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Examining the TFP growth of information technology service sector: a cross-country analysis

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Abstract

This paper aims to estimate the total factor productivity (TFP) growth of the information technology (IT) service industry and quantify the factors that affect TFP growth. It analyzes the IT service industry panel data of 42 economies from 2000 to 2014. TFP growth is decomposed into technical change (TC), scale component (Scale), and technical efficiency change (TEC). Furthermore, the sources of technical change are quantified by a time trend and observable technological shifters. The former is measured using a time trend variable, whereas the latter is captured using external factors, such as the share of foreign value-added in final outputs (FVS), which indicates how the IT industry relies on international outsourcing. Our results show that the average TFP growth rates of the IT service industry experienced an overall upward trend during the sample period. We found that the rise of TEC significantly contributed to TFP growth during 2000–2007. Moreover, the improvement of TC measured by inputs and FVS made a noticeable contribution to TFP growth during 2008–2014.

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1. Introduction

With the rapid development of information technology (IT), the global economy has entered a digital era, with IT being recently identified as a crucial impetus for economic growth. In 2014, the global IT capital goods sales equaled $685 billion; global IT services spending was $967 billion (Gartner 2014). The development of IT services has primarily supported the expansion of global value chains (GVCs). Using IT services is a crucial organizational competency for firms to connect with upstream suppliers and downstream customers (Jitpaiboon et al. 2013). If IT is developed effectively and deployed efficiently, it can improve information sharing, operations, product designs, and the coordination between different agents within and across organizations.

Even though many studies have examined the relationship between international outsourcing and its impacts on manufacturing, few tend to focus on the IT service sector. This paper aims to conduct a cross-country analysis of the IT service sector. Specifically, we measure the productivity growth of the IT service industry and quantify factors that promote or impede productivity growth. Total factor productivity (TFP) has been widely used to measure productivity growth. Solow (1957) defines TFP as the rate of change in output per unit of an aggregate measure of input. This measure is equivalent to technical change when production technology is assumed to be constant returns to scale. This paper applies the parametric stochastic frontier analysis (SFA) based on the translog production function to compute the TFP growth of the IT service industry. Unlike the traditional non-parametric data envelopment analysis (DEA), the SFA approach accounts for the measurement errors of variables and other unobservable influences that the DEA ignores and treats as part of an inefficiency measurement (Chou et al. 2012).

To identify the determinants of the IT industry's productivity, this paper decomposes TFP growth into technical change, scale component, and technical efficiency change. Furthermore, the sources of technical change are quantified by a time trend and observable technological shifters. The former is measured by a time trend variable, whereas the latter is captured by external factors, such as the share of foreign value-added in final outputs, which indicates how the IT industry relies on international outsourcing (Los et al. 2015).

Previous studies have used the SFA to decompose TFP growth into three components, including technical change, returns to scale, and technical efficiency.[1] Technical change is often analyzed and captured by a time trend or vector of time dummies.[2] However, technical change modeled entirely in terms of a time trend or year-on-year variations fails to account for the observable determinants of technical change and productivity growth. Recent studies based on stochastic frontier analysis have found that some external factors, such as development infrastructure, finance, and human capital, tend to shape the technical change.[3] Incorporating external factors provides more information about the sources of TFP growth. As international outsourcing has expanded

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[1] Kumbhakar et al. (2000) provide a comprehensive discussion about the decomposition of productivity change.

[2] Baltagi and Griffin (1988) propose a procedure for estimating a general index of technical change. Kumbhakar (2004) tests and compares the technical change using both a general index and time trend model.

[3] Heshmati and Kumbhakar (2011, 2014), Mastromarco and Zago (2012), and Heshmati and Rashidghalam (2020) use stochastic frontier techniques to break down Divisia TFP. They model technical change using a time trend and other exogenous factors or technological shifters such as FDI, Internet users, human capital, and infrastructures. Moreover, Ng (2012) finds that machinery and equipment investment and human capital contribute to higher TFP growth in the telecommunications services industry. Shao and Lin (2016) decompose the Malmquist productivity index of the IT service industry and reveal that productivity growth is mainly driven by innovation-based technological progress.

across manufacturing and service sectors, many firms source intermediate inputs from more cost-efficient producers domestically and abroad. Some empirical studies find that international outsourcing can improve efficiency (Andersson and Stone 2017; Yane 2021). As a result, when we examine the determinants of TFP in the IT service sector, it is necessary to consider imported intermediate inputs.[4]

According to Amiti and Wei (2009), there are four possible channels through which offshoring can affect productivity: static efficiency gain, restructuring, learning externalities, and variety effects. First, average productivity rises due to a compositional effect when firms offshore the less efficient parts of their production stage. Second, if offshoring makes the remaining workers more efficient, then it pushes out the technology frontier. This situation is more likely to occur when offshoring of service inputs, such as computing and information. Third, firms may improve efficiency if they learn from the imported services. For example, a new software package could raise the average productivity of workers. Finally, productivity could rise as firms access new material or service input varieties.[5]

This paper analyzes panel data on the IT service industry of 42 economies from 2000 to 2014. The period in this paper is noteworthy because it allows us to investigate the performance of the IT service industry during and after significant changes in economic conditions such as the 2008 global financial crisis. This article contributes to the literature as follows: first, it is related to a growing study on the consequences of international outsourcing on the growth of productivity in the IT service industry. The result indicates that international sourcing had positive but limited impacts on the TFP growth of the IT service industry. However, the impacts of international outsourcing vary between countries. Second, this article relates to many studies breaking down TFP growth over time. We separated the effect of technical change measured by international outsourcing and a time trend. The results reveal that technical efficiency largely promoted the TFP growth before 2008, and input-biased technical change and international outsourcing have large impacts on the TFP growth after 2008.

This paper is organized as follows. Section 2 describes the model and methodology that decomposes TFP growth into several determinants. Section 3 demonstrates the data sources and estimation results. The final section contains the conclusions.

2. Model and Methodology

In a single output case, the production function is expressed as $Y = f(\mathbf{x}, t)\exp(-u)$, where Y denotes the output, $f(\cdot)$ is the production function, $\mathbf{x}$ denotes a vector of J inputs, and t is the time trend variable. The production function also includes $u > 0$ to measure output-oriented technical inefficiency, which measures the proportion by which actual output falls short of maximum possible output. Thus, we define technical efficiency as $Y/f(\mathbf{x}, t) = \exp(-u) \leq 1$.

[4] Chou and Shao (2014) estimate the TFP growth of IT firms by using data envelopment analysis (DEA). Unlike previous literature, we rely on SFA to estimate TFP growth. Both SFA and DEA assume that firms cannot produce using the most efficient possible ways. However, SFA accounts for potential output reductions due to random shocks beyond the control of producers, which is different from DEA.

[5] Some studies find that offshoring has significant effects on productivity (Egger et al. 2001; Kordalska et al. 2016) and the labor market (Hijzen et al. 2005; Egger and Egger 2006; Zhu 2021).

Then, we define the Divisia TFP following Jorgenson and Griliches (1967). When there are multiple inputs, TFP change is expressed as follows: [6]

$$\dot{TFP} = \dot{Y} - \sum_{j}^{J} S_j \dot{X}_j \, , \tag{1}$$

where $S_j = w_j X_j / \left(\sum_j w_j X_j\right)$ is the cost share of inputs j in the total costs, and w_j is the price of input j (j = 1, 2, …, J). [7] Totally differentiating the production function and using Equation (1) yields

$$\dot{TFP} = (1 - RTS^{-1}) \sum_{j}^{J} \eta_j \dot{X}_j + \frac{\partial \ln Y}{\partial t} - \frac{\partial u}{\partial t} = Scale + TC + TEC. \tag{2}$$

In the right hand side of Equation (2), the first term $Scale \equiv (1 - RTS^{-1}) \sum_j^J \eta_j \dot{X}_j$ indicates the components of returns to scale, where $\eta_j = \partial \ln Y / \partial \ln X_j$ is the output elasticity with respect to input j. Summing all of the output elasticities yields returns to scale (RTS), that is, $RTS = \sum_j^J \eta_j$. It measures the percentage response of output to a one percent change in all inputs simultaneously. When there are economies of scales or increasing returns of scale, then $RTS > 1$ and the term $(1 - RTS^{-1}) > 0$.

The second term captures the technical change, $TC \equiv \partial \ln Y / \partial t$. It refers to the shift in the production frontier between two time periods. This movement of production frontier could imply the capacity of innovativeness due to some external factors.

The final term measures the technical efficiency change, $TEC \equiv -\partial u / \partial t$, which captures the difference between the actual output and the maximum output indicated by the production frontier. The TEC reflects the rate at which an inefficient producer moves towards the production frontier to obtain higher efficiency when everything else is constant. Specifically, a positive TEC would indicate that a producer moves closer to the production frontier. Additionally, a positive TEC can be interpreted as the capability of a producer to catch up with its leading competitors. Such catch-up effort suggests the improvement in technical efficiency between two time periods.

In this paper, we use a production function approach. The main advantage with the production function approach is that it does not require information on prices and allows for non-constant returns to scale. In addition, the production function is assumed to be continuous at any point and twice-continuously differentiable. Assuming a flexible translog functional form to represent the production function with an exogenous factor Z, the model can be written as follows:

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[6] Subscripts i and t are omitted to avoid notational clutter.

[7] A dot over a variable indicates its annual rate of change.

$$\ln \mathrm{Y}_{it} = \alpha_i + \sum_{j}^{J} \alpha_j \ln X_{jit} + \frac{1}{2} \sum_{j}^{J} \sum_{k}^{K} \alpha_{jk} \ln X_{jit} \ln X_{kit} + \alpha_t T_t + \frac{1}{2} \alpha_{tt} T_t^{\,2}$$

$$+ \sum_{j}^{J} \beta_{jt} T_t \ln X_{jit} + \beta_z Z_{it} + \frac{1}{2} \beta_{zz} (Z_{it})^2 + \beta_{zt} T_t Z_{it} - u_{it} + v_{it} \,, \qquad (3)$$

where $\ln \mathrm{Y}_{it}$ denotes the logarithm of value-added of country *i* in period *t*; $\ln X_{jit}$ denotes the logarithm of input *j* of country *i* in period *t*. The inputs are measured by the number of labor and fixed capital stock. T_t is a time trend (1 for year 2000, …, and 15 for year 2014). The error term, $\varepsilon_{it} = v_{it} - u_{it}$, is decomposed into technical inefficiency (u_{it}) and a random error term (v_{it}). We assume that u_{it} follows a positive half-normal distribution or a positive truncated normal distribution, while v_{it} follows a normal distribution with zero mean and constant variance. Based on the distributional assumption of error terms, we use maximum likelihood approach to estimate the parameters in Equation (3). The α_i captures the fixed effect, which allows country-specific heterogeneities to differ from technical inefficiency and considers possible correlations between heterogeneities and inputs (Greene 2005). [8] The random error term is distributed with zero mean and constant variance. In Equation (3), *Z* denotes the share of foreign value-added in final outputs, which reflects how much imported contents are embedded in production activity. We assume that engaging in international outsourcing tends to affect the technology level of producers, leading to the shift of production function.

Using Equation (3), we estimate the output elasticities with respect to input *j* (η_j) and RTS. Using Equation (4), we can estimate the returns to scale effect. Furthermore, Equations (5) yields technical change (TC_{it}) of country *i* in year *t* as follows:

$$\eta_{jit} = \frac{\partial \ln Y_{it}}{\partial \ln X_{jit}} = \alpha_j + \sum_{k}^{K} \beta_{jk} \ln X_{kit} + \beta_{jt} T_t \,. \qquad (4)$$

$$TC_{it} = \frac{\partial \ln Y_{it}}{\partial T_t} = \alpha_t + \alpha_{tt} T_t + \left(\sum_{j}^{J} \beta_{jt} \ln X_{jit} \right) + \beta_{zt} Z_{it} \,. \qquad (5)$$

Furthermore, TC_{it} in Equation (5) is decomposed into the pure ($TC_{it}^{T} = \alpha_t + \beta_{tt} T_t$), non-neutral ($TC_{it}^{M} = \sum_j^J \beta_{jt} \ln X_{jit}$), and external technology shifter ($TC_{it}^{Z} = \beta_{zt} Z_{it}$) components. Pure TC_{it}^{T} reflects neutral shift of the production function captured by time trend; non-neutral TC_{it}^{M} means input-biased TC; and TC_{it}^{Z} component is attributed to external technology shifter (Z).

Technical efficiency (TE_{it}) of country *i* in year *t* is measured as follows:

[8] Kumbhakar et al. (2015) provide Stata commands to estimate the stochastic frontier production based on panel data.

$$TE_{it} = E[\exp(-u_{it}) \mid \varepsilon_{it}], \tag{6}$$

where u_{it} is assumed to be non-negative, TE_{it} ranges between 0 and 1. After acquiring TE_{it}, technical efficiency change (TEC) can be obtained as follows:

$$TEC_{it} = \frac{TE_{i(t+1)} - TE_{it}}{TE_{it}}. \tag{7}$$

3. Data and Results

3.1 Data Sources

This paper relies on two databases to estimate the TFP growth and its determinants. First, we construct the dataset using the Socio-Economic Accounts (SEA) from World Input-Output Database (WIOD), which covers annual time-series data for 42 economies during 2000–2014.[9] The database provides industry-level data such as outputs, gross value added, number of labor, and nominal capital stock. Because the data are expressed in national currency, we also use the official exchange rates provided by WIOD to convert national currencies into constant 2010 US$. We also exclude Russia from the sample because of a large number of missing data. Thus, there are 42 countries in our sample.

Second, we use the University of International Business and Economics (UIBE) GVC Index, which provides GVC indicators (such as foreign value-added in final outputs, backward and foreign GVC participation index) based on the WIOD.[10] This paper focuses on the IT service sector, and we use the data of sector "Computer programming, consultancy and related activities; information service activities," which is provided in WIOD.

3.2 Estimation Results

The IT service sector has achieved development over the recent decades. In Panel A of Figure 1, the result shows that the share of the IT service sector's value-added in gross GDP rose from roughly 1.5% in 2000 to 1.7% in 2014. Figure 1 also illustrates the five countries which had top IT service outputs in 2014. It shows that India and Germany had large GDP shares of the IT service sector and dramatic increase rate. The growth rates of the US and Japan stayed stable during the sample period. On the other hand, China's share of the IT service sector's value-added in gross GDP was relatively low during 2000–2014.

Panel B shows the foreign value-added share (FVS) in the final outputs of the IT service sector during 2000–2014. A high level of FVS indicates that the production of the IT service sector tends

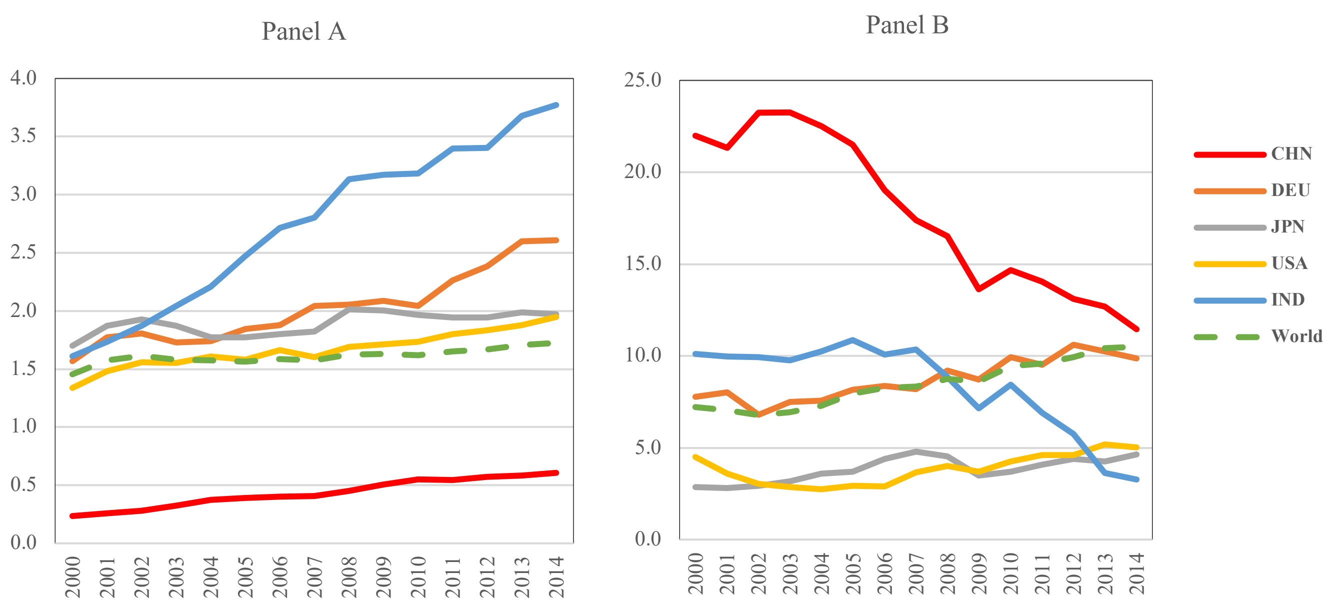
[9] WIOD includes a remaining non-covered part of the world economy, which is called the "rest of the world" region. In addition, we exclude Russia due to missing data.

[10] Wang et al. (2017) propose a framework to estimate the share of foreign value-added in final outputs.

to rely more on imported intermediate inputs, which may include not only goods but also capital, labor, and service inputs. From Panel B, we observe that the FVS increased during the sample period, ranging between 6.8% and 10.5%. This result suggests that the production of the IT service sector increasingly depends on imported intermediate inputs.

However, the changing trend exhibits heterogeneity across countries. The FVS of China and India took overall downward trends during the sample period, implying that these two countries reduced the reliance on imported intermediate inputs for the production of IT service sector. On the other hand, the FVS of Germany, Japan, and the US showed upward trends in the same period.

Figure 1 GDP share and foreign value-added share of IT service (%)



Source: WIOD and UIBE GVC Index.
Notes: Panel A presents the share of IT service sector's value-added in gross GDP. Panel B presents the foreign value-added share (FVS) in final outputs of IT service sector. CHN: China, DEU: Germany, JPN: Japan, USA: the United States, IND: India.

To estimate the production function, this paper uses the single-stage maximum likelihood procedure. The stochastic approach allows for the decomposition of output growth into several components: input accumulation and TFP growth. The latter can be further decomposed into technical change (TC), technical efficiency change (TEC), and scale components (Scale). **Table 1** presents the average value of output elasticities and returns to scale (RTS) during 2000–2014.[11] Output elasticities with respect to capital, labor, and intermediate materials are calculated from the derivatives of the production function. Average output elasticities with respect to capital, labor, and intermediate materials were positive throughout the sample period. This result implies that the outputs of the IT service sector tend to rise in response to a one percent increase in the three inputs. Intermediate materials have the largest elasticity, while labor has the smallest elasticity among the

[11] To save space, the coefficients for the translog production function are reported in Appendix.

three inputs. Furthermore, the average RTS for each year was less than one, suggesting decreasing returns to scale in production over the sample period.

Table 1 Output elasticities with respect to three intermediate inputs, 2000–2014

year	Capital	Labor	Materials	RTS
2000	0.178	0.054	0.729	0.962
2001	0.182	0.053	0.729	0.964
2002	0.186	0.053	0.727	0.966
2003	0.187	0.053	0.726	0.966
2004	0.189	0.053	0.725	0.967
2005	0.186	0.053	0.728	0.967
2006	0.185	0.053	0.729	0.967
2007	0.180	0.053	0.732	0.965
2008	0.178	0.054	0.732	0.964
2009	0.178	0.053	0.734	0.965
2010	0.178	0.054	0.733	0.965
2011	0.178	0.054	0.733	0.965
2012	0.174	0.054	0.736	0.965
2013	0.175	0.054	0.737	0.965
2014	0.174	0.054	0.737	0.966
2000–2007	0.184	0.053	0.728	0.966
2008–2014	0.176	0.054	0.735	0.965

Notes: This table shows the results for returns to scale (RTS), output elasticities with respect to capital, labor, and intermediate materials, respectively. The average values for each year are calculated using sector-level output as weights.

Table 2 shows the results for the average TFP growth and its broad components: TC, Scale, and TEC. The TFP growth was positive during 2000–2014, and this result implies that the productivity of the IT service industry constantly rose during the sample period. Moreover, we also compare the TFP growth in two periods 2000–2007 and 2008–2014. It shows that the average TFP growth during the first period was 0.9% and exhibited a downward trend. On the other hand, the average TFP growth during the second period was 0.6% and showed an upward trend.

For the components of TFP growth, TC captures the degree to which TFP growth is attributed to the shift in the production frontier over time. Thus, TC indicates the technology improvement or innovation capability of a country's IT service industry. As shown in Table 2, TC was negative from 2000 to 2006, while it became positive after 2007. The average TC has increased steadily over time from -0.1% during 2000–2007 to 0.6% during 2008–2014. The upward trend of TC implies that the TFP growth of the IT service industry increasingly benefits from technology improvement or innovation capability. In addition, TEC measures the extent to which TFP growth is driven by the efforts made by a country's IT service industry to catch up with its more efficient IT service counterparts in other countries. The TEC was positive throughout the sample period, which suggests a constant improvement in the technical efficiency of the IT service industry. However, the contribution of TEC to TFP growth has become weaker over time. The average TEC fell from 1.3% during 2000–2007 to 0.2% during 2008–2014. Scale components, which measure the effects of input changes on output growth, are zero in the case of constant RTS, or are greater (less) than zero in the case of increasing (decreasing) RTS, assuming positive input growth. Scale components in TFP growth of the IT service industry were negative except in 2009, which implies that firms in this industry had already reached a certain size where scale economies are no longer effective in promoting productivity.

Furthermore, TC is decomposed into three components: the pure (TC^T), non-neutral (TC^M), and external technology shifter (TC^Z) components. TC^T reflects the neutral shift of the production function captured by time trend. The results in Table 2 show that TC^T was negative during 2000–2010, whereas it became positive during 2011–2014. TC^M, meaning non-neutral input-biased TC, stayed roughly 0.3%. Finally, TC^Z component is attributed to external technology shifter (i.e., foreign value-added share) and ranged between 0.1% and 0.2%. This result implies that international sourcing has raised the technology level over time.

Overall, we find that the IT service industries in the 42 economies enjoy productivity growth. For the determinants of TFP growth, the results indicate that the improvement of technical efficiency made a larger contribution to TFP growth during 2000–2007, but its influence has declined subsequently. On the other hand, the rise in TC accounted for a larger proportion of TFP growth during 2008–2014. Notably, we find that international souring positively affected TFP growth, although its effects were limited.

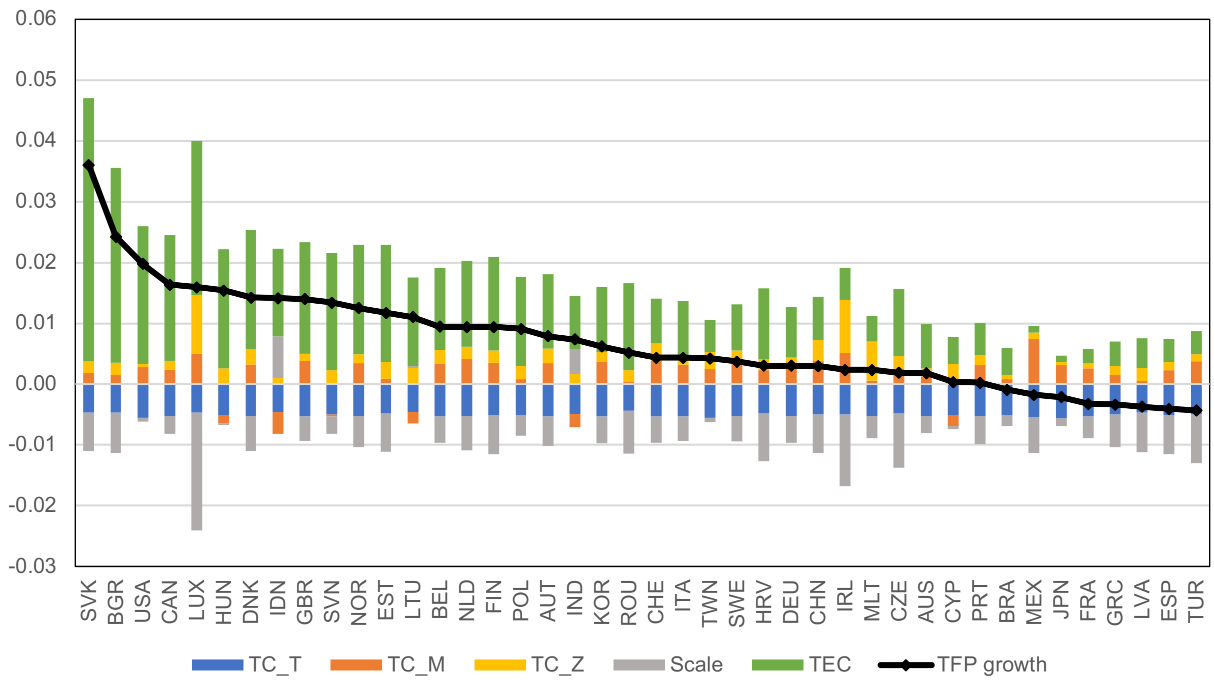
Table 2 TFP growth rates and its components

year	TFP growth	TC	Scale	TEC	TC^T	TC^M	TC^Z
2001	0.015	-0.004	-0.001	0.020	-0.009	0.003	0.001
2002	0.025	-0.004	0.000	0.029	-0.008	0.003	0.001
2003	0.011	-0.003	-0.003	0.017	-0.007	0.003	0.001
2004	0.011	-0.002	-0.003	0.016	-0.006	0.003	0.001
2005	0.003	-0.001	-0.003	0.006	-0.005	0.003	0.001
2006	0.005	0.000	-0.002	0.007	-0.004	0.003	0.001
2007	0.000	0.001	-0.005	0.003	-0.003	0.003	0.001
2008	0.002	0.003	-0.004	0.004	-0.002	0.003	0.001
2009	0.006	0.003	0.001	0.002	-0.001	0.003	0.001
2010	0.005	0.004	-0.003	0.003	0.000	0.003	0.002
2011	0.004	0.005	-0.003	0.002	0.001	0.003	0.002
2012	0.007	0.006	-0.001	0.002	0.002	0.003	0.002
2013	0.007	0.007	-0.002	0.001	0.003	0.003	0.002
2014	0.008	0.008	-0.002	0.001	0.004	0.003	0.002
2000–2007	0.009	-0.001	-0.003	0.013	-0.005	0.003	0.001
2007–2014	0.006	0.006	-0.002	0.002	0.001	0.003	0.002

Notes: This table shows the results for TFP growth and its components: technical change (TC), scale effect (Scale), and technical efficiency change (TEC). Furthermore, TC is decomposed into three components: pure TC measured by time trend (TC^T), non-neutral input-biased TC (TC^M), and TC measured by FVS (TC^Z). The average values for each year are calculated using sector-level output as weights.

We next turn to consider the performance of individual country**.** Figure 2 illustrates the average TFP growth of the IT service industry and its components by countries during 2000–2007. The countries are arranged in descending order of TFP growth, and most countries have positive TFP growth during 2001–2007. The figure shows that Slovakia, Bulgaria, and the USA had relatively high levels of TFP growth. On the other hand, the TFP growth of some countries was negative over this period, such as Turkey, Spain, and Latvia. Inspecting the components of TFP growth reveals that TEC accounts for a considerable proportion of TFP growth, particularly for countries with higher TFP growth. In contrast, TC^T and Scale components have negative effects on the TFP growth for most countries. In addition, we observe that TC^Z increases the TFP growth of all countries. In particular, TC^Z accounted for a relatively larger share of TFP growth of Luxembourg, Ireland, and Malta.

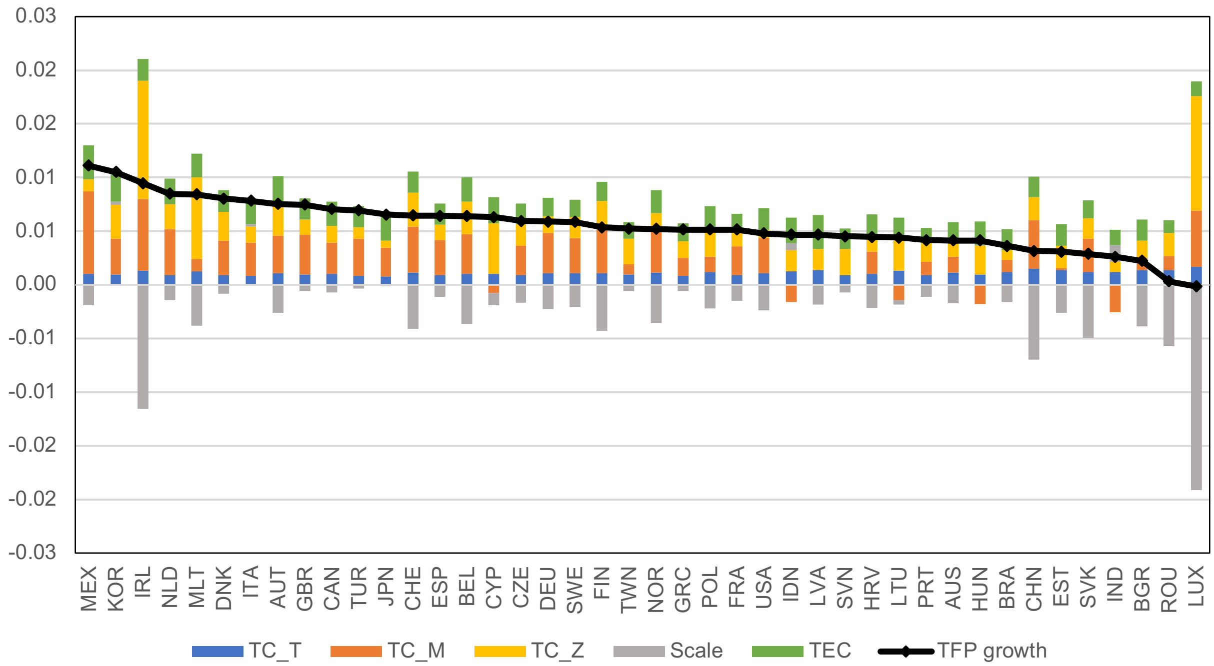
Figure 2 TFP growth rate and its components by countries, 2000–2007



Notes: This figure shows the results for TFP growth and its components: technical change (TC), scale effect (Scale), and technical efficiency change (TEC). Furthermore, TC is decomposed into three components: pure TC measured by time trend (TC_T), non-neutral input-biased TC (TC_M), and TC measured by FVS (TC_Z). The average values for each country are calculated using sector-level GDP as weights.

Figure 3 illustrates the average TFP growth of the IT service sector and its components by countries during 2008–2014. The countries are arranged in descending order of TFP growth, and all the countries have positive TFP growth over this period except for Luxembourg. We find that Mexico, South Korea, and Ireland had relatively high levels of TFP growth. When it comes to the components of TFP growth, TC^M and TC^Z account for a large proportion of TFP growth. Similar to the results in the first period, TC^Z accounted for a relatively larger share in the TFP growth of countries Luxembourg, Ireland, and Malta during the second period. TC^T has positive but limited impacts on TFP growth. On the other hand, Scale component negatively affected the TFP growth of most countries.

Figure 3 TFP growth rate and its components by countries, 2008–2014



Notes: This figure shows the results for TFP growth and its components: technical change (TC), scale effect (Scale), and technical efficiency change (TEC). Furthermore, TC is decomposed into three components: pure TC measured by time trend (TC_T), non-neutral input-biased TC (TC_M), and TC measured by FVS (TC_Z). The average values for each country are calculated using sector-level GDP as weights.

4. Conclusions

This paper applies a one-stage stochastic frontier function to examine the TFP growth of the IT service sector. The analysis is based on cross-country unbalanced panel data on the global level for 42 countries in the period 2000–2014. Using a translog production function, we decompose TFP growth into the effects of technical change (TC), scale components (Scale), and technical efficiency change (TEC). In order to measure technical change, we adopt a time trend and an external technology shifter. This division allows us to examine the effect of international outsourcing on TFP growth. The share of foreign value-added in final outputs (FVS) measures how production activities rely on international outsourcing. We incorporate this indicator into a translog production function in a flexible manner to represent an observable technology shifter. Moreover, time trend is used to capture unobservable technological determinants.

Our results show that the average TFP growth rates of the IT service industry were positive, which implies that the productivity of the global IT services underwent an overall upward trend during the sample period. In addition, this paper quantifies the determinants that affect the TFP growth of the IT service industry. It reveals that the rise of TEC remarkably contributed to the TFP growth during 2000–2007. On the other hand, TC measured by time trend was negatively associated with the TFP growth over this period, which implies that other external determinants (e.g., R&D, infrastructures, and human capital) may fail to raise the TFP growth of the IT service industry. During 2008–2014, the TEC's contribution to the TFP growth of the IT service industry became much smaller. By contrast, we find that the improvement of TC measured by inputs and FVS accounted for TFP growth. Notably, FVS made a large contribution to TFP growth in Luxembourg, Ireland, and Malta. Moreover, the impact of TC measured by time trend on TFP growth became increased by a small degree magnitude.

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