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Article

ICT development and total factor productivity growth

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Abstract: Total factor productivity (TFP) is essential for disentangling the determinants of economic growth, productivity, and the standard of living. Understanding the variations in TFP, however, is greatly challenging because of the many assumptions that comprise the theoretical growth framework. In this paper, we aim to explore the determinants of TFP growth for countries at different stages of information and communication technology (ICT) development. To address the endogenous nature of the associated growth variables, we implement a three-stage-least (3SLS) square panel regression to improve the efficiency and asymptomatic accuracy of the estimators. We find that transmission channels, such as financial openness and trade globalization, have contributed substantially to growth in both advanced and developing countries. However, we also discover that greater financial openness can undermine a country's TFP growth if the financial system is not sufficiently developed. When time horizons are decomposed into pre-ICT development and post-ICT development periods, a significant crowding-out effect is observed between ICT investment and financial openness in the pre-period, implying that the allocation of resources is critical for countries in the developing stage. Trade and finance policies that are adopted by advanced and developed countries might not be ideal for underdeveloped countries. Discretion in choosing adequate policies regarding financial integration and trade liberalization is advised for these emerging countries.

Keywords: total factor productivity; ICT development; aging population
JEL Classification: F41; F43

1. Introduction

Total factor productivity (TFP) has been recognized as a vital element in determining economic growth and labor productivity. Previous literature suggests that the growth rate of TFP has contributed more to explaining national economic growth than any other factors (Shackleton, 2013; Jones, 1999; van Ark and Pilat, 1993)[1]. The importance of TFP linkage to economic growth and labor productivity can be observed worldwide, including in G7, OECD, Latin American, and East Asian countries (Easterly and Levine, 2001)[2]. Past studies indicate that TFP growth is particularly crucial for middle-income countries (Kim and Jungsoo, 2017). One study estimated that the decrease in the TFP growth rate explained approximately 85% of the economic growth slowdown in the sample, while decreases in labor and capital growth played only negligible roles (Eichengreen et al., 2012)[3]. For countries in the transitional stage, TFP growth is essential, and only countries with high TFP growth have the chance to advance into advanced income categories (Krammer, 2010)[4].

TFP growth is also important for industrial countries. In the United States, for example, TFP acted as a primary driving factor that enhanced labor productivity in the early 1920s, with ratios as high as 40% to 60% of the US's productivity attributable

to TFP during this period (Gordon, 2012 & 2013). The spectacular TFP growth of the United States in the 1960s and 70s, which was approximately 20% higher than the TFP growth of the United Kingdom and Germany, has attracted much research attention. It has been suggested that TFP growth is one of the most important reasons that explains the relative impressive performance of U.S. economic conditions in recent decades (Dougherty and Jorgensen, 1996 & 1998; Wolff 1991; Islam 1999). More recently, the growth of TFP has significantly slowed down in advanced countries since the global financial crisis in 2007 (Cette et al., 2016). Nevertheless, to date, cross-country TFP disparities continues to be sizeable, and the gaps have not converged even among the most advanced nations (Tebaldi, 2016; Bakker et al., 2020).

Because TFP plays such an important role in determining a country's economic performance, this study aims to further understand the variation in TFP across countries. Specifically, the purposes of this research are twofold. First, we identify the determinants of the variation in TFP and examine the extent of the contribution of each. In particular, countries with sound financial infrastructure might respond differently to shocks than countries with poor, underdeveloped financial systems, or there may be a so-called threshold effect (Klein, 2005; Prasad et al., 2007; Eichengreen et al., 2011). Thus, we provide empirical evidence for these two groups of countries separately. Second, the relationships between the major determinants are explored regarding their substitutability and complementarity. The short-run and long-run impacts are discussed for different time spans when economic conditions and technology progression are different. By doing so, the detailed impacts can be appropriately addressed.

Studies exploring the determinants of TFP growth abound. It is generally agreed that education, health, infrastructure, imports, institutions, openness, competition, financial development, geographical predicament, and absorptive capacity all contribute to TFP growth (Isaksson, 2007). While market efficiency is an important contributor for OECD countries, education has found to play the most crucial role in developing countries' TFP growth (Kim and Loayza, 2019). The stagnation of TFP growth in developing countries has been an important stream for macroeconomists. Daude and Fernández-Arias (2010) claim that the TFP stagnation of Latin American countries is a predominant phenomenon. To close the gap between Latin American and the developed countries' TFP growths, Fernández-Arias and Fernández-Arias (2021) discuss productivity-specific policies and suggest that growth stagnation in Latin America results from low productivity growth and is not necessarily attributed to factor accumulation.

In this study, we include data from 118 countries from 1981 to 2015. We focus on the three aspects of TFP determinants that have been widely acknowledged in mainstream research: financial openness, the development of information and communication technology (ICT), and trade globalization. These three determinants have been proven to be significant in enhancing the growth of TFP. However, their impacts have only been investigated separately, without consideration of simultaneous interactions in an integrated model. The true effect of each of these major determinants on TFP growth is thus unclear. The endogenous nature between financial development and trade openness is documented and might hinder the implementation of the comprehensive model (Aizenman and Noy, 2009). To solve this problem, our study

employs a three-stage least squares (3SLS) method integrating the aforementioned factors as the three major determinants in a system of equations. Panel data that range from 1981 to 2015 for 118 countries are collected for analysis. This way, the impact of each determinant can be elucidated by controlling the simultaneity effects.

With appropriate decomposition of the country grouping and time frame segmentation, this study explores the attribution of the determinants to TFP growth across different economic environments and technology progression stages for countries with different degrees of financial integration. In addition, we uncover the relationship among these determinants.

The remainder of this paper is arranged as follows. Section II introduces the past literature concerning the major determinants of TFP growth. We then present the theoretical model in section III. The data and empirical strategies are explained in section IV. Section V explains the results. An empirical discussion is presented in section VI. Finally, caveats and conclusions are provided in section VII.

2. Determinants of TFP Growth

Our study identifies the three major determinants of TFP growth: financial openness, the development of ICT, and trade globalization. The hypotheses are embedded in the extant literature with prevailing evidence. This section discusses the relevant literature regarding the importance of these determinants.

2.1. Financial openness

Countries around the world started to deregulate their financial markets and had more liberalized economic activities in the 1970s. The first wave was initialized in the United States, where capital controls were relinquished in 1973. Later, Germany, Canada, Switzerland, and the United Kingdom followed suit with capital liberalization in 1979. Such abolishment of capital controls in the major industrial countries acted as a catalyst triggering capital crossing borders in other advanced nations[5]. The intensified growth of financial openness in the mid-1980s functioned as an "indirect effect" supporting the improvement in TFP growth (Mishkin, 2006; Kose et al. 2006; Kose et al. 2009; Arif-Ur-Rahman and Inaba, 2020; Eichengreen et al. 2011; Henry 2007; Quinn and Toyota, 2008; Bonfiglioli 2008; Bekaert et al., 2011). The explanation is that financial openness enhances aggregate efficiency, resulting from the development of commercial sectors, improvement in the governance of incumbent firms, and better-structured institutions. In addition, when countries have more liberalized financial markets, the economies benefit from allocative efficiency and have increased competitiveness (Bekaert et al., 2005). These indirect impacts of financial openness permanently affect productivity and economic growth.

The voluminous literature regarding the positive relationship between financial openness and TFP growth has been documented in cross-country studies. As Eichengreen et al. (2011) point out, countries must reach a certain threshold in terms of institutional and economic development before they can expect to benefit from capital account liberalization, implying that the relationship between TFP growth and financial openness for developing countries can be very different. While most of the developed countries abolished various restrictions on capital flows in the mid-1970s,

the developing countries' degree of financial openness remained low until the late 1980s (Edwards 2007; Obstfeld 2009). Pratap and Urrutia (2012) argue that financial crises in emerging countries are generally followed by a significant fall in TFP. In the case of Mexico, the 1995 financial crisis cut TFP growth by half and the productivity of GDP per capita by 74 percent. The evidence from Mexico suggests that the impacts of financial openness on TFP could be different for countries with financial system infrastructures of various degrees of maturity. Thus, more endeavors to understand the factors that drive TFP growth over time in an international context are necessary, given that the adaptiveness of financial openness and the degree of financial integration are substantially different across countries[6].

2.2. ICT development

Another appealing determinant that plays a critical role in driving TFP is ICT development. The innovation of ICT started in the 1990s. Integrated with existing production, ICT enhances the efficiency of the traditional goods market by improving communication and inventory management, including logistics, distribution, and warehousing. New economic activities brought by social media, such as Facebook, and the sharing economy, such as Uber and Airbnb, appeared after the introduction of smartphones in 2007. In recent years, arguments articulating revolutionary ICT that results in positive productivity growth have proliferated. Spiezia (2012), for example, suggests that ICT investment stimulated positive value-added growth in business sectors in 18 OECD countries from 1995 to 2007. ICT-producing industries account for two-thirds of TFP for Germany, the United Kingdom, and Slovenia. The strong impact of ICT development on productivity and TFP has also been observed in Europe and other regions, for example, by Dahl et al. (2011) and Miller and Atkinson (2014)[7]. Applying survey data covering more than 35,000 firms from 2010 to 2015 in the United States, Bloom et al. (2019) concludes that 40% of productivity is highly associated with management practices, which are primarily driven by ICT, R&D, and human capital. In the pre-ICT period, the average labor productivity of the United States was 1.5% between 1973 and 1995, while between 1995 and 2014, labor productivity surged to 2.2% (Furman, 2015; Jorgenson, 2005 & 2008; Stiroh, 2002; van Ark et al., 2008). Many researchers believe that the surge in labor productivity and, in turn, the increased speed of economic growth is attributed to the development of ICT (Jorgenson et al., 2005; Acharya, 2016)[8]. Byrne and Corrado (2017) emphasize that ICT is crucial to the development of service industries. A similar view of the contribution of ICT to TFP is also supported by Jorgenson et al. (2008), Neil and Lawrence (2001), and Oliner and Sichel (2000)[9].

It is worth noting that the contribution of ICT to TFP growth is uneven across industries and countries. A positive effect occurs in high-skilled industries and OECD economies (Ilmakunnas and Miyakoshi, 2013). Spiezia (2012), for example, finds that communication investment has played a dominant role in Finnish productivity growth, and software investment has played a pivotal role in Japan. Similar findings are also confirmed by Le Clech and Guevara-Pérez (2013) in Latin American and Caribbean Countries. On the other hand, an adverse effect of ICT investment on TFP growth was

found in West African countries (Bollou and Ngwenyama, 2008) and on the low-skilled and aging manufacturing industries (Ilmakunnas and Miyakoshi, 2013).

2.3. Trade globalization

The third major driving factor of TFP growth to be investigated in this paper is the globalization of trade. The benefits of trade to a nation, such as minimizing opportunity cost, exploring specialization, and increasing efficiency, can be traced back to the theories of Adam Smith and David Ricardo (Haider et al., 2020). Trade has also been widely discussed in the recent literature, as it improves economies of scale, intensifies competition, encourages efficiency, and diffuses technology (Parente and Prescott, 1999; Miller and Upadhyay, 2000; Christopoulos and McAdam, 2013). In addition to providing a rich variety of goods across borders, trade supports domestic businesses in adopting new ideas and technologies from international counterparts, called the technological spillover effect. Keller and Yeaple (2009) and Connolly (2003) believe that import-related spillover knowledge has a significantly positive contribution to domestic production due to the uptakes of domestic firms' imitation and inspiration from imported high-technological products or machines, resulting in an upgrade of infrastructure and R&D ability (Coe and Helpman, 1995, 2009)[10]. Sebastian (1998) confirms a positive relationship between trade globalization and TFP growth utilizing 93 countries with nine indicators denoting trade openness. Therefore, in this study, it is also argued that a higher degree of trade globalization results in higher TFP growth.

The unevenness and sustained disparity of TFP growth across countries is marked, and many researchers have investigated the causes. In addition to the three major factors discussed above, other factors that have been discussed in the international macroeconomic literature include the quality of institutions, applications of production, the degree of infrastructure development, etc. In this study, however, we focus primarily on financial openness, ICT development, and trade globalization, controlling GDP and the lags of the relevant effects. With the new technologies introduced into the global economy amid the deregulation of the financial market, an investigation employing a robust econometric method is worthwhile to determine the impact of these factors on the growth of TFP and their simultaneous relationships modeled in a system of equations.

3. An illustrative framework

In this section, we present a framework to investigate the underlying determinants that contribute to TFP growth. Our hypotheses are built upon several strands of literature, focusing on financial openness, ICT development, and trade globalization, each of which has been separately analyzed in the extant literature regarding the impact on TFP growth. We integrate these three determinants into a model of system equations to show how each of the determinants influences TFP growth while interacting with one another. The model is as follows:

$$TFP_{i,t} = \beta_0 + \beta_1 Finance_{i,t} + \beta_2 ICT_{i,t} + \beta_3 Trade_{i,t} + X_{1,i,t} + \varepsilon_{1,i,t} \quad (1)$$

$$Finance_{i,t} = \alpha_0 + \alpha_1 ICT_{i,t} + \alpha_2 Trade_{i,t} + X_{2,i,t} + \varepsilon_{2,i,t} \quad (2)$$

$$Trade_{i,t} = \eta_0 + \eta_1 Finance_{i,t} + \eta_2 ICT_{i,t} + X_{3,i,t} + \varepsilon_{3,i,t} \quad (3)$$

$$ICT_{i,t} = \delta_0 + \delta_1 Trade_{i,t} + \delta_2 Finance_{i,t} + X_{4,i,t} + \varepsilon_{4,i,t} \quad (4)$$

where $TFP_{i,t}$ represents the TFP growth of country i in year t, measured as the growth rate of Solow residuals based on growth accounting of the neo-classical growth model. *Finance* represents financial openness, ICT represents ICT development, and Trade denotes trade globalization. X are the control variables, including GDP level and the various periods of lag terms of the explanatory variables, depending on the significance level: elderly population ratio, and age-specific labor population ratios of the countries. Equation (1) is the main regression that incorporates all three major determinants in the equation, in which each variable can be explained by holding other factors under control. To account for the endogeneity problems that arise from the interdependent relationships between the three major determinants, Equations (2) through (4) are expressed to form the three-stage least regression (3SLS) model[11]. The relationship between the explanatory variables can thus be explored simultaneously. Similar applications can be found in extant studies, such as Imbs (2004) and Chang et al. (2012).

4. Data and empirical strategies

The dataset of this study contains 118 countries over the time period from 1981 to 2015, with the data collected from several sources. Total factor productivity and ICT are extracted from the Total Economy Database—The Conference Board (Byrne and Corrado, 2016). Based on the growth accounting methodology, the growth rate of TFP, or the Solow residuals, can be obtained from income growth minus the growth of capital, labor, and ICT. Last, ICT development is measured by the growth rate of the percentage of the contribution of the ICT industry to GDP, which is calculated directly by Conference Board.

For financial openness (FO), two sources of data are included. The first set is the data constructed by Lane and Milesi-Ferretti (2006), denoted as Total Liability and Total Assets, which have been employed widely in the relevant literature (Steiner and Saadma, 2016; Estrada et al. 2015; Philip et al, 2017). Inspired by Kose et al. (2009), who adopt both quantitative (*de facto*) and qualitative (*de jure*) measures for financial openness to analyze their impacts on TFP, this study uses similar concepts but from a different source. *The Globalization Index*, published annually by the KOF Swiss Economic Institute, the oldest economic research institute in Switzerland, was originally constructed by Dreher (2006). It also contains *de facto Financial Openness* and *de jure Financial Openness*. However, different from the *de facto* and *de jure* variables used by Kose et al. (2009), the KOF *de facto* and *de jure* FO are composite measures with a broader range of variable selections than the set adopted by Kose et al. (2009). The KOF's *de facto* FO includes weighted measures of foreign direct investment, portfolio investment, debts, and reserves to GDP. It is a measure of a comprehensive stock of external assets and liabilities. *De jure* financial openness is a qualitive measure composed of the weighted average of investment restrictions, capital account openness, import barriers, mean tariff rate, and international investment agreement (Gygli et al., 2019)[12,13]. As Kose et al. (2009) suggested that *de facto* and *de jure* financial openness could generate somewhat different results, we adopt both of these measures of financial openness from the KOF Index as well as the simple

form of total asset or total liability in the empirics to explore the theoretical conjecture of the model.

For trade globalization, we adopt the variable *Trade Globalisation, de jure (KOFTrGIdj)* from the KOF Globalisation Index dataset. This variable is a composite of several cross-country legal aspects of trade, including trade regulations, trade taxes, tariffs, and trade agreements (Gygli et al., 2019). The sources of other control variables are as follows. Gross domestic product (GDP) is from Penn World Table (PWT) 10.0, and the labor ratios by age groups are from World Population Prospects, 2019, of the World Bank.

For an initial understanding of the relationships between TFP growth and GDP growth, these two variables are first visually compared in **Figure 1**, in which average values from each country are depicted in the three selected time frames. The left panel in **Figure 1** is for the whole sample period (from 1981 to 2015). The middle and right panels are for the periods of 1981~2003 and 2004~2015, respectively. The red dashed lines are the mean values of the corresponding variables in the period. The reason that we create the subperiod samples, 1981~2003, and 2004~2015, is because of the "productivity slowdown" that allegedly became a universal phenomenon in the post-2004 period (Eichengreen et al. 2015)[14]. Concerns over the productivity slowdown are pervasive, and researchers have tried to understand its causes (Bergeaud et al. 2015; Cadarelli and Lusinyan, 2015, Cette et al. 2016)[15]. As Fernald (2014) suggests that the slowdown of TFP growth is merely the return to previous typical rates due to the subsidence of the extraordinary gains from the IT revolution, we refer to 2004 as the turning point for the pre- and post-ICT development periods. It is plausible to assume that the determinants might affect TFP growth differently in the pre-ICT period than in the post-ICT period due to the different economic environment and technology progression stage. Another reason to study distinct time periods is to investigate the relationships between the determinants and TFP growth over the short term, in contrast to the long term. Kim et al. (2010) indicate a long-run complementarity relationship between financial development and trade openness but a substitutionary relationship in the short run. Thus, with this subperiod analysis, more time-varying relationships between the variables can be explored.

All three panels in **Figure 1** exhibit positive relationships between the growth of TFP and the growth of GDP, and the panel of the post-ICT development period shows a slightly flatter slope than that in the pre-ICT period, visually suggesting a productivity slowdown in the preliminary graphical presentation. The extant studies mostly focus on industrial countries to determine factors relevant to the productivity slowdown. Whether the stagnant productivity might be a local or universal phenomenon across all types of countries requires further investigation, as suggested by Cardarelli and Lusinyan (2015).

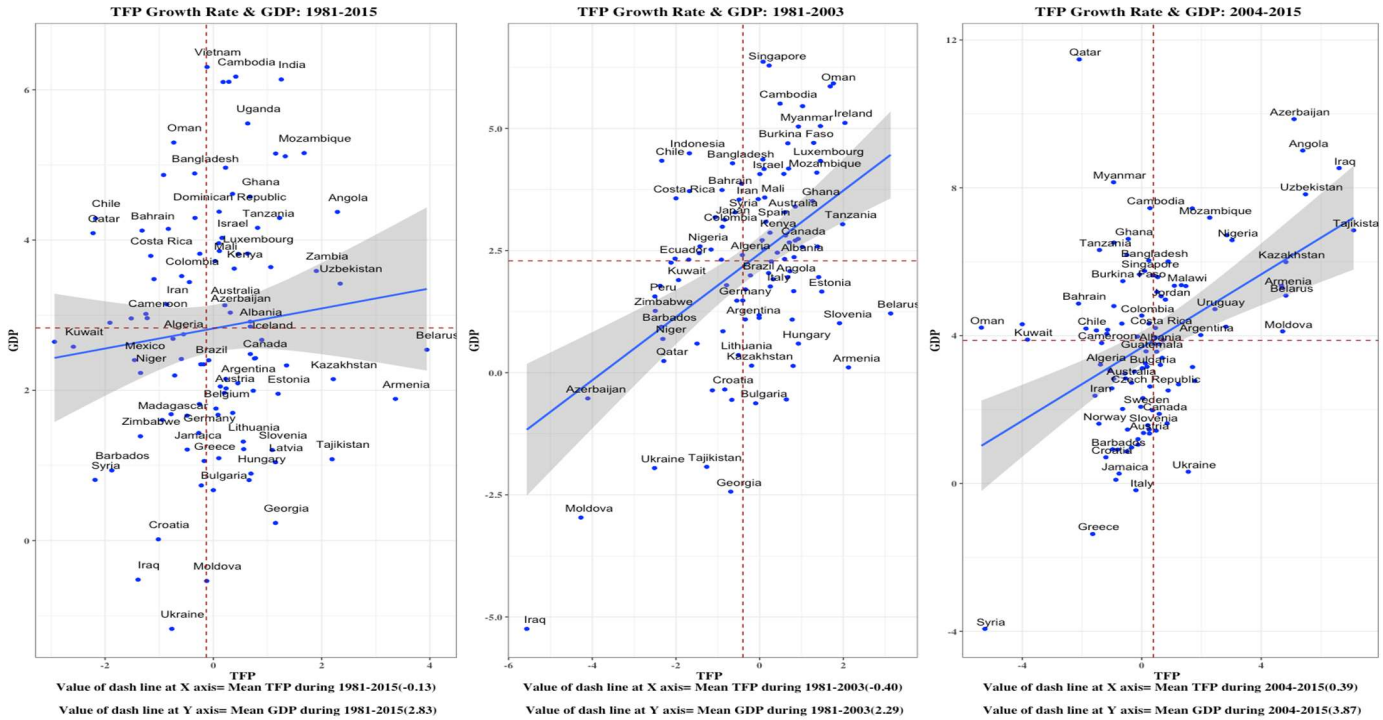

Figure 1. The growth between TFP and GDP.

To identify the factors enhancing TFP growth in a cross-country study, additional groupings are needed. Following the suggestion of Kose et al. (2019), we separate 118 countries into two groups—more financially open (MFO) and less financially open (LFO) countries—based on the median of *total liability (*a *de facto* financial openness measure composed by Lane and Milesi-Ferretti, 2006)[16]. **Figure 2** depicts the TFP growth rates for the whole sample, LFO countries, and MFO countries over three periods: before 1994, 1994~2004, and 2005~2015. For both LFO and MFO countries, TFP values are negative before 1994 but turn positive between 1994 and 2004. Then, in the post-2004 period, TFP shows a noteworthy slowdown in the MFO group. This graphical presentation of the changes in TFP in MFO countries is in line with past studies, and the phenomenon has been widely discussed (Eichengreen et al., 2015). However, little research has been focused on the LFO countries, whose TFP level still seems to remain high in the post-2004 period. This noteworthy phenomenon in **Figure 2** calls for deeper analysis in the empirical section.

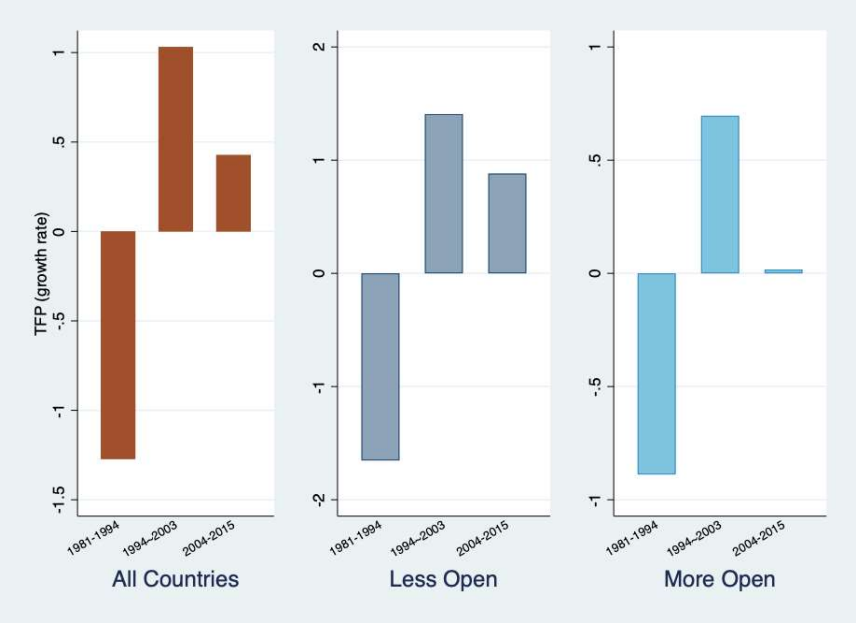

Figure 2. Total factor productivity of LFO and MFO countries.

In the next step, we attempt to observe the linkage between ICT growth and TFP growth, as depicted in **Figure 3**. Countries are distinguished as MFO and LFO for comparison purposes. The graphical presentation shows a weak positive relationship between these variables in both MFO and LFO countries. MFO countries have a slightly greater positive impact of ICT on TFP than LFO countries. Based on these three figures, it is plausible to presume that the relationships between TFP growth, GDP growth, and ICT development depend on the degree of financial openness and the time span. Thus, in our empirical section, the models are established by time period and degree of financial openness for deeper probing. Other relevant variables are also included in the formal analyses to control for confounding effects.

Figure 3. ICT on total factor productivity (the period of 1981~2015).

5. Results

To empirically test the relationships described in the theoretical model of Equations (1) through (4), we first run a baseline 3SLS model using the financial openness variable constructed by Lane and Milesi-Ferretti. The original construction of the variable comes with two forms: total liability and total asset. Since the results generated from the two forms are similar, only the total liability result is shown throughout the rest of the paper. **Table 1** is presented in Column (1). Columns (2) and (3) are the results using the KOF *de facto* and *de jure* measures, respectively, as financial openness for the same regressions. Comparing the three columns, similar outcomes are observed except that the current measure of financial openness has an insignificantly negative impact on TFP growth in the liability measure (Column 1), while the impacts are significantly positive for both KOF measures (Columns 2 and 3). These results are aligned with the findings of Kose (2009), suggesting that both the *KOF de facto* and *KOF de jure* measures include more comprehensive, well-rounded aspects of financial openness than the total asset or total liability measures. Thus, the rest of the research reports only the results generated from the *KOF de facto* and *KOF de jure* FO measures.

Table 1. The relation between TFP and Determinants.

	Liabilities	**KOF *de facto***	**KOF *de jure***
TFP	(1)	(2)	(3)
Finance	−9.887	13.826*	52.482***
	(−1.45)	(1.79)	(3.82)
ICT	1.527***	2.012***	1.629***
	(15.98)	(20.09)	(16.44)
Trade	57.208***	3.082	13.022
	(3.79)	(0.24)	(1.55)
D_2004	−1.286**	−1.393**	−1.184*
	(−2.25)	(−2.23)	(−1.79)
Year	0.087**	0.091**	0.116***
	(2.51)	(2.42)	(2.79)
Finance			
Trade	0.747***	0.517***	0.606***
	(14.78)	(11.88)	(9.42)
ICT	−0.110***	−0.115***	0.176***
	(−9.71)	(−13.56)	(13.56)
GDP	0.026***	0.032***	−0.062***
	(5.15)	(8.42)	(−10.90)
Trade			
Financial	2.090***	0.380***	0.399***
	(5.32)	(3.69)	(3.88)
ICT	−0.003***	−0.001	−0.001
	(−3.09)	(−1.19)	(−1.10)

Table 1. (*Continued*).

	Liabilities	**KOF *de facto***	**KOF *de jure***
GDP	0.020***	0.011***	0.010***
	(7.72)	(5.65)	(5.25)
ICT			
Trade	2.559***	2.014**	−0.703
	(3.24)	(2.56)	(−0.89)
Financial	−6.612***	−2.899***	−0.220
	(−17.10)	(−7.84)	(−0.59)
W40_r	24.625**	0.411	30.327***
	(2.39)	(0.04)	(2.93)
W60_r	−14.120*	17.162**	8.250
	(−1.70)	(2.09)	(0.99)
Old_ratio	0.127	−0.481***	0.102
	(1.08)	(−4.14)	(0.87)
Observations	2401	2401	2401
AIC	42085.413	40140.857	44917.366
BIC	42310.975	40366.419	45142.928
chi2	1284.845	1403.074	1243.219
p	0.000	0.000	0.000

Note: The explanatory variables contain lags in all three stages of the model raging from 1 to 4 lag periods as the regressors depending on the relative significance levels. The results are not shown to conserve space. *indicates $p < 0.10$, ** indicates $p < 0.05$, and *** indicates $p < 0.010$. W40_r and W60_r represent ratios of workers' age of 40~59 and 60+, respectively.

To understand how countries with financial markets in different stages of development respond differently when shocks strike economies, it is of interest to decompose our sample into LFO, MFO, and OECD countries for comparison purposes, as suggested by Kose et al. (2009). LFO countries are the least developed group in terms of financial structure, and the OECD countries represent the most-developed group. The MFO group contains many countries with mixed financial backgrounds. The results are presented in **Tables 2** and **3**; the former uses the *KOF de facto,* and the latter uses the *KOF de jure* as the measure of financial openness.

Table 2. The relation between TFP and determinants with degree of financial openness (The data of KOF de facto used as financial openness).

	LFO	**MFO**	**OECD**
TFP	(1)	(2)	(3)
Finance	−98.967***	55.93***	18.230***
	(−4.36)	(4.38)	(3.86)
ICT	1.681***	1.693***	0.848***
	(8.41)	(17.63)	(15.54)
Trade	24.312	33.081**	16.356**
	(1.04)	(2.37)	(2.47)

Table 2. (*Continued*).

	LFO	MFO	OECD
D_2004	−2.668	−1.197	−0.131
	(−1.54)	(−1.59)	(−0.43)
Year	0.172*	0.13***	−0.030
	(1.64)	(2.97)	(−1.46)
Finance			
Trade	0.736***	0.359***	0.520***
	(13.48)	(16.60)	(14.92)
ICT	−0.091***	−0.039***	−0.125***
	(−9.90)	(−10.99)	(−13.64)
GDP	0.013***	0.007***	0.069***
	(3.36)	(2.63)	(9.53)
Trade			
Finance	0.167	0.296**	0.121
	(1.54)	(2.09)	(0.53)
ICT	−0.003**	−0.007***	0.005**
	(−2.06)	(−5.47)	(2.46)
GDP	0.003	0.015***	0.009*
	(1.09)	(5.03)	(1.73)
ICT			
Trade	−0.964	−2.034**	3.719***
	(−0.74)	(−2.12)	(5.61)
Finance	−4.681***	−8.175***	−2.068
	(−5.25)	(−5.55)	(−1.54)
W40_r	0.413	0.582	−33.299**
	(0.02)	(0.04)	(−2.00)
W60_r	25.113*	41.73***	−43.881***
	(1.68)	(3.78)	(−3.76)
Old_ratio	−0.227	−0.703***	−0.305**
	(−1.07)	(−4.34)	(−2.11)
Observations	844	1557	951
AIC	13403.310	26503.954	12909.490
BIC	13588.098	26712.624	13098.933
chi2	309.976	753.735	486.125
p	0.000	0.000	0.000

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$. W40_r and W60_r represent ratios of workers' age of 40~59 and 60 +, respectively.

Table 3. The relation between TFP and Determinants. (The data of KOF de jure used as financial openness).

	LFO	**MFO**	**OECD**
TFP	(1)	(2)	(3)
Finance	13.609	51.165***	47.018***
	(1.24)	(3.69)	(4.84)
ICT	1.914***	1.183***	0.741***
	(12.56)	(11.97)	(11.14)
Trade	7.808	22.605	12.765
	(0.52)	(1.57)	(1.28)
D_2004	−1.384	−1.447**	−0.283
	(−1.58)	(−2.16)	(−0.59)
Year	0.087*	0.144***	0.053
	(1.60)	(3.19)	(1.57)
Finance			
Trade	0.557***	0.290***	0.186***
	(6.03)	(10.91)	(13.06)
ICT	0.139***	0.037***	0.005
	(8.74)	(10.01)	(0.89)
GDP	−0.054***	−0.014***	−0.013***
	(−10.21)	(−5.44)	(−3.09)
Trade			
Finance	4.144***	6.428***	2.043*
	(4.31)	(4.33)	(1.65)
ICT	0.003	−0.022***	0.002
	(0.98)	(−7.82)	(0.66)
GDP	−0.008*	0.003	0.014***
	(−1.74)	(0.42)	(2.61)
ICT			
Trade	−2.297*	−5.886***	2.789***
	(−1.76)	(−6.25)	(4.18)
Finance	8.199***	28.261***	7.722***
	(9.32)	(20.15)	(4.88)
W40_r	25.225	15.468	−42.880**
	(1.55)	(1.17)	(−2.42)
W60_r	17.491	10.778	−64.006***
	(1.23)	(1.08)	(−5.21)
Old_ratio	−0.187	−0.272*	−0.172
	(−0.94)	(−1.87)	(−1.13)
Observations	862	1576	955
AIC	14908.372	22736.090	12259.374
BIC	15093.983	22945.010	12448.980
chi2	881.543	905.003	375.611
p	0.000	0.000	0.000

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$. W40_r and W60_r represent ratios of workers' age of 40~59 and 60+, respectively.

Comparing **Tables 2** and **3**, it is uncertain whether the KOF *de facto* measure or the KOF *de jure* measure offers a superior theoretical prediction. The signs and the significance levels of the determinants are comparable, and the AIC and BIC values are similar. In these two tables, financial openness positively enhances TFP growth in MFO economies and OECD countries, while a significantly negative sign of financial openness in LFO nations is observed in **Table 2**, and no significant result is present in **Table 3**, suggesting that financial openness might be beneficial only when countries are fully developed and have a sound financial infrastructure, like the MFO and OECD countries. The different effects of financial openness in the two types of countries call for further investigation. In addition, the negative impact of the dummy variable 2004 (D_2004) in **Tables 1** through **3** indicates that the slowdown of TFP is conspicuous in the post-2004 period, suggesting that further decomposing the analyses into pre- and post-ICT periods is appropriate. By doing so, we allow the determinants to freely affect the two time periods. The results are presented in **Tables 4** and **5**.

Table 4. The relation between TFP and determinants, 1981~2004.

	(1)	(2)	(3)	(4)	(5)
	KOF *de facto*	**KOF *de jure***	**LFO**	**MFO**	**OECD**
(I) TFP					
Finance	27.860**	33.138	−103.307***	13.169	40.252***
	(2.10)	(1.18)	(−4.10)	(0.68)	(4.29)
ICT	2.966***	2.292***	1.639***	1.273***	0.870***
	(18.28)	(13.79)	(6.18)	(10.10)	(12.73)
Trade	−33.513	17.395	−59.006*	−28.721	−61.219***
	(−1.34)	(0.57)	(−1.69)	(−1.25)	(−4.95)
Year	0.125**	0.073	0.242*	0.187**	0.183***
	(2.00)	(1.09)	(1.86)	(2.46)	(3.97)
(II) Finance					
Trade	0.645***	0.311***	0.521***	0.290***	0.227***
	(15.15)	(6.83)	(9.96)	(8.79)	(11.13)
ICT	−0.092***	0.059***	−0.004	0.031***	−0.002
	(−11.65)	(6.07)	(−0.36)	(8.35)	(−0.25)
GDP	0.019***	−0.022***	−0.003	−0.014***	−0.023***
	(5.49)	(−5.57)	(−0.73)	(−4.70)	(−3.02)
(III) Trade					
Finance	0.155	8.444***	2.980***	4.448***	4.679***
	(1.42)	(3.81)	(2.85)	(3.47)	(3.80)
ICT	0.001	−0.010***	0.015***	−0.015***	0.008**
	(0.71)	(−3.10)	(4.60)	(−6.21)	(2.53)
GDP	0.011***	0.006	0.012**	0.011**	0.046***
	(4.25)	(1.00)	(2.29)	(2.02)	(4.84)

Table 4. (*Continued*).

	(1)	(2)	(3)	(4)	(5)
	KOF *de facto*	**KOF *de jure***	**LFO**	**MFO**	**OECD**
(IV) ICT					
Trade	3.969***	−2.060**	5.166***	−6.628***	7.429***
	(3.88)	(−2.02)	(3.76)	(-4.85)	(8.41)
Finance	−5.792***	14.463***	−4.302***	32.212***	0.201
	(−8.36)	(17.80)	(-3.89)	(16.28)	(0.10)
W40_r	6.183	12.048	33.629*	11.220	−26.942
	(0.47)	(0.94)	(1.71)	(0.60)	(-1.14)
W60_r	27.160**	13.764	34.565	19.189	−41.209***
	(2.34)	(1.22)	(1.52)	(1.35)	(−2.60)
Old_ratio	−0.454***	−0.140	0.413	−0.254	−0.120
	(−2.63)	(−0.83)	(1.19)	(−1.16)	(−0.58)
Obs no.	1491	1491	507	984	605
AIC	26660.886	27805.173	9508.363	14908.431	8294.099
BIC	26867.867	28012.154	9673.275	15099.204	8465.903
chi2	1202.813	1483.485	157.231	602.076	265.327
p	0.000	0.000	0.000	0.000	0.000

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$. W40_r and W60_r represent ratios of workers' age of 40~59 and 60+, respectively.

Table 5. The relation between TFP and determinants, 2005~2015.

	(1)	(2)	(3)	(4)	(5)
	KOF *de facto*	**KOF *de jure***	**LFO**	**MFO**	**OECD**
(I) TFP					
Finance	14.935	12.178**	20.912***	12.697	15.246*
	(1.18)	(2.07)	(3.03)	(1.45)	(1.85)
ICT	0.616***	0.647***	0.413***	0.455***	0.475***
	(6.00)	(6.71)	(2.91)	(5.09)	(5.42)
Trade	30.925***	24.094***	−10.088	42.005***	37.402***
	(5.42)	(4.63)	(−1.23)	(8.08)	(5.54)
Year	−0.001	−0.105	0.229	0.026	0.022
	(−0.01)	(−1.33)	(1.19)	(0.25)	(0.22)
(II) Finance					
Trade	0.629***	0.382***	0.476***	0.253***	0.161***
	(24.40)	(6.96)	(6.28)	(8.30)	(9.63)
ICT	−0.008	0.106***	0.050***	0.023***	−0.003
	(−1.01)	(7.43)	(3.96)	(3.04)	(−0.46)
GDP	−0.005	−0.054***	−0.010*	−0.011**	0.003
	(−1.26)	(−8.53)	(−1.61)	(−2.34)	(1.07)

Table 5. (*Continued*).

	(1)	(2)	(3)	(4)	(5)
	KOF *de facto*	**KOF *de jure***	**LFO**	**MFO**	**OECD**
(III) Trade					
Finance	0.457***	15.844***	2.408	9.187***	3.283*
	(2.98)	(4.03)	(1.54)	(3.96)	(1.79)
ICT	−0.000	0.003	−0.014***	0.013**	0.028***
	(−0.04)	(0.37)	(−2.96)	(1.92)	(3.00)
GDP	0.003	−0.082***	−0.046***	−0.013	−0.015*
	(0.67)	(−4.03)	(−3.28)	(−1.25)	(−1.65)
(IV) ICT					
Trade	0.760	−2.693***	−8.199***	−1.109	3.678***
	(0.78)	(−2.77)	(−4.27)	(−1.03)	(5.47)
Finance	1.328	12.036***	18.059***	21.580***	3.851
	(1.14)	(10.04)	(6.80)	(10.85)	(1.52)
W40_r	54.034***	45.752***	19.916	79.154***	30.990*
	(3.06)	(2.70)	(0.59)	(4.14)	(1.79)
W60_r	16.025	7.951	11.616	−2.869	−9.800
	(1.40)	(0.72)	(0.56)	(−0.23)	(−0.80)
Old_ratio	−0.823***	−0.638***	−0.777***	−0.535***	−0.551***
	(−5.20)	(−4.25)	(−2.89)	(−3.08)	(−3.91)
Obs	659	659	250	409	245
aic	9306.62	11285.28	3461.52	5458.82	2057.13
bic	9477.27	11455.92	3595.34	5611.34	2190.18
chi2	202.79	333.88	46.39	214.08	139.37
p	0.000	0.000	0.000	0.000	0.000

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$. W40_r and W60_r represent ratios of workers' age of 40~59 and 60+, respectively.

Columns 1 and 2 of the two tables are models conducted with the KOF *de facto* and KOF *de jure* FO measures, respectively. Similar results are obtained from these two sets of variables. To simplify the presentation of our results, columns (3) through (5) exhibit only the results generated by KOF *de jure.* The reason is that the *de jure* financial openness results in **Table 3** have slightly smaller AIC and BIC results than those in **Table 2**. In addition, Kose (2009) suggests that the *de facto* measure might not show as clear an impact on TFP growth as does the *de jure* variable.

Inspecting the rest of the columns of these two tables, we can observe similar results for most of the determinants, except that financial openness has opposite signs in Panels I and IV in the LFO country group. The impacts of old_ratio are different in the two tables, which also suggests that the general economic or technological environments before and after 2004 could be quite different.

6. Implications and discussion

Our empirical findings are generally consistent with the extant literature. Based on our system Equations (1)~(4) and subsamples of MFO and LFO, financial openness, ICT development, and trade globalization have strong, positive effects enhancing TFP growth. In terms of the impact of financial openness, our findings are supported by Kose et al. (2009). For ICT development, the significantly positive impact on TFP growth is in accordance with the findings of Basu et al. (2004), van Ark et al. (2008) and Dahl et al. (2011), who focus on the United States and European countries. For trade globalization, our results also show a positive impact on TFP growth, and they are in line with the findings of Parente and Prescott (1999) and Miller and Upadhyay (2000), suggesting that international trade can promote domestic industrial efficiency, enlarge the scale of the economy, and facilitate policy reforms.

One notable difference from Kose et al. (2009) is that the positive impact of financial integration on TFP is significant only when using the *de jure* measure[17]; our baseline model shows statistically significant results for both KOF *de facto* and *de jure* financial openness variables, as in **Table 1**, with the latter variable having greater statistical significance and greater impact. When the sample is broken down into the three groups, LFO, MFO, and OECD, as presented in **Tables 2** and **3**, the impact of financial openness in the models of the KOF *de facto* measure becomes significantly negative for LFO countries, while it remains positive for MFO and OECD countries. The negative impact of financial openness is not as significant when measured with the *de jure* measure. The implications of these results are twofold. First, financial openness enhances TFP growth for countries with more-developed financial systems but could harm TFP growth for countries with a low degree of financial development. This phenomenon can be explained by the theory of Calvo et al. (1996) and Prasad et al. (2003), which supports the procyclicality of macroeconomic responses in developing countries when abundant capital starts to inflow and outflow from the countries. These procyclical phenomena involve the volatility of consumption, output, and spreads on sovereign bonds, which also causes counterproductive effects, instead of protective effects, when financial crises hit[18].

The second implication of the results lies in the suitability of the *de facto* and *de jure* financial openness variables. Unlike previous studies, we employ a more comprehensive measure of financial openness[19], the KOF *de jure* financial openness, which is a weighted average index including qualitative measures of capital openness, investment restrictions, and international investment agreements on financial openness. It considers the *pull factors* that serve as the main drivers attracting capital flows across countries. The measurement of KOF *de jure* in this paper is appropriate to explain the heterogeneity of country-specific factors, such as the quality of institutions, country-specific shocks, and macroeconomic fundamentals (Diego and Komaromi, 2019). The KOF *de facto* financial openness, on the other hand, includes quantitative measures, such as international debts and other FDI, portfolio investment, international reserves, and international income payments. It considers the *push factors* that serve as the main drivers of capital flows during a financial crisis (Fratzsher, 2011). The impacts from the two measures might thus generate somewhat different results in the same model since they have different explanatory power in

different economic settings. Supporting the views of the aforementioned papers, in this paper, the KOF *de facto* financial openness measure explains LFO countries better, suggesting that the year-to-year fluctuation of quantitative measures affects countries' economic condition when the countries have less mature and vulnerable financial systems. The KOF *de jure* financial openness, on the other hand, is suitable for explaining the economic condition when the countries are well-developed and have sound financial infrastructure because qualitive policies take time to establish, and once established, their impacts are stable and long-standing, which protects the countries from short-term turmoil. Thus, the different natures of the variables are suitable for analyzing the different types of country groups.

It is worth noting that ICT development in Equation (4) is significantly explained by age-specific working population ratios[20]. In **Table 1**, for example, W40_r, the ratio of the workers in the 40- to 50-year-old age group to the total population, positively contributes to ICT development, while the old_ratio, which measures the ratio of elderly individuals 65 years old and older to the total population, deteriorates ICT development[21]. The findings are in accordance with those of Feyer (2007), who believes that various demographic structures account for one-quarter of the productivity gap of OECD countries from 1960 to 1990[22], and Eggertsson et al. (2019), who state that an aging population harms output per capita in the United States.

Throughout **Tables 1** to **3**, the negative coefficient of the 2004 dummy indicates that the growth of TFP slows down after 2004. This phenomenon has been observed by many researchers, including Cette et al. (2016). Economists generally perceive the slowdown of TFP growth starting in the mid-2000s, when the impact of technological advances started to play a marginal role in economic development (Gordon, 2012 & 2013). Fernald (2014) articulates that the slowdown could be merely the return to previous typical rates due to the subsidence of the extraordinary gains from the IT revolution since the mid-1990s. The analyses for the pre-period show that financial openness is harmful to TFP growth, especially for the LFO economies in **Table 4**. However, financial openness positively stimulates TFP growth in 2005~2015 for all types of countries. As Edwards (2007) and Obstfeld (2009) point out, while the most-developed countries abolished their various restrictions on capital flows in the mid-1970s, the developing countries' degree of financial openness remained low even in the late 1980s. In the early subperiod, financial crises tended to be regional phenomena of developing countries, as in the case of the financial crises in Mexico, Asia, and Russia in the early 1990s. For those countries, more financial openness might facilitate capital flight during the crisis and thus undermine economic performance.

Another notable finding is the endogenous relationships between the explanatory variables. For example, financial openness and trade globalization are complementary to each other, as shown in Panels II and III throughout **Tables 1** to **5**. These results are supported by Bos et al. (2020), Zhang et al. (2015), and Khan et al. (2021), who use data from different countries to demonstrate positive relationships between financial openness, trade, and allocative efficiency. However, the endogenous relationship between ICT development and financial openness is not so conspicuous and requires further discussion. In **Table 2**, ICT development seems to influence financial openness negatively, as shown in Panel II, and financial openness influences ICT development negatively, as shown in Panel IV[23]. On the other hand, when using *de jure* financial

openness data, as in **Table 3**, the endogenous relationship between these two factors turns positive. Thus, we turn to the analyses from the shorter time periods, as in **Tables 4** and **5**. In the results of the pre-period, in Panel IV, LFO retains a prominent negative sign even with the *de jure* financial openness measure. Considering that *de jure* measures have more stable and enduring power in determining cross-border activities, we trust that the results generated by the *de jure* measure are more robust and convincing, as suggested by Kose (2009). The impact of ICT development is thus concluded to deepen the degree of financial openness in a country, but a stronger degree of financial openness dampens ICT development in the LFO setting, indicating that they have a substitute relationship to each other[24]. In contrast, financial openness is complementary to ICT development when a country has an adequate financial system, as manifested in the results of the MFO group in the first subperiod and all types of countries in the second subperiod.

7. Conclusions and remarks

The importance of TFP growth's contribution to labor productivity and economic growth has been well acknowledged. However, identifying the driving determinants of TFP and understanding the extent to which each determinant contributes require further exploration. This paper applies the three-stage-least square (3SLS) regression to data for 118 countries from 1981 to 2015 to investigate the determinants of TFP growth. Several findings are worth noting. First, unlike the extant studies that discuss the determinants independently, this paper incorporates three key factors, financial openness, ICT development, and trade globalization, to analyze their relationships with TFP growth as well as the interactive relationship between them. Following previous studies that consider different measures of financial openness, this study employs a set of FO measurements: KOF *de jure* and KOF *de facto* financial openness originally derived by Dreher (2006), and total assets and total liabilities data from Lane and Milesi-Ferretti (2006). Comparing the results from the different measures, our results indicate a consistent positive effect of financial openness on TFP growth from the 1980s until the present, as suggested by Kose et al. (2009). Our results further show that greater financial openness, however, might undermine a country's TFP growth in the absence of a well-developed financial system. This phenomenon is consistent with conventional wisdom that sudden, large capital inflows and outflows can often create financial crises and counterproductive macroeconomic effects in underdeveloped countries. Conservative financial policy that restricts large capital movement, especially during economic downturns, is advised for this type of country.

The endogenous relationship between ICT development and financial openness is substitutional in the period of 1981 to 2004 but becomes complementary in the more recent decades. ICT development promotes financial openness because financial sectors rely heavily on IT technology for communication and verification. In the early development stages when technology is immature, the substitutional relationship is due to resource competition across industries and results in the crowding-out effect. The empirical findings in this paper suggest that ICT development positively fosters TFP growth for developed and developing countries. A caveat is worth making; developing countries may consider investing in ICT development in the early stage of

economic development since the externalities of ICT development would greatly enhance trade globalization. In the later stage of a country's development, ICT development might continue to enhance one's financial openness when the capital markets are evolved, and financial supervisory authorities are well established. Our findings are generally consistent with the empirics of Abeliansky et al., 2021 and Gnangnon 2020, which suggest that ICT development enhances export diversification for all countries but is particularly beneficial to the less developed countries (LDCs).

As technology evolves and infrastructure is built, these two factors positively enhance each other. Additionally, trade globalization generally enhances the growth of TFP. However, when countries are distinguished by level of financial openness and by time period, only countries with more advanced financial systems, such as OECD countries, are found to have benefited from trade globalization in recent decades. For countries with immature financial infrastructure and technology in the beginning stage of development, trade may instead harm TFP growth. Finally, this study indicates that aging population may slow down TFP through the deterioration of ICT development. Appropriate measures to keep a healthy working population age distribution are crucial for maintaining sound TFP growth. In conclusion, our results are aligned with the threshold theory proposed by Eichengreen et al. (2011) that globalization might benefit countries only when the general financial infrastructure is well developed. Policies that are adopted by advanced countries might not be ideal for underdeveloped countries. Discretion in choosing adequate policies toward financial integration and trade liberalization is advised for countries in transitional stages. A potentially fruitful future avenue of research may employ threshold models (Hansen 1999; Seo et al., 2019; Diallo, 2020; and Wang, 2015) to determine the exact cutoff points of financial openness, which influences national policy responses to ICT development.

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Notes

1. TFP is comparable to traditional Solow residuals measured by the difference between outputs and inputs from the Cobb–Douglas production function; for details, please refer to Costello (1993).
2. According to Furman (2015), the TFP growth of the United States is quite volatile; the growth has varied from 1.9% in 1948~1973, 0.3% in 1973~1995, and 1.8% in 1995~2014. Moreover, Furman (2015) emphasizes that G7 countries have shown a slowdown of TFP growth since 2010. For example, the TFP growth of Germany was 1.4% from 1985 to 2010, but it was only 0.9% after 2010.
3. According to the World Bank, the per capita income of middle-income economies ranges between $996 and $12,195 (Kim and Park, 2017).
4. His sample covers 27 countries, and covers the time span from 1990 to 2006.

5. Then, the tsunami of financial globalization also swept over the capital controls of developing countries in the 1980s and 90s. A substantial increase of capital inflows to Latin America occurred, averaging $8 billion a year in the second half of the 1980s and surging to $40 billion in 1991 (Calvo et al. 1996).
6. For instance, the findings of Quinn and Toyoda (2008), Prasad et al. (2003), Gupta and Yuan (2009), Mitton (2006) support the hypothesis that a higher degree of financial openness supports higher productivity.
7. This includes the West African countries of Cameroon, Senegal, Benin, Côte d' Ivoire, Mali and Burkina Faso.
8. Acharya (2016) distinguishes the ICT contribution as intangible capital accumulation and positive externalities in two areas, and finds a significant impact from ICT's intangible capital accumulation on TFP but a small contribution from positive externalities of ICT on TFP in OECD countries.
9. However, the slowdown of TFP growth in the United States after 2004 might also originate from ICT. ICT contributed significantly to wholesale and retail trade in the previous periods, for example, from 1994 to the early 2000s, through industrial reorganization. After 2004, ICT contributed less in areas such as trade and non-IT manufacturing (for details, see Byrne et al. 2017).
10. Five ASEAN countries, Indonesia, Malaysia, Singapore, Thailand and Philippines, have substantially benefited from firm-to-firm interaction through trade activities and foreign direct investment. These channels enable local firms to acquire foreign technology and knowledge (Dogan and Wong, 2020).
11. Dell'Ariccia et al. (2008) provide empirical evidence indicating that financial integration has positively enhanced economic growth through total factor productivity, domestic financial sector development, and macroeconomic policies.
12. The de jure (qualitative) perspective explains that an environment that welcomes international capital and has relevant laws to protect investor rights is an essential indicator for investors who are willing to invest long-term capital in foreign countries. On the other hand, capital cross-border restrictions often originates from risk-aversion and aims to avoid political uncertainty, exercise arbitrage, or alleviate tax burdens.
13. Dreher (2006) constructed a globalization index that integrates economic, social and political globalization. Since the globalization index employs a weighted average of many variables, the KOF globalization index has recently become a popular index.
14. Cardarelli and Lusinyan (2015) claim that a slowdown of TFP growth across US states has started. Interestingly, they find that the slowdown of TFP growth occurs in states with less ICT usage. ICT equipment and accessories production does not directly influence TFP growth, but usage and applications do.
15. Cette et al. (2016) show that the growth of TFP for Germany, Italy, Spain, and other countries reached the peak around 1995, remained fairly stable, and then started to decline in 2004. Goldon (2015) finds that the TFP of the United States declined from 1.43% in 1996~2004 to 0.54% in the period of 2004~2014.
16. There are 62 and 56 countries categorized as more financially open (MFO) and less financially open (LFO) countries, respectively.
17. Kose et al. (2009) applied longitudinal data covering 21 industrial and 46 developing countries from 1966 to 2005.
18. Therefore, this implies that the costs of borrowing on international markets are procyclical as well.
19. Kose et al. (2009) employ capital account openness measured by Annual Report on Exchange Rate Arrangements and Exchange Restrictions (AREAER) as a de jure indicator. In addition, Kose et al. (2009) apply total liabilities to GDP as a measure of de facto financial openness in their paper. They find a positive influence on TFP growth when the de jure indicator is applied, but the positive relation is not found when de facto financial openness is considered.
20. Basu and Fernald (2007) emphasize that TFP should rise with ICT-using sectors but with a long lag. This view is also supported by Edquist and Henrekson (2017); they find a positive relationship between ICT and TFP growth with a lag of seven to eight years. In this paper, we choose a lag of four years, and the results of the coefficients for lags are available upon request.
21. Aiyar et al. (2016) point out that the "age distribution of Europe's workforce has shifted towards older workers in the past few decades, and this aging phenomenon is expected to accelerate in the years ahead." More specifically, Aiyar et al. (2016) show that the workforce aged 55−64 years old in Germany, Italy, Czech Republic, Estonia, Greece, Hungary, Poland, Portugal, Slovakia, Slovenia, and Spain would exceed 20% in 2035.
22. Feyrer (2007) articulates that change in age structure has significantly influenced aggregate productivity for nations. He utilizes TFP as productivity and identifies groups at ten-year intervals from 10 to 60 years old and above for OECD countries. He finds a striking result: the 40−49-year-old group is the most productive group, compared to the lowest

productive cohort, the 10−19-year-old group in OECD countries. Moreover, Feyrer (2008) suggests that 25%−33% of the productivity gap between rich-poor nations could be attributed to the difference in the steady-state population. Summers (2014) believes that the stagnant growth of the United States is highly related to the aging population, which he calls the "secular stagnation hypothesis."

23. The variable ICT development in this paper is ICT growth to the contribution of GDP growth.

24. The possible argument regards the order of development between financial openness and ICT development. Financial openness started in the late 1970s in United States and Western European countries. However, the innovation of the internet occurred in the mid-1990s. Therefore, even financially open nations were not necessarily equipped with superior ICT technologies and environment.

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