational attainment) and its cost weights $\bar{v}_{h,j}$ given by two-period average shares of each type in the nominal value of labour compensation controlled by the labor income of industry production accounts.

The same user-cost approach is also applied to *K* and *X* to account for the contribution of different types of capital asset (Z_k) and intermediate input (X_x) in production with type-specific, two-period average cost weight defined as $\bar{v}_{k,j}$ and $\bar{v}_{x,j}$, respectively:

(3b) $$\Delta \ln K_j = \sum_k \bar{v}_{k,j} \Delta \ln Z_{k,j}, \text{ and}$$

(3c) $$\Delta \ln X_j = \sum_x \bar{v}_{x,j} \Delta \ln X_{x,j}$$

It should be noted that the equations from (2) through the whole set of (3) also explicitly express the methodological framework for the CIP industry-level data construction that is linked to and controlled by the national production and income accounts.

Using the value-added concept, equation (2) can be rewritten as:

(4) $$\Delta \ln Y_j = \bar{v}_j^V \Delta \ln V_j + \bar{v}_j^X \Delta \ln X_j$$

where V_j is the real value-added in *j* and v_j^V is the nominal share of value-added in industry gross output.

Through rearranging equations (2) and (4), we can obtain an expression for the sources of industry value-added growth (i.e. measured in terms of input contributions):

(5) $$\Delta \ln V_j = \frac{\bar{v}_j^K}{\bar{v}_j^V} \Delta \ln K_j + \frac{\bar{v}_j^L}{\bar{v}_j^V} \Delta \ln L_j + \frac{1}{\bar{v}_j^V} v_j^T$$

Growth of aggregate value-added by the APPF approach is expressed as weighted industry value-added in a Törnqvist index:

(6) $$\Delta \ln V = \sum_j \overline{w}_j \Delta \ln V_j$$

where w_j is the share of industry value-added in aggregate value-added. With ICT-specific grouping, we can rewrite equation (6) as:

(6a) $$\Delta \ln V = \sum_{j \in ICT-P} \overline{w}_j \Delta \ln V_j + \sum_{j \in ICT-U1} \overline{w}_j \Delta \ln V_j + \sum_{j \in ICT-U2} \overline{w}_j \Delta \ln V_j + \sum_{j \in NonICT-1} \overline{w}_j \Delta \ln V_j + \\ + \sum_{j \in NonICT-2} \overline{w}_j \Delta \ln V_j + \sum_{j \in NonICT-3} \overline{w}_j \Delta \ln V_j$$

where the grouping notation ICT-P stands for ICT-producing industries, ICT-U1 for ICT-using in manufacturing and ICT-U2 for ICT-using in services, and where NonICT-1 stands for non-ICT group in manufacturing, NonICT-2 for non-ICT in services and NonICT-3 in others (see next section for the grouping and Appendix Table for the details of industries in each group).

By combining equations (5) and (6), we can have a new expression of aggregate value-added growth by weighted contribution of industry capital growth, industry labor growth and TFP growth:

(7) $$\Delta \ln V \equiv \sum_j \overline{w}_j \Delta \ln V_j = \sum_j \left(\overline{w}_j \frac{\overline{v}_j^K}{\overline{v}_j^V} \Delta \ln K_j + \overline{w}_j \frac{\overline{v}_j^L}{\overline{v}_j^V} \Delta \ln L_j + \overline{w}_j \frac{1}{\overline{v}_j^V} v_j^T \right)$$

Through this new expression, we have introduced the well-known Domar weights in our industry aggregation (Domar 1961), i.e. a ratio of each industry's share in total value-added (w_j) to the proportion of the industry's value-added in its gross output (v_j^V).

If we maintain the stringent assumption that capital and labour inputs have the same marginal productivity in all industries we can define aggregate TFP growth as:

(8) $$v^T \equiv \sum_j \overline{w}_j \Delta \ln V_j - \overline{v}^K \Delta \ln K - \overline{v}^L \Delta \ln L$$

However, this assumption is not likely to hold particularly in the case of China as argued above. It is therefore interesting to look at the difference of the two measurement approaches. By subtracting equation (7) from equation (8) and rearranging, we can show how the aggregate TFP growth is attributed to Domar-weighted industry TFP growth and to the effect of factor reallocation across industries (Jorgenson, Ho and Stiroh 2005a):

(9) $$\begin{aligned} v^T = & \left(\sum_j \frac{\overline{w}_j}{\overline{v}_j^V} v_j^T \right) \\ & + \left(\sum_j \overline{w}_j \frac{\overline{v}_j^K}{\overline{v}_j^V} \Delta \ln K_j - \overline{v}_K \Delta \ln K \right) \\ & + \left(\sum_j \overline{w}_j \frac{\overline{v}_j^L}{\overline{v}_j^V} \Delta \ln L_j - \overline{v}_L \Delta \ln L \right) \end{aligned}$$

The *reallocation* terms in the second and third brackets can be simplified as:

(9') $$v^T = \sum_j \frac{\overline{w}_j}{\overline{v}_j^V} v_j^T + \rho^K + \rho^L$$

It should be noted that the Domar-weighted industry TFP growth term $\sum_{j} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T$ can also be expressed as the Domar-weighted sum of ICT-specific group TFP growth (see equation 6a for group denotation):

$$\sum_{j} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T = \sum_{j \in ICT-P} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T + \sum_{j \in ICT-U1} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T + \sum_{j \in ICT-U2} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T + \sum_{j \in NonICT-1} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T + \\ + \sum_{j \in NonICT-2} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T + \sum_{j \in NonICT-3} \frac{\bar{w}_j}{\bar{v}_j^V} v_j^T$$

Equation (9) expresses the aggregate TFP growth in terms of three sources: Domar-weighted industry TFP growth, reallocation of capital and reallocation of labor across industries. This Domar weighting scheme ($\bar{w}_j / \bar{v}_j^V$), originated by Domar (1961), plays a key role in the direct aggregation across industries of the Jorgensonian growth accounting framework. A direct consequence of the Domar-aggregation is that the weights do not sum to unity, implying that aggregate productivity growth amounts to more than the weighted average of industry-level productivity growth (or less, if negative). This reflects the fact that productivity change in the production of *intermediate inputs* do not only have an "own" effect but in addition they lead to reduced or increased prices in downstream industries, and that effect accumulates through vertical links. As elaborated by Hulten (1978), the Domar aggregation method establishes a consistent link between the industry level productivity growth and the aggregate productivity growth. Productivity gains of the aggregate economy may exceed the average productivity gains across industries because flows of intermediate inputs between industries contribute to aggregate productivity by allowing productivity gains in successive industries to augment one another. The same logic can explain productivity losses.

The next two terms reflect the impact on aggregate TFP growth of the reallocation effect of capital (ρ^K) and labor (ρ^L) across industries, respectively. Each of the reallocation term is obtained by subtracting cost-weighted aggregate factor (capital or labor) input growth from the Domar-weighted input growth across industries. It should be noted that both theoretically and methodologically, when these terms are not negligible, it indicates that industries do not face the same factor costs, which suggests a violation of the assumption of the widely used aggregate approach. However, one should not expect a significant reallocation effect in an economy where there is a well developed market system. This is a very useful analytical tool for the Chinese case where strong government interventions in resource allocation may have caused severe market distortions (Hsieh and Klenow 2009; Wu 2016).

3. Data and ICT-Specific Industry Grouping

The CIP data—a brief introduction

This study uses updated and revised CIP (China Industrial Productivity) data based on the publically available CIP 3.0 (see Wu 2015; Wu and Ito 2015; Wu, Yue and Zhang 2015 for the construction of the CIP data and details of data sources and problems). The principle of the CIP data construction adheres to the underlying theory as expressed in equation (2) as well as in the set of equation (3). This means that in the case of input and output data the CIP industry accounts are made coherently consistent with the Chinese national accounts as control totals as given in the official input-output system, reconstructed and interpolated for the time series of the accounts (Wu and Ito 2015). It should be noted that in constructing industry accounts we do not, or are unable to, challenge the official national accounts data except for necessary consistency adjustments. Therefore, the widely reported and discussed data falsification problems should be born in mind when interpreting our results.[2]

In the case of employment data, the CIP industry accounts are built on all available employment statistics and surveys, reconstructed to ensure consistency with population censuses as control totals. Workers include both employees as well as self-employed (farming households and self-employed retailers and transporters), cross-classified by gender, age and educational level. Besides, the labor compensation at industry level is controlled by the national income accounts (Wu, Yue and Zhang 2015). In the absence of national investment matrix, however, despite tremendous efforts have been made to reconstruct industry investment flows, the lack of coherence between individual industries and the national accounts has remained as a major obstacle to establishing economy-wide consistency in the productivity analysis for the Chinese economy (Wu 2015).

The revision of the nominal input and output data is based on the lately available Chinese 2012 input-output tables. Accordingly, updated national accounts data for the period 2007-2012 are used to interpolate the input-output series between the 2007 and 2012 tables replacing the extrapolated series from 2007 onwards in CIP 3.0. The nominal accounts are double-deflated by a producer price index (PPI) matrix, constructed based on official PPIs for the agricultural and industrial sectors and relevant components of consumer price index (CPI) for service industries (Wu and Ito 2015). However, our PPI revision is still domestic transactions-based by nature, that is, has not yet been able to take into account the effect of the price changes of imported intermediate inputs. This may however induce some biases to industries that have been heavily depending on imported materials, including many Chinese ICT producers.

ICT-specific industry grouping

Since we are interested in how ICT has affected the productivity performance in the Chinese economy, the whole economy could be divided into two large sectors, ICT sector and non-ICT sector. This kind of technology is diffused among industries by means of ICT capital assets and skilled labor. Therefore, to explore the role of ICT we may consider distinguishing industries that are highly related to information technology from those are not through their intensity of using ICT equipment. The ICT intensity is defined as the share of ICT capital stock on total equipment capital stock.

In the absence of ICT equipment data, we opt for using the US criteria for ICT intensity in capital stock in the present study. This is justifiable because empirical studies have shown that the diffusion of ICT has similarities across countries (van Ark et al. 2002; O'Mahony and De Boer 2002). We may also argue that the rapid globalization through direct investment and trade in manufacturing has enhanced such diffusion. Following Jorgenson, Ho and Stiroh (2005a), we first take the median of ICT intensity of all industries in 1995 as the benchmark

[2] China's official estimates of GDP growth have long been challenged for upward bias (see Wu 2013 and 2014). Alternative estimates have indeed shown slower growth rates than the official accounts. The most affected sectors are manufacturing and so-called "non-material services" (including non-market services). Wu (2013) shows that the official industrial output index has substantially moderated the impact of external shocks. Besides, Wu (2014) also shows that the 5-6 percent annual growth of labor productivity in "non-material services" based on official data appears to be too good to be true if considering the international norm of between -1 and +1 percent per annum in the literature (Griliches 1992; van Ark 1996).

and then define the industries whose ICT intensity exceeds the median as intensive users of ICT and those below the median as non-ICT industries. Besides, ICT producers should be distinguished from ICT users. As explained by Jorgenson (2001), on the one hand, as ICT-producing industries become more efficient, more ICT equipment and software can be produced using the same cost. This raises the productivity of ICT producers and contributes to aggregate TFP growth through ICT users. On the other hand, investment in ICT equipment leads to the growth of productive capability in ICT-using industries as labor is working with more efficient equipment. Such an increase in the deployment of ICT affects TFP growth only if there are spillovers from ICT producers to ICT users.

To better investigate the industry origin of the ICT impact on the aggregate TFP performance, we also feel necessary to distinguish manufacturing and services industries in ICT users and non-ICT users. Therefore, we categorize the 37 CIP industries into six groups as defined in equation (6a), namely ICT-producing, ICT-using in manufacturing, ICT-using in services, non-ICT manufacturing, services and others (see Table A1 for details). This grouping is guided by our desire to study differences across industries that vary in ICT-using intensity. Although such breakdown is somewhat subjective, causal inspection suggests that it is reasonable.

For example, three industries, "electronic and telecommunication equipment" (CIP21), "instruments and office equipment" (CIP22) and "post and telecommunication services" (CIP30) are primary producers of ICT capital goods and should be distinguished from ICT users and non-ICT users. Industries such as "electric equipment" (CIP20) and Transport and Storage (CIP29) are considered most ICT-intensive users, hence should be labeled as ICT-using in manufacturing and ICT-using in services respectively. Industries like "coal mining" (CIP02) and "real estate activities" (CIP32) are not ICT-intensive and hence are grouped into non-ICT in manufacturing and non-ICT in services accordingly. Finally, to differentiate non-ICT-intensive agriculture and construction from the above groups, we put them into the non-ICT group in "other industries".

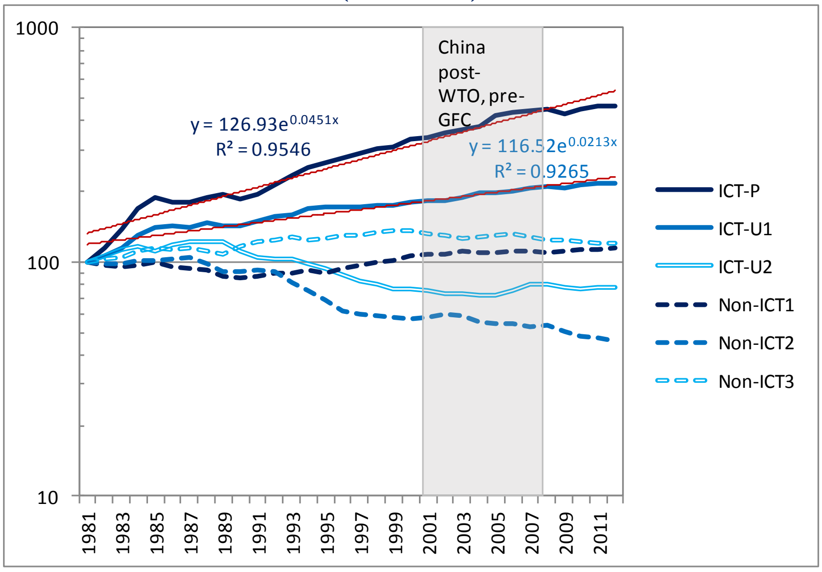
Based on the above discussion, we conjecture that the productivity growth of ICT-producing and ICT-using manufacturing groups may generally outperform the rest groups. We may also expect the latter group, as the one using ICT equipment most intensively and benefited by the spillover effect of the former, growing more rapidly than the former group, hence being the most important contributor to the aggregate TFP growth.

4. EMPIRICAL RESULTS

Sources of gross output growth by ICT-specific group

Let us begin with an examination of ICT-specific group level sources of growth as reported in Table 1 for each sub-period based on a gross output production function as expressed in equation (2). In Figure 2 we depict the gross output-based TFP in index for each group. Note that the so-estimated group TFP is not intended to be analytical with any theoretical underpinning; rather it serves as a residual indicator ignoring any connection with other industry or the rest of the economy. This is however a necessary starting point because in the ultimate analysis these groups are used as building blocks of the national economy and originators of aggregate productivity growth.

FIGURE 2
TOTAL FACTOR PRODUCTIVITY INDEX BY ICT-SPECIFIED GROUP
(1981 = 100)



Source: As Table 1.
Notes: ICT-P: producing; ICT-U1: using in manufacturing; ICT-U2: using in services; non-ICT1: manufacturing; non-ICT2: services; non-ICT3: others.

As shown in Figure 2, among the six groups only the ICT-producing and the ICT-using manufacturing demonstrate a positive linear trend in the growth of total factor productivity, but the former was twice as fast as the latter over the entire period in question (as suggested by the estimated coefficients from the simple regression models in Figure 2). Such a gap in TFP performance between the two groups may reflect that the price decline of ICT components, which were mainly used by Chinese ICT makers, was faster than that of ICT equipment facing Chinese ICT users.

It is also interesting to see that in the case of the ICT-producing group there was a short-term jump in TFP growth following China's WTO entry implying that this group was likely benefitted by the WTO-induced greater exposure to the world ICT market albeit shocked by the global financial crisis (GFC). There were nonetheless no WTO and GFC effects observed in the ICT-using manufacturing group that appears to have undergone along a much steadier TFP trend. In sharp contrast, all other groups including the ICT-using services group generally experienced little TFP improvement following China's WTO entry.

The estimated sources of gross output growth in Table 1 and their relative contributions expressed in percentage shares in Figure 3 can help better understand the TFP indices presented in Figure 2. Based on these estimates, we can summarize three worth noting points. Firstly, ICT-related sectors were indeed outstanding performers in terms of gross output growth. The ICT-producing group was the champion over each sub-period despite radical policy regime shifts or macroeconomic shocks. This group was followed by the ICT-using manufacturing group before the GFC shock. During China's post-WTO period 2001-2007, these two groups achieved a very high growth rate of 25.8 and 18.5 percent per annum respectively. However, in the wake of GFC while they lost steam like many others and considerably slowed down to 13.0 and 11.9 percent, the ICT-using services group accelerated (Table 1).

Secondly, even in the case of outstanding output growth, the ICT-related industries were still increasingly driven by the rise of intermediate inputs, reflected by a rising ratio of input materials growth to gross output growth, i.e. $\Delta \ln X_j / \Delta \ln Y_j$ using our denotations. In the case of ICT-producing, based on Table 1, the $\Delta \ln X_j / \Delta \ln Y_j$ ratio rose from 0.42 in 1981-1991 to 0.63 in 1991-2001, 0.68 in 2001-2007 and further 0.76 in 2007-2012. In the case of ICT-using manufacturing, this ratio also rose from 0.52 to 0.67, 0.73 and 0.75 accordingly. In these two cases, since the contribution to gross output growth by labor and capital inputs was more or less stable over time, this implies an inevitable decline in the TFP growth, that is, as reported in Table 1, 6.69, 5.55, 4.46 and 0.83 percent per annual for the former over each sub-period and 3.95, 1.99, 2.22 and 0.98 percent per annum for the latter (see Figure 3 for relative factor contributions).

This was also generally phenomenal in other groups mainly services, though there was no clear trend in some cases. For example, a similar rise in $\Delta \ln X_j / \Delta \ln Y_j$ is also observed in non-ICT other sectors covering mainly agriculture and construction, from 0.46 in 1981-1991 to 0.64 in 1991-2001, and then further to an average of 0.83 over the rest through 2012. Consequently, this group's TFP growth declined from 1.94 percent in 1981-1991 to 0.85 in 1991-2001, -0.48 in 2001-2007, and further to -1.34 percent in 2007-2012 (Table 1 and also see Figure 3).

Thirdly, while both ICT and non-ICT manufacturing industries experienced a decline or sometime stability in the ratio of capital input growth to gross output growth, i.e. $\Delta \ln K_j / \Delta \ln Y_j$, both ICT and non-ICT services experienced a rise of the ratio rather substantially in some cases. We could observe that over the entire period, the $\Delta \ln K_j / \Delta \ln Y_j$ ratio of the ICT-producing group declined from 0.17 to 0.13 and in the case of ICT-using manufacturing it stayed at around 0.16. But, in sharp contrast, it rose from 0.32 to 0.44 in the case of ICT-using services and from 0.44 to 0.81 in the case of non-ICT services. This largely explains their poor TFP performances over time (Table 1 and Figure 3).

TABLE 1

SOURCES OF GROSS OUTPUT GROWTH IN CHINA BY ICT-SPECIFIC INDUSTRY GROUP

(Gross output-weighted annual growth rate in percent)

	Y	L[1]	K[1]	X[2]	*TFP*	Y	L[1]	K[1]	X[2]	*TFP*
Group	1981-1991					1991-2001				
ICT-producing	21.21	0.53	3.55	10.45	*6.69*	26.12	0.61	3.44	16.52	*5.55*
ICT-using manufacturing	13.32	0.30	2.13	6.94	*3.95*	12.85	0.06	2.24	8.56	*1.99*
ICT-using services	9.84	1.66	3.15	4.60	*0.43*	7.08	0.92	5.03	4.38	*-3.26*
Non-ICT manufacturing	7.97	0.42	2.82	6.08	*-1.36*	10.92	0.13	1.64	7.06	*2.09*
Non-ICT services	6.98	1.09	3.05	3.63	*-0.79*	9.30	2.44	4.39	7.10	*-4.63*
Non-ICT other sectors	6.94	0.55	1.27	3.18	*1.94*	9.02	0.37	2.04	5.76	*0.85*
	2001-2007					2007-2012				
ICT-producing	25.76	0.87	3.05	17.37	*4.46*	13.01	0.59	1.72	9.88	*0.83*
ICT-using manufacturing	18.49	0.43	2.39	13.45	*2.22*	11.92	0.07	1.95	8.92	*0.98*
ICT-using services	12.09	0.72	4.54	5.79	*-0.48*	12.99	0.66	5.77	7.29	*-0.73*
Non-ICT manufacturing	15.04	0.51	2.26	11.68	*0.58*	11.39	0.03	2.52	8.14	*0.69*
Non-ICT services	10.53	1.61	5.66	4.80	*-1.54*	6.62	1.53	5.38	2.49	*-2.77*
Non-ICT other sectors	8.31	-0.44	2.36	6.86	*-0.48*	7.61	-0.63	3.37	6.21	*-1.34*

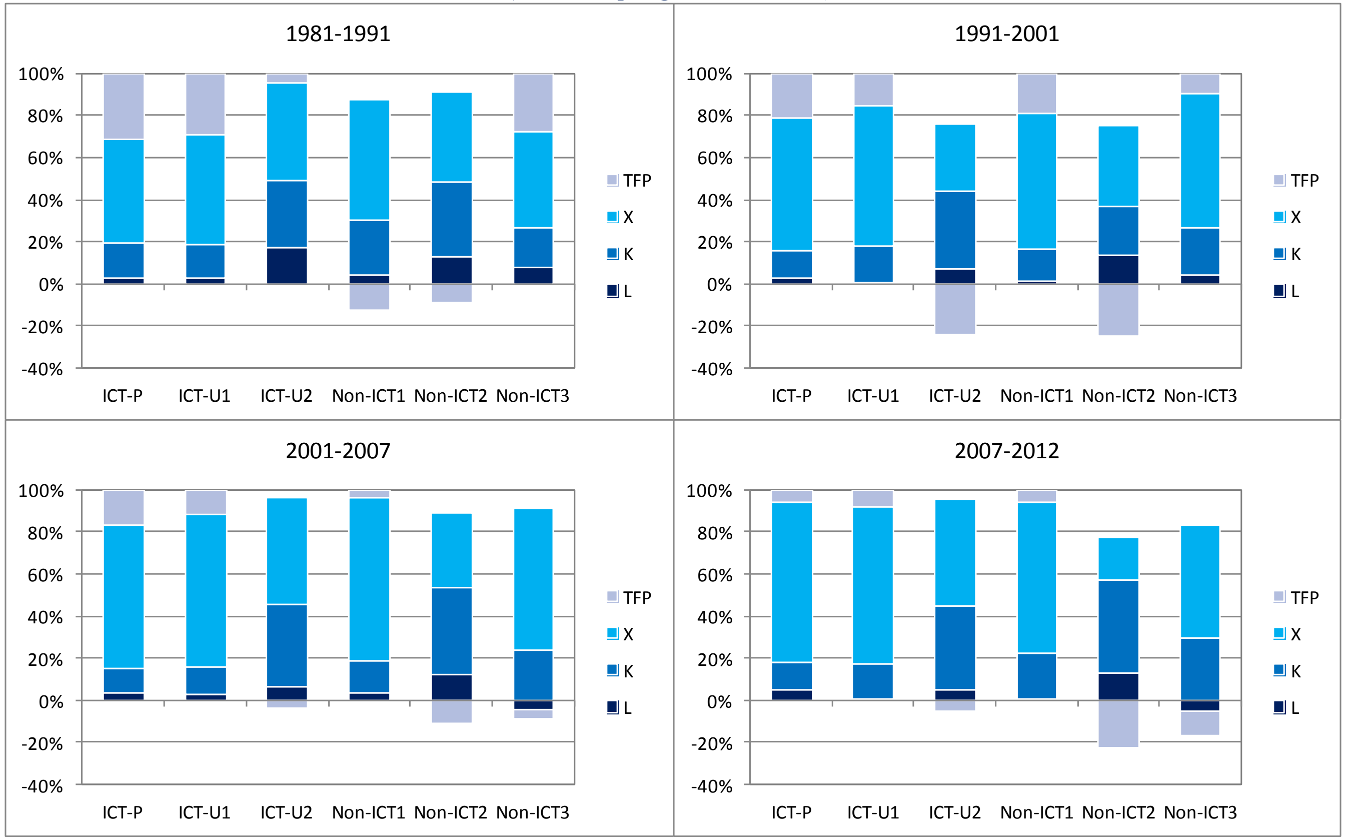
Source: Authors' calculation based equation (2) using updated and revised CIP 3.0 data.

Notes: 1) All primary factor inputs are measured in flows of factor services rather than stocks. 2) Intermediate inputs include all materials, energy and services that are purchased by producers.

FIGURE 3

SOURCES OF GROSS OUTPUT GROWTH IN CHINA BY ICT-SPECIFIC INDUSTRY GROUP

(Gross output growth = 100%)



Source: Authors' calculation based Table 1.

Notes: ICT-P: producing; ICT-U1: using in manufacturing; ICT-U2: using in services; non-ICT1: manufacturing; non-ICT2: services; non-ICT3: others.

ICT-specific group contribution to aggregate growth and source of growth

The above observations provide what the CIP data may imply in a less analytical manner or largely in a descriptive way in that there is no connection whatsoever between industries economy-wide through market and government industry-specific policies as well as affected by institutional deficiencies. However, from the observations, we have seen that these ICT-specific groups have performed very differently in their output growth and sources of the growth over time, which well justifies the importance of taking into account industry heterogeneity as discussed in our methodological section *a la* Jorgenson (2001). We devote this sub-section to examine group contributions to China's aggregate value added growth that is made through the gross output growth of individual groups and industries, in parallel to the scrutiny of the sources of the aggregate value added growth. The results are summarized in Table 2.

TABLE 2

SOURCES OF AGGREGATE VALUE-ADDED GROWTH IN CHINA, 1981-2012

(Contributions are share-weighted growth rate in percent)

	1981-1991	1991-2001	2001-2007	2007-2012	*1981-2012*
	Industry contribution to value-added growth				
Value-added growth due to (%)	8.81	8.85	11.37	9.22	*9.38*
-ICT-producing	*0.52*	*0.67*	*1.25*	*0.68*	*0.74*
-ICT-using manufacturing	*2.15*	*1.86*	*2.34*	*1.37*	*1.97*
-ICT-using services	*1.37*	*0.99*	*2.82*	*2.74*	*1.75*
-Non-ICT manufacturing	*1.73*	*3.10*	*2.55*	*3.04*	*2.54*
-Non-ICT services	*0.79*	*0.41*	*1.48*	*0.72*	*0.79*
-Non-ICT other sectors	*2.25*	*1.81*	*0.93*	*0.68*	*1.60*
	Factor contribution to value-added growth				
Value-added growth due to (%)	8.81	8.85	11.37	9.22	*9.38*
- *Capital input:*	*5.82*	*7.00*	*9.45*	*10.39*	*7.64*
- Stock	5.83	7.08	9.54	10.38	*7.68*
- Capital quality (composition)	-0.01	-0.08	-0.09	0.02	*-0.04*
- *Labor input:*	*1.12*	*1.12*	*0.59*	*0.25*	*0.88*
- Homogeneous hours	1.07	0.69	0.54	-1.00	*0.51*
- Labor quality (composition)	0.06	0.43	0.05	1.26	*0.37*
- *Aggregate TFP*	*1.86*	*0.72*	*1.32*	*-1.42*	*0.86*

Source: Authors' estimates.

As shown in the first panel of Table 2, adopting double-deflation procedures and using the industry weights from our ICT-specific industry grouping, the Chinese economy achieved a real value added growth of 9.38-percent per annum over the period 1981-2012. On average, the three ICT-related groups made up 47 percent of China's GDP growth (4.46 ppts out of the 9.38-percent of annual growth), or 29 percent if focusing only on ICT-related manufacturing. This 29-percent contribution is represented by 2.71 ppts out of the 9.38-percent annual growth, of which 0.74 ppts could be attributed to ICT-producing and 1.97 to ICT-using manufacturing. As expected, the latter group, as the one using ICT equipment most intensively and benefited by the spillover effect of the former, indeed expanded more rapidly, hence being the most important contributor to the aggregate GDP and TFP growth (see Table 4 on TFP growth).

The largest GDP contributor was nevertheless the non-ICT manufacturing group that accounted for 27 percent (2.54 ppts) of the GDP growth. This should not be a big surprise given the nature of China's catch up through export-oriented manufacturing. It is clear now that the estimates of gross output growth in Table 1 cannot be easily translated into the estimates of value added growth in Table 2 without properly considering the different roles of industries interacted and connected through their intermediate inputs.

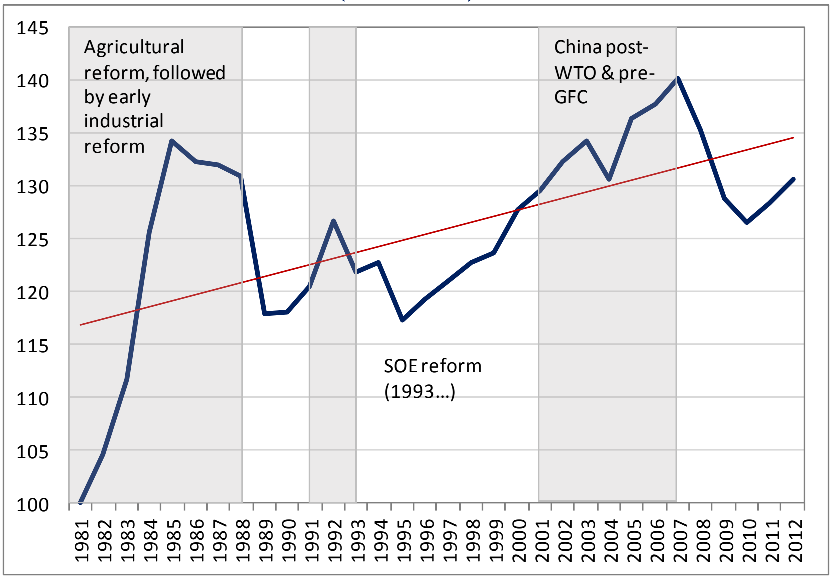
The estimated TFP performance was highly unstable over time with the highest TFP growth achieved in the initial reform stage in the 1980s and the worst in the wake of GFC.[3] Of the economy-wide 9.38-percent annual value added growth for the entire period, the contribution of capital input was 7.64 ppts, labor input 0.88 ppts, and TFP growth 0.86 ppts on average. This means that the Chinese economy relied 81.4 percent of its real value-added growth on the growth of capital input, 9.4 percent on the growth of labor input, and the rest 9.2 percent on total factor productivity growth. Over time, the contribution of capital input increased from 66.1 percent in the 1980s to 83.1 percent post WTO and then even jumped to 112.7 percent post GFC (10.39 capital input growth versus 9.22 value added growth in 2007-2012, Table 2).

On the other hand, the contribution of labor input declined from 12.8 percent in the 1980s to 5.2 percent post WTO and then dropped to only 2.7 percent post GFC. In fact, the decline in hours worked was substantial by 1.0 ppt per annum in 2007-2012. This was nonetheless cancelled off by labor quality improvement by 1.26 ppts. The contribution of the quality of capital was insignificant on average.[4]

FIGURE 4

AN INDEX OF CHINA'S AGGREGATE TOTAL FACTOR PRODUCTIVITY

(1981 = 100)



Source: Based on results reported in Table 2.

If the estimated annual aggregate TFP growth rates are translated into an index benchmarked on the initial year 1981 as shown in Figure 4, we observe a very volatile TFP performance around its underlying trend (level not rate) with substantial shocks. Using the trend line as a yardstick to identify major shocks, one may find that the shocks are largely institutional. The first TFP drive was observed in the early 1980s associated with China's agricultural reform and more or less maintained by early industrial reform from the mid 1980s. The TFP collapsed following the 1989 political crisis but somewhat recovered in the early 1990s in response to Deng's call for bolder reforms in 1992. But this did not last long before

[3] Table A2 reports the details for individual industries.

[4] This might be due to the limited set of asset types ("structures" and "equipment") that is available in the current CIP database. If a distinction between ICT and non-ICT assets could be made, a higher measured contribution is to be expected, see Jorgenson and Vu (2013).

it lost steam along with the SOE reform in 1994. It began to accelerate following China's WTO entry and peaked by the eve of the global financial crisis. Note that the current CIP data is not yet long enough for us to sufficiently examine the post-GFC decline in TFP growth and if it had indeed turned positive after 2010.

TABLE 3
DECOMPOSITION OF AGGREGATE LABOR PRODUCTIVITY GROWTH IN CHINA
(Contributions are weighted growth in percent)

	1981-1991	1991-2001	2001-2007	2007-2012	*1981-2012*
			Growth of Labor Productivity		
Value-Added Growth (APPF)	8.81	8.85	11.37	9.22	*9.38*
-Value added per hour worked	*6.26*	*7.26*	*10.08*	*11.55*	*8.18*
- Natural hours[1]	*2.55*	*1.59*	*1.28*	*-2.33*	*1.21*
			Factor Contribution		
Value-Added per hour worked	6.26	7.26	10.08	11.55	*8.18*
- Capital deepening	*4.34*	*6.10*	*8.71*	*11.72*	*6.94*
- Labor quality	*0.06*	*0.43*	*0.05*	*1.26*	*0.37*
- TFP growth	*1.86*	*0.72*	*1.32*	*-1.42*	*0.86*

Source: Authors' estimates.
Note: 1) Different from user cost-weighted homogeneous hours in Table 2.

Table 3 presents the results of a decomposition of China's aggregate value-added per hour worked into changes in capital deepening, labor quality and TFP. This enables us to separate the contribution of hours worked from the contribution of genuine labor productivity improvement and its sources. The Chinese economy once benefited significantly from the increase in hours worked or the so-called "demographic dividend". This has, however, declined overtime as shown in Table 3 from 2.55 percent per annum in 1981-91 to 1.28 following China's WTO entry. However, in the last period 2007-2012, the growth of hours worked turned negative and dropped substantially by 2.33 per annum. This clearly indicates the complete loss of the "demographic dividend". Although the growth of value-added per hour worked increased from 6.25 to 11.55 percent per annum, it appeared to be increasingly relying on the growth of capital deepening ranging from 4.34 to 11.72 percent per annum. In fact, Table 3 shows that the TFP growth was not necessarily in line with, or completely contradictory to, the pace of capital deepening, which suggests serious misallocation of resources.

The ICT-specific industry origin of aggregate TFP growth

In order to explicitly account for differences across ICT-specific groups and their impact on China's aggregate TFP performance, we now introduce the Domar aggregation approach to the APPF framework as given in equation (9) following the ICT studies on the US economy by Jorgenson, Ho and Stiroh (2005a and 2005b). This is to account for genuine TFP improvement within industries and factor reallocation effects across industries. The results presented in the first line of Table 4 are estimated with the stringent assumption that marginal productivities of capital and labour are the same across all industries, which are the same as those presented in Table 2 and Table 3 above. As expressed in equation (9), if using Domar weights such an aggregate TFP growth rate can be decomposed into three additive components, i.e. 1) the change of aggregate TFP originated in industries summed up by Domar weights; 2) the change of capital reallocation across industries; and 3) the change of labor reallocation across industries.

On average of the entire period 1981-2012, China's Domar-weighted TFP growth is estimated at 0.63 percent per annum, compared to the aggregate TFP growth of 0.86 percent per annum. This implies a net factor reallocation effect of 0.23 ppts. Table 4 also shows the contribution of each industrial group to the Domar-weighted annual TFP growth (see Table A2 for the results of individual industries). The biggest contributor to the Domar-weighted aggregate TFP growth was the ICT-using manufacturing group, contributing 0.92 ppts. The ICT-producing group contributed 0.37 ppts. The non-ICT using in services was the worst performer, dragging down the Domar weighted TFP growth by 0.99 ppts (Table 4). Such a sharp contrast across industry groups in TFP performance can also be observed over different sub-periods, which clearly suggests that treating individual industries homogenous in the growth accounting can substantially distort our view of the productivity performance of the Chinese economy, and give no vision of the industry origin of the aggregate TFP performance.

TABLE 4

DECOMPOSITION OF CHINA'S AGGREGATE TOTAL FACTOR PRODUCTIVITY GROWTH: DOMAR-AGGREGATION VIS-À-VIS FACTOR REALLOCATION EFFECTS

(In percentage points except aggregate TFP growth in percent per annum and)

	1981-91	1991-01	2001-07	2007-12	*1981-12*
Aggregate TFP growth	1.86	0.72	1.32	-1.42	*0.86*
1. Domar-weighted TFP growth	1.47	0.63	1.47	-2.08	*0.63*
-ICT-producing	*0.35*	*0.32*	*0.56*	*0.28*	*0.37*
-ICT-using manufacturing	*1.33*	*0.99*	*0.92*	*-0.06*	*0.92*
-ICT-using services	*0.14*	*-1.08*	*1.00*	*-0.18*	*-0.14*
-Non-ICT manufacturing	*-1.05*	*1.42*	*-0.05*	*0.18*	*0.14*
-Non-ICT services	*-0.28*	*-1.41*	*-0.94*	*-1.66*	*-0.99*
-Non-ICT other sectors	*0.96*	*0.41*	*-0.01*	*-0.65*	*0.33*
2. Reallocation of K (ρ^K)	-0.26	-0.35	-1.33	-0.08	*-0.47*
3. Reallocation of L (ρ^L)	0.65	0.44	1.19	0.74	*0.70*

Source: Authors' estimates following equation (9).

In terms of Domar-weighted TFP growth, both the period of the 1980s and the period post WTO were equally appraisable with a very impressive 1.47-percent annual growth. The ICT-producing and manufacturing groups were the key TFP contributors during the former period and all the three ICT-related groups were positive and significant TFP drivers during the latter period. The post-GFC period 2007-2012 however saw a considerable TFP decline by 2.08 percent per annum, worst throughout the whole period in question. Yet, the ICT-producing group, together with the non-ICT manufacturing group (0.18), still registered a positive TFP growth of 0.28 percent per annum (Table 4).

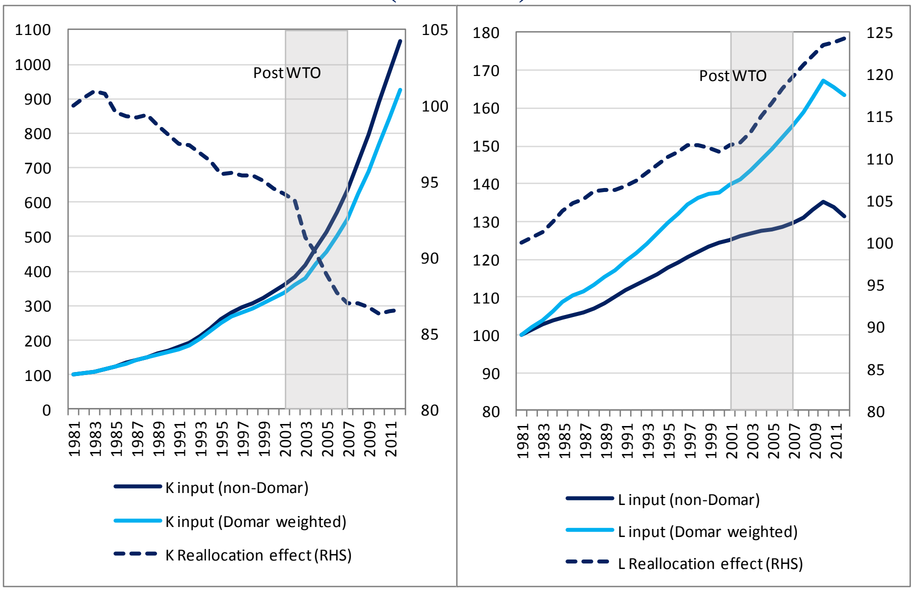
The effect of factor reallocation

The slower Domar-weighted TFP growth (0.63) compared to the aggregate TFP growth (0.86) implies that the net reallocation of capital and labor is positive. Following equation (9), in Table 4 we show that this effect consists of a positive labor reallocation effect (ρ^L) of 0.70 ppts, yet a negative capital reallocation effect (ρ^K) of -0.47 ppts. Figure 5 depicts the two reallocation effects as indices benchmarked on the initial time point 1981.

It should be noted that such a magnitude of reallocation effect is typically not observed in market economies. Based on their empirical work on the US economy in 1977-2000, Jorgenson, Ho and Stiroh (2005a) showed that first, the reallocation effect was generally negligible and second, if it was non-negligible for some sub-periods, the capital and labor reallocation effects generally moved in opposite directions. Jorgenson, Gollop and Fraumeni (1987) also reported the reallocation of capital that was typically positive and the reallocation of labor that was typically negative for the US economy for the period 1948-79. This is because capital grew more rapidly in industries with high capital service prices, hence high returns on capital, whereas labor grew relatively slowly in industries with high marginal compensation.

In the case of China, such a large magnitude and unexpected sign of capital and labor reallocation effects have two important implications. First, individual industries indeed face significantly different marginal factor productivities suggesting that there are barriers to factor mobility which cause misallocation of resources in the economy. The flip-side of this finding is that corrections to the distortions can potentially be productivity-enhancing, which is good news in terms of much talked and long awaited structural reforms.

FIGURE 5
DOMAR AND NON-DOMAR WEIGHTED FACTOR INPUT INDICES AND REALLOCATION EFFECTS
(1981 = 100)



Source: Based on results reported in Table 4.

We find that the effect of labor reallocation remained generally positive over time. This suggests that labor market was much less distorted than the capital market benefitting from increasing labor mobility along with reforms. Notably, the post-WTO period experienced the most significant productivity gain attributable to labor reallocation (1.19 in 2001-07) which could be driven by the rapid expansion of export-oriented, labor-intensive industries that was in line with China's comparative advantage. Besides, the effect of labor reallocation was also strong in the wake of the global financial crisis (0.74 in 2007-12) reflecting that labor responded more quickly to the changes of market conditions.

The case of capital reallocation is different. It maintained a negative reallocation effect throughout the entire period with the period of post-WTO the worst (-1.33). This may reflect local governments' increasing engagement in GDP race by promoting local urbanization and a new round of extensive heavy industrialization that has been criticized as repetitious and redundant (Wu 2008).

5. Concluding Remarks

In this study, we apply Jorgensonian APPF industry origin of productivity framework, incorporating Domar weights for industry aggregation, to Chinese ICT-specific industry groups in China's post-reform growth from 1981 to 2012. In the absence of a direct measure of ICT asset, our ICT-specific industry grouping adopts the ICT-intensity criteria used in the US case (Jorgenson et al. 2005), assuming that the similarities found in the ICT intensity across industries across countries can be reasonably held for China. This allows us to decompose China's productivity growth into the contribution of the so-grouped ICT industries and the factor reallocation effects across the groups.

We show that Chinese ICT-producing and using manufacturing groups appear to be the most important driver of China's productivity growth over the entire period in question, although we cannot rule out that the so-grouping may to some extent be mixed up with China's most dynamic and productive downstream industries that are close to the most competitive end market and thus less exposed to government direct interventions (Wu 2016). However, ICT-related industries are by nature more market based and more open to international competition than other industries.

We find that while sharing 29 percent of China's 9.38-percent annual value added growth, these industries contributed 149 percent to China's 0.83-percent annual aggregate TFP growth. This, together with a strong gain from the labor reallocation effect across industries, has enabled the economy to compensate for its heavy productivity losses by services and the economy-wide misallocation of capital resources. This could be good news to Chinese policy makers who have been searching for new engines of China's growth and hoping that technological innovation is the way out for the currently overcapacity and inefficiency-burdened real sector.

This ever first endeavor could be further improved by several challenging data works. The top priority is a proper construction of productive ICT assets for individual industries, controlled by the industry-specific total equipment as currently available in the CIP database. While working on this paper we did explore a commodity flow approach but failed to find a way to allocate ICT commodities among industries. We then attempted to empirically model the relationship between changes in skilled labor and changes in ICT assets using the US data, but not yet successful. We do hope that the Chinese statistical authority could listen to researchers' long appeal for establishing national investment matrix that is coherently linked to the national accounts.

Besides, we could consider further improving the CIP industry-specific producer price index to incorporate price changes of imported materials. This is not only to make the price matrix more realistic and reflect the true intermediate costs facing Chinese producers, but more importantly to improve our measure of the real value added growth for industries that heavily rely on imported parts and materials, among which ICT-related industries should be unquestionably on the top of the list.

Appendix

Table A1

CIP/China KLEMS Industrial Classification and ICT-Specific Grouping

CIP	EU-KLEMS	Grouping	Industry	
01	AtB	Non-ICT3	Agriculture, Forestry, Animal Husbandry and Fishery	AGR
02	10	Non-ICT1	Coal mining	CLM
03	11	Non-ICT1	Oil and gas extraction	PTM
04	13	Non-ICT1	Metal mining	MEM
05	14	Non-ICT1	Non-metallic minerals mining	NMM
06	15	Non-ICT1	Food and kindred products	F&B
07	16	Non-ICT1	Tobacco products	TBC
08	17	Non-ICT1	Textile mill products	TEX
09	18	Non-ICT1	Apparel and other textile products	WEA
10	19	Non-ICT1	Leather and leather products	LEA
11	20	Non-ICT1	Saw mill products, furniture, fixtures	W&F
12	21t22	ICT-U1	Paper products, printing & publishing	P&P
13	23	Non-ICT1	Petroleum and coal products	PET
14	24	Non-ICT1	Chemicals and allied products	CHE
15	25	Non-ICT1	Rubber and plastics products	R&P
16	26	Non-ICT1	Stone, clay, and glass products	BUI
17	27t28	Non-ICT1	Primary & fabricated metal industries	MET
18	27t28	Non-ICT1	Metal products (excl. rolling products)	MEP
19	29	ICT-U1	Industrial machinery and equipment	MCH
20	31	ICT-U1	Electric equipment	ELE
21	32	ICT-P	Electronic and telecommunication equipment	ICT
22	30t33	ICT-P	Instruments and office equipment	INS
23	34t35	ICT-U1	Motor vehicles & other transportation equipment	TRS
24	36t37	ICT-U1	Miscellaneous manufacturing industries	OTH
25	E	ICT-U1	Power, steam, gas and tap water supply	UTL
26	F	Non-ICT3	Construction	CON
27	G	ICT-U2	Wholesale and Retail Trades	SAL
28	H	Non-ICT2	Hotels and Restaurants	HOT
29	I	ICT-U2	Transport and Storage	T&S
30	64	ICT-P	Post and Telecommunications	P&T
31	J	ICT-U2	Financial Intermediation	FIN
32	K	Non-ICT2	Real Estate Activities	REA
33	71t74	ICT-U2	Leasing, Technical, Science & Business Services	BUS
34	L	Non-ICT2	Public Administration and Defense	ADM
35	M	Non-ICT2	Education	EDU
36	N	Non-ICT2	Health and Social Security	HEA
37	O&P	Non-ICT2	Other Services	SER

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

Notes: ICT-P: producing; ICT-U1: using in manufacturing; ICT-U2: using in services; non-ICT1: manufacturing; non-ICT2: services; non-ICT3: others.

TABLE A2

INDUSTRY CONTRIBUTIONS TO VALUE-ADDED AND TOTAL FACTOR PRODUCTIVITY GROWTH 1981-2012

	Value-Added			Total Factor Productivity		
	VA weight	VA growth	Contribution to aggregate VA growth	Domar weight	TFP growth	Contribution to aggregate TFP growth
AGR	0.195	5.02	1.09	0.313	0.45	0.32
CLM	0.016	4.98	0.07	0.032	-0.03	-0.02
PTM	0.017	-7.34	-0.12	0.026	-12.88	-0.32
MEM	0.005	9.84	0.05	0.014	0.64	0.01
NMM	0.006	10.00	0.06	0.013	2.16	0.03
F&B	0.027	11.35	0.30	0.128	0.29	0.03
TBC	0.012	9.37	0.10	0.018	-3.59	-0.08
TEX	0.026	11.33	0.29	0.112	1.10	0.10
WEA	0.009	15.15	0.13	0.037	1.22	0.04
LEA	0.004	13.95	0.06	0.020	0.84	0.02
W&F	0.007	14.84	0.11	0.027	1.36	0.04
P&P	0.011	13.60	0.15	0.040	1.32	0.05
PET	0.011	-0.37	-0.04	0.047	-3.98	-0.17
CHE	0.036	15.51	0.55	0.139	1.75	0.23
R&P	0.012	19.10	0.22	0.050	2.43	0.11
BUI	0.025	11.39	0.28	0.079	0.82	0.09
MET	0.031	8.62	0.24	0.140	-0.49	-0.07
MEP	0.012	18.77	0.23	0.052	2.64	0.11
MCH	0.034	14.81	0.53	0.123	3.12	0.34
ELE	0.015	21.24	0.30	0.068	3.08	0.14
ICT	0.015	37.76	0.51	0.079	6.78	0.31
INS	0.003	13.48	0.05	0.011	1.82	0.02
TRS	0.018	21.63	0.40	0.079	3.46	0.22
OTH	0.016	19.78	0.31	0.046	3.81	0.18
UTL	0.027	9.55	0.28	0.109	-0.52	-0.02
CON	0.055	9.48	0.51	0.213	0.13	0.02
SAL	0.077	8.70	0.64	0.144	-0.21	-0.07
HOT	0.019	9.32	0.17	0.053	-1.38	-0.06
T&S	0.051	8.24	0.42	0.105	-1.18	-0.11
P&T	0.013	13.56	0.18	0.024	0.78	0.04
FIN	0.048	10.88	0.44	0.074	2.95	0.05
REA	0.039	9.53	0.36	0.056	-7.71	-0.43
BUS	0.023	8.25	0.25	0.059	-0.90	-0.01
ADM	0.032	11.61	0.38	0.062	1.03	0.07
EDU	0.025	-6.17	-0.16	0.043	-7.33	-0.31
HEA	0.012	-6.20	-0.07	0.032	-5.31	-0.17
SER	0.017	4.27	0.11	0.038	-4.02	-0.10
Sum	***1.000***		***9.38***	***2.707***		***0.63***

Source: See Tables 2 and 4.

Notes: See Table A1 for industry abbreviation. Value added and TFP growth rates are annualized raw growth rates in percent. Industry contribution to VA and TFP growth is weighted growth rate in percentage points. See equation (9) for Domar aggregation.

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