Productivity drivers of infrastructure companies: network industries to maximize economies of scale in the digital era

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Abstract

What drives the productivity dynamics of infrastructure companies? Using a panel of firms in fourteen countries, we study total factor productivity (TFP) enhancers of utility and network services companies. We find that the catching up of TFP with the technological frontier drives productivity growth at higher speeds in Asian countries than in European countries. We also find that financial leverage exerts a positive effect on TFP growth for larger infrastructure firms, and more financially developed countries utilize economies of scale through better use of financial resources. Large utility and transportation companies display a higher rate of TFP growth, indicating that a competition policy to encourage M&As would be prudent for the utility/transportation sectors to maximize economies of scale. In contrast, we find diseconomies of scale for energy companies in some countries. Moreover, young network firms improve TFP growth faster than their peers in countries with fewer product market regulations. Therefore, the policies should remove entry barriers while facilitating the exit of old and low-productivity firms from the network markets. Finally, policymakers should offer well-targeted fiscal incentives for intangible investments to boost TFP because the accumulation of intangible assets such as digital technology promotes more scale economies through network effects.

Keywords: total factor productivity; utility and network services; infrastructure companies; energy industry; transportation industry; (dis)economies of scale; financial leverage; intangible assets

JEL Classification: D24; E22; G38; L25; L87; L9; O34

1. Introduction

Productivity growth is important for economic development.[1] Utility and network services constitute infrastructure services—e.g., utilities, transportation, telecommunication, energy, and postal—that elevate an economy's productivity; at the same time, these are the industries through which people most feel the benefits of technological progress because they use these services in everyday life.

The main utility and network services are the transportation, telecommunications, and energy industries. Transport infrastructure is an important determinant of productivity (Deng, 2013). The existence of high-speed railway stations has a positive and statistically significant association with knowledge productivity and regional innovation (Komikado et al., 2021). Broadband as a networking technology has led to an average annual GDP growth of 0.38 percent in OECD countries (Koutroumpis, 2019). Poor countries benefit more than rich countries from the information and communication technology (ICT) revolution (Appiah-Otoo and Song, 2021). In the energy sector, Mizutani et al. (2020) found that structural reforms, such as reducing entry barriers by allowing third-party access to the electricity supply industry, have increased GDP to 0.7 percent in OECD countries. Thus, scaling up technology and productivity of utility and network service sectors has a sizable impact on social change through more efficient and comfortable living conditions for people. This leads to the question of what drives productivity growth in the utility and network services sectors. How can we achieve more efficiencies in utility or network service production?

[1] For example, Nakatani (2018, 2019a) found that the contribution of productivity shock to economic growth is sizable during the financial crises.

Firm-level productivity growth is primarily driven by new technology adoption. Productivity growth is also determined by the speed of the enlargement of the technology frontier. The development of the technological frontier is driven by technological innovation via research and development (R&D). The world economy also benefitted from digitalization, automation, and the information technology revolution (Berg et al., 2021). The diffusion of digital technology played a significant, positive role in firm-level productive efficiency in the telecommunications industry (Majumdar, 1997). Recently, digital activities have emerged as important determinants of productivity in the travel industry (Pawlak, 2020). These productivity enhancers—R&D, patents, and software—are categorized as intangible assets. Given that we live in a knowledge economy, there has been an increase in the role and significance of intangible capital stocks in enhancing productivity.

Little research has been done on cross-country comparisons of productivity drivers of utility and network services firms. Therefore, we use firm-level data compiled in the Orbis database from 1996 to 2015 and analyze productivity dynamics in the infrastructure industry across fourteen advanced/developing countries to understand the universal productivity drivers. Our main contribution is to decipher the determinants of total factor productivity (TFP) of network service firms across countries and industries using a large data sample. Our analysis provides valuable policy implications for infrastructure companies.

2. Literature Review

Our study builds on several theories—intangible assets, financing, productivity convergence, scale economies, and the life cycle of firms—which are discussed below.

Technological innovation via R&D is considered the main engine of productivity growth. Greenwood et al. (1997) showed how the introduction of more efficient capital goods acts as an important source of productivity change. This context draws attention to the intangible assets resulting from R&D/other investments, which have accumulated on the corporate balance sheets in the current digital economy. Traditionally, patents have been considered one of the main intangible assets; Griliches (1979) used the knowledge production function representing the process of transforming R&D into patents. Intangible assets are nonmonetary assets that lack physical substance, such as R&D, goodwill, brand equity, patents, copyrights, software, licenses, image, and organization. It is better to use intangible assets than R&D expenses as a productivity-enhancer variable because R&D investments do not necessarily yield successful commercial gains, while intangible assets are the actual assets (such as intellectual property rights) that produce value-added and include the effects from non-R&D innovation spending.

Financing is another productivity enhancer, as better access to credit strengthens firms' competitiveness and innovation capabilities. Leverage can also indicate resource mobilization through financing; lower leverage might be reflective of financial frictions (e.g., difficulties in monitoring or enforcing contracts, collateral constraints, and costly insolvency regimes), which inhibit technological innovation and exert detrimental productivity effects.

Firm productivity growth is also driven by new technology adoption. Acemoglu et al. (2006) showed that productivity converges to the world technology frontier as firms imitate/adopt the frontier technology and engage in innovation. Their theory suggests that it considers the distance to the technology frontier when estimating productivity growth. Thus, we include the initial TFP level to capture the productivity convergence to the frontier.

We control for firm characteristics. A crucial one is firm size to capture economies of scale since there is a positive relationship between firm size and productivity. Larger firms are well equipped to utilize economies of scale optimally through lower marginal costs to allocate resources efficiently. Cohen and Klepper (1996) showed that the likelihood of a firm carrying out R&D increases with firm size, and Mairesse and Mohnen (2002) highlighted that scale economies make larger incumbent firms more inclined to carry out R&D activities.

The economies of scale are relevant in industries dominated by high fixed costs (Christensen, 2001), which is the case of the infrastructure industry. Mocholi-Arce et al. (2021) found that increases in the scale of operations lowered the total costs of water companies. Firm size also plays a major role in the transportation sector. Cowie and Asenova (1999) attributed economies of scale in the bus industry to the fact that they face fewer organizational constraints. Coto-Millán et al. (2014) found that airport size positively influences the technical/scale efficiencies of airports.

However, few studies have analyzed the manner in which economies of scale can be amplified through other factors, such as financing and intangible assets. Transport firms' access to finance can help them utilize more financial resources to maximize scale economies. Similarly, large transportation firms with large intellectual property and knowledge capital can use intangible assets to maximize economies of scale. In this context, Gamo-Sanchez and Cegarra-Navarro (2015) highlighted the importance of knowledge management programs for enhancing airport efficiency. Thus, the analytical section of our study focuses on these heterogeneous effects of economies of scale via leverage and intangible assets.

Considering another characteristic of firm age, young firms play an important role in stimulating productivity growth. As the life-cycle theory of firm dynamics suggests, new entrants increase their productivity more rapidly than old firms through "*learning by doing*" in new markets (Bahk and Gort, 1993). For financial and competitive reasons, young firms rely on markets to buy knowledge-based technology created by large corporations instead of developing in-house R&D solutions (Acs et al., 1994). Schneider and Veugelers (2010) documented that young German firms consider financial constraints to be the main impediment to innovation activities aimed at achieving higher productivity.

3. Methodology and Data

Following the empirical methodology developed by Nakatani (2021a), the regression equation is

$$\Delta ln(TFP_{i,j,k,t}) = \beta_1 + \beta_2 ln(TFP_{i,j,k,t-1}) + \beta_3 Leverage_{i,j,k,t-1} + \beta_4 ln(Size_{i,j,k,t}) + \beta_5 ln(Age_{i,j,k,t}) + \beta_6 Intangible\ Assets_{i,j,k,t-1} + \mu_{j,t} + \gamma_t + \vartheta_k + v_i + \varepsilon_{i,j,k,t},$$

where the subscripts i, j, k, and t represent the firm, industry, country, and time period, respectively; $ln(TFP_{i,j,k,t})$ is the natural logarithm of TFP, and its difference approximates TFP growth. β_2 captures the convergence to the productivity frontier, $Leverage_{i,j,k,t}$ denotes liabilities divided by total assets, $ln(Size_{i,j,k,t})$ represents the natural logarithm of total assets, $ln(Age_{i,j,k,t})$ is the natural logarithm of firm age, $Intangible\ Assets_{i,j,k,t}$ is the intangible fixed assets divided by total fixed assets, $\mu_{j,t}$ represents the industry-specific time fixed effects, γ_t represents the time fixed effects, ϑ_k represents the country fixed effects, v_i represents the firm fixed effects, and $\varepsilon_{i,j,k,t}$ is the error term.

An endogeneity problem arises from simultaneous decisions of firm behavior. For example, it is the case when firms need financing to invest in new technology, which improves TFP, such as new software (i.e., intangible assets). In this case, leverage, TFP, and intangible assets are influenced by a firm's behavior simultaneously. These three variables are flow variables that can fluctuate greatly every year. This is why we need to lag these two explanatory variables: leverage and intangible assets. In this way, we treat "leverage" and "intangible assets" variables as exogenous independent variables because the dependent variable (TFP growth this year) cannot influence past borrowings (i.e., leverage) and past (intangible) assets.

In contrast, the age of a firm is not a choice variable for the firm, and it is automatically determined by time. Additionally, firm size is defined by the size of the balance sheet (i.e., a natural logarithm of total assets), and it does not change dramatically every year; small and medium-sized enterprises (SMEs) usually do not abruptly become large enterprises in one year. For instance, the ratio of liability to paid-in capital and retained earnings on the debt side could change every year due to the borrowing decisions of firms, although the sum of these items on the asset side of the balance sheet—total assets—does not often fluctuate dramatically every year in practice since this is a stock variable accumulated over the past few years. Thus, there is less of a need to take a lag for these two firm characteristics.

We acknowledge the omitted variable bias resulting from the exclusion of business/regulatory environment, electricity, vocational training, and political stability. Since we do not have such information, we cannot include these institutional variables in our regressions. Nevertheless, we believe that the omitted variable bias does not pose a serious problem to our econometric specification for the following reasons. First, most of these factors are captured by the time-varying industry-specific fixed effects $\mu_{j,t}$ constructed by using the four-digit industry classification codes. For example, nationwide factors such as political stability can be captured by the inclusion of time fixed effects γ_t. However, the time fixed effects cause a multicollinearity problem, and hence they are automatically excluded from the estimation. This means that we can effectively control time fixed effects by including granular industry-level time fixed effects ($\mu_{j,t}$) instead of the national-level time fixed effects (γ_t). Second, other omitted variables common for the same industry, such as the business and regulatory environments, have been well captured and controlled by the four-digit level industry-specific time-varying fixed effects ($\mu_{j,t}$). Third, the firm-specific fixed effects, v_i, captures the firm-specific omitted variables, such as training, and geographic factors, such as electricity infrastructure. Thus, almost all the aforementioned omitted variables have been controlled by the industry-specific time-varying and firm-specific fixed effects, $\mu_{j,t}$ and v_i, respectively.

We use the Orbis database published by Bureau van Dijk. The database is a cross-country longitudinal dataset including the balance sheets/income statements of listed/unlisted firms. We use the four-digit industry classifications—the Statistical Classification of Economic Activities in the European Community (NACE)—to control for industry-specific time fixed effects, such as changes in product market regulations. The utility and network services sectors are defined by the statistical office of the European Union (Eurostat) in Table 1. To avoid small sample bias, we include countries with at least 500 observations (China, Colombia, France, Germany, Hungary, Italy, Japan, Poland, Romania, South Korea, Spain, Thailand, the United Kingdom, and the United States). Table 2 shows the sample period and descriptive statistics for each country. Figure 1 presents the industrial compositions of our sample across countries.

We clean the database in the following manner. First, we exclude observations involving apparent reporting mistakes, e.g., firms with negative values for total/tangible/intangible assets, sales, or the number of employees in any year. We also eliminate observations for which the costs of materials/employees are missing or nonpositive values. We exclude firms lacking NACE codes because we cannot control for their industry-specific fixed effects. Additionally, we exclude observations with a negative firm age or liability. We remove observations in which the ratios of liability to total assets or intangible assets to total assets exceed unity.

We use the TFP method by Gandhi et al. (2020), who proposed a nonparametric identification strategy to estimate gross output production functions requiring flexible inputs since the structural estimation methods suffer from an identification problem when the production function contains flexible inputs. The output of the production function is value-added calculated by subtracting the materials or cost of goods sold from turnover revenue. The labor input is the cost of employees, while the capital stock is tangible fixed assets, comprising property, plants, machinery, and equipment.

We compare our regression analyses across countries first by running regressions county-by-county, and then generate a pooled estimation across countries later. Country-by-country regression is preferred over pooled estimates because some companies are multinational. For example, a firm in one country has subsidiaries in other countries, indicating that such subsidiaries do not constitute independent observations, especially because they share intangible assets, including blueprints, brand equity, copyrights, software, and organizational capital.[2] There might also be a definitional difference owing to different accounting policies, such as the depreciation duration.

Since our analysis is based on firm-level data, in which we treat each firm's data equally, it may not necessarily represent the aggregate sectoral-level TFP dynamics. Instead, this research aims to find the common drivers of the TFP growth of infrastructure companies. It could be the

[2] In the case of Japanese multinationals, sharing the same intellectual property is evidenced by the repatriation of royalties from foreign affiliates to parent companies (Tajika and Nakatani 2008).

case that our data lack representative information about SMEs relative to large companies. To check this, following Dvouletý and Blažková (2021), if we calculate the share of SMEs in our largest data sample of two countries, Spain and Italy, the shares are 99.1% and 98.4%, respectively. Therefore, the representativeness of the data does not appear to be a major issue in our research.

4. Baseline Results

The baseline estimation results are shown in Table 3. Although the timeframe of the data sample used in Table 3 differs across countries owing to data availability, the main findings remain unchanged, except for intangible assets. Thus, the conclusions here are robust to using data for different time periods. For all countries, we find that productivity tends to catch up with the technology frontier. The positive effects of leverage on TFP growth are also observed in most countries. We also find that larger/younger infrastructure firms have higher levels of productivity growth than their peers. We find a positive relationship between intangible assets and productivity growth in most countries, although their size and the significance of their effects are heterogeneous. A detailed discussion of each explanatory variable is provided below.

First, the lagged TFP variables are statistically significant at the one percent level, with negative signs for all the countries. Firms with low TFP levels experience higher levels of TFP growth, which is consistent with the idea that TFP tends to catch up with the technology frontier, given that low-productivity firms can increase their TFP by adopting the existing technology. Conversely, high-productivity firms have less room for productivity improvement since they require new expensive technologies to further increase productivity. This finding is consistent with Boame and Obeng (2005), who found that technical and efficiency changes improved the productivity of bus transit systems.

Second, for all countries that have more than 12,000 observations, the results for leverage yield the expected signs and are statistically significant at the one percent level. Leverage has a positive impact on TFP growth in the infrastructure industry because leveraging financial resources can be critical to the performance of firms operating in a high-technology industry (such as telecommunications), which requires firms to make massive investments to gain a competitive advantage and reach the productivity frontier. Borrowing for large investments and staying at the productivity frontier play a crucial role in the survival and success of these rapidly growing network industries.

Third, the coefficients for firm size are positive and statistically significant at the one percent level in all countries, except China, Germany, and the United States. Larger infrastructure firms experience higher TFP levels than smaller firms because larger firms have more resources that can be invested in innovation activities to increase productivity. Our results are also consistent with the results of studies showing the presence of economies of scale in the transportation sector. In comparison to the ICT sector (Nakatani, 2021a), our results show that the magnitude of economies of scale is approximately half in the utility and network service sectors. The negative coefficients for firm size in China, Germany, and the United States are driven by the fact that the majority of sample firms are energy companies (Figure 1). As we will see in Section 7, diseconomies of scale are observed in the energy sector.

Fourth, firm age is negatively statistically significant in six countries. This result indicates that firms experience lower TFP levels with age, which is consistent with the life-cycle hypothesis of TFP dynamics. In China, firm age is positively associated with TFP growth with a high statistical significance, implying that younger infrastructure firms show lower levels of productivity growth. In China, many new firms enter the market but exit as a result of failure.

Finally, the results for intangible assets are heterogeneous. In our sample of fourteen countries, nine exhibit positive coefficients for intangible assets. In four of the aforementioned nine countries (France, Hungary, Italy and the United Kingdom), the coefficients are statistically significant at the one percent level, implying that intangible assets are positively associated with the TFP growth of infrastructure firms. It may be the case that, only after the accumulation of a certain critical mass of knowledge capital, the effects of R&D and intangible investment on productivity growth become significantly positive (Kancs and Siliverstovs, 2016). Conversely, the sign of the coefficient of intangible assets is negative and statistically significant at the 10 percent level in Romania and Spain; however, the negative statistical significance disappears when we conduct regressions using the same data period below.

5. Robustness Checks

To examine whether the cross-country differences in the baseline results stem from the different data periods, we conduct an estimation using the last 10-year period of data (after 2005) in Table 4. Therefore, the estimated results for China, Colombia, Hungary, and the United States are the same as those for the baseline. Overall, the results are fairly similar to our baseline results, confirming the robustness of our outcomes.

First, for all countries, the coefficients of the lagged TFP level are negative and highly statistically significant. In Table 4, we compare the average productivity convergence speeds toward the productivity frontier by multiplying the average TFP levels by the coefficients of lagged TFP levels across countries. Our results show that Asian countries such as Japan and South Korea have relatively higher average convergence speeds than European countries.

Second, in most countries, we do not detect a statistically significant relationship between intangible assets and TFP growth. This differs from our baseline results in Table 3 in that the negative coefficients of intangible assets are no longer statistically significant in Romania and Spain. The coefficients on intangible assets are positive for ten countries and highly statistically significant at the one percent level in France, Hungary, Italy and the United Kingdom. This supports the idea that, in some countries, intangible assets have positive spillover effects on productivity growth in the infrastructure industry, possibly via higher levels of R&D and other digitalized intellectual properties such as patents and software.

6. Utility Sector

We conduct the same empirical analysis by limiting the sample to the narrow definition of the utility sector (NACE codes ranging from 3500 to 3900 in Table 1): electricity, gas, steam and air conditioning supply; water collection, treatment, and supply; sewerage; waste collection, treatment, and disposal activities; materials recovery; remediation activities; and other waste management services. Our motivation is that the productivity drivers of the utility sector could be different from those of the network services industries (e.g., telecommunications, postal services, and transportation), as the industry-specific characteristics, such as their life cycles and degree of competition, could be different. We use the same data period as the one used in the robustness check (after 2005) to compare the results of the utility sector across countries.

Table 5 presents the estimation results. First, the positive impact of leverage on TFP growth seems larger for some countries (Colombia, France, Japan, Romania, and the United Kingdom). Second, in the utility sector, we find that firm age does not determine TFP dynamics for most countries. Third, economies of scale are prevalent in the utility sectors of most countries, consistent with the literature (Abbott and Cohen, 2009; Fuentes et al., 2017). These outcomes reflect the fact that increases in the scale of utility operations lower total costs by reducing the amount of inputs and transactional costs (Pollitt and Steer, 2012). Fourth, intangible assets have a positive effect on the TFP growth of utility companies in four European countries. Finally, we find that the catching up of TFP with the technology frontier is also relevant for utility companies.

7. Energy Sector

Similarly, we study the energy sector separately because Ajayi et al. (2020) found that the productivity dynamics in the energy sector are very different from those of the other sectors. The energy sector mainly includes electricity and gas companies (NACE four-digit code 3500). For comparative purposes, we again restrict the sample period to data after 2005. Owing to insufficient data observations in this specific industry, some countries have been excluded from the results in Table 6.

We find some interesting results. First, the main driver of TFP growth in the energy sector is catching up with the technology frontier, consistent with Marinho and Resende (2019). This is manifested by the highly statistically significant and negative coefficients of the lagged TFP levels in all sample countries. Second, in some countries, we find diseconomies of scale in the energy industry, which is evidenced by the negative and statistically significant coefficients of firm size for China, Poland, South Korea, and the United States. This is in stark contrast to the other utility and network services industries, where we find a positive effect of firm size. This may be related to the finding that the ownership unbundling of electricity and gas companies improves competition (Ghosh and Kathuria, 2016; Pollitt, 2008). Our finding about diseconomies of scale in the energy sector is in line with the findings in the empirical literature (Newbery, 1997; Pompei, 2013). Third, leverage is not statistically significant for more than half of the sample countries, implying that financing is not an important driver of TFP growth in the energy industry. Finally, intangible assets are positively associated with TFP growth in a few countries. Note that our results exhibit statistically insignificant coefficients on intangible assets in various industries in South Korea. This is because, in several product areas, Korean firms have yet to reach the innovation frontier stage, and even large Korean companies continue to produce large volumes of products under subcontracting and licensing agreements (Hobday et al., 2004).

8. Heterogeneous Effects

We further investigate the heterogeneous impacts of leverage and intangible assets by introducing the cross-terms of these variables with firm age and size in Table 7 because the impact of leverage/intangible assets might differ depending on firm characteristics.

We find that leverage has a positive effect on TFP growth for larger infrastructure firms, as evidenced by the positive and statistically significant coefficients of the interaction term of leverage and firm size for China, Italy, Poland, Romania, and Spain. Thus, the economies of scale are amplified by the availability of financial resources in the infrastructure industry. To the best of our knowledge, this finding has not been identified by previous studies.

Regarding the effect of intangible assets, we find that it is amplified by economies of scale, as shown by the statistically significant positive coefficients of the cross-term of intangible assets and firm size in China, Japan, and the United Kingdom. The positive effect of intangible assets on TFP growth is larger for younger firms in Japan and China, as shown by the relevant estimated coefficients, although the opposite is found for Colombia, France, and Italy.

Furthermore, we examined the heterogeneous effects of leverage. This is motivated by the recent theory by Aghion et al. (2019). Better credit access enables firms to innovate and allows less-productive incumbent firms to remain in the market longer. These scholars provided evidence of an inverted U-shaped relationship between credit constraints and productivity growth by aggregating the data at the sectoral level. Therefore, we include the squared term of the lagged leverage variable in the regressions presented in Table 8.

In Table 8, nine out of the fourteen sampled countries show the expected combinations of the negative coefficients of the squared leverage variable and positive coefficients of the leverage variable. These results are in line with the latest theory of the inverted U-shaped relationship between financing and productivity.[3] Among these nine countries, five countries show statistically significant coefficients of both squared and linear terms of leverage. An economic intuition is that leverage has a positive relationship with TFP because firms utilize their financial resources for innovation-related investments. However, this relationship can be offset by the need to deleverage if the firms are highly leveraged. Our nonlinear effects of leverage in Table 8 are supported by the empirical finding of Coricelli et al. (2012), who found a hump-shaped relationship between leverage and productivity growth. They employed a certain threshold to estimate the nonlinear impact of productivity, while our empirical strategy is more sophisticated in the sense that the effect of leverage is based on a smooth quadratic function.

[3] This is analogous to the inverted U-shaped relationship between public debt and economic growth (or fiscal balance) (Nakatani 2021b). The intuition is that that net benefits to debt financing arise for firms/countries with low debt levels but decrease as leverage reaches high levels.

We further included a quadratic term of firm age in Table 9. Consistent with Dvouletý and Blažková (2021), we find that half of the sample countries show a nonlinear U-shaped relationship between firm age and TFP, while the other coefficients are not affected much.

9. Sensitivity Analysis

Furthermore, we conduct an analysis to see if our results are sensitive to definitions of variables, econometric methods, and control variables. We confirm the robustness of our results for most variables with some supplementary findings below.

First, we examined the alternative TFP measure by De Loecker and Warzynski (2012) in Table 10 and Levinsohn and Petrin (2003) in Table 11 (we could not estimate TFP for a few countries in Table 11 due to data unavailability). The results underscore the importance of intangible assets as a productivity driver since Table 10 shows the statistically significant and positive coefficients of intangible assets in more countries than our baseline.

Second, we tried the generalized method of moments as an alternative estimation method to address endogeneity in Table 12. The results show the statistical significance of intangible assets again, while convergence speeds captured by the lagged TFP levels are slower than the baseline.

Third, we used the number of employees as an alternative proxy for firm size in Table 13. We find that economies of scale prevail in the infrastructure industry of most countries, even when we use the number of employees.

Finally, we included cash flow divided by total assets to check the sensitivity of our results to additional control variables since Brown et al. (2009) found significant effects of cash flow on R&D that improve productivity. We did not find any pattern of cash flow across countries in Table 14, which was statistically insignificant in most countries.

10. Pooled Analysis

In the last section of the regression analysis, we pool all countries into the same sample and conduct regressions for each network industry in Table 15. The first column includes all infrastructure industries, and it confirms our baseline findings. We found several industrial differences as follows.

We find that the economies of scale and the leverage effect are the strongest in the telecommunications industry, as evidenced by the largest coefficients of firm size and leverage. This reflects the fact that telecommunications companies require massive investment to be on the technology frontier and utilize its network effects in the markets. In contrast, both the leverage effect and economies of scale are the least relevant for the energy sector, in which we found diseconomies of scale in several countries.

Furthermore, intangible assets are statistically insignificant for telecommunications and postal industries, which show faster convergence speeds toward technology frontiers (as shown by their relatively large lagged TFP coefficients). In contrast, intangible assets are found to be important productivity drivers in the energy and utility sectors.

11. Policy Implications

We have four policy implications involving—(1) financing policies for infrastructure companies, (2) mergers and acquisitions (M&A) policies to maximize economies of scale, (3) industrial policies to foster strong dynamism, and (4) innovation policies regarding intangible assets.

First, increasing the availability of financial resources is crucial to increasing TFP, except for the energy industry, because better access to financing helps infrastructure companies enhance resource allocation. Such leverage effects are found to be prevalent in the transportation, telecommunication, and utility sectors. Government programs providing credit access to resource-constrained infrastructure firms can increase investment and productivity. Conversely, credit constraints hamper optimal resource allocation and deter productivity-enhancing investments. It would be also useful to develop macroprudential policies to avoid banking distress (Nakatani 2020) and address non-performing loans, and thereby ensure that commercial banks do not constrain utility and network services companies.

Second, economies of scale are prevalent, except in the energy sector. Transportation companies operating at the same level of the supply chain and performing comparable logistics functions can cooperate horizontally to increase firm productivity (Verdonck et al., 2013) through potential cost savings (Leitner et al., 2011). These companies can also extend their resource portfolio to facilitate more efficient transport planning (Krajewska and Kopfer, 2006). Water utility companies can consolidate their plants or vertically integrate to save costs and operate water supply systems more efficiently. A competition policy to encourage M&As would be prudent for these utility and network service sectors to utilize economies of scale. In this context, Teti and Tului (2020) found that in the infrastructure/utilities sectors, M&As are efficient and economically reasonable. Urakami and Parker (2011) found that the consolidation of Japanese water utilities positively influenced cost effectiveness. Importantly, we also find that in the utility and network services sectors, economies of scale are amplified by leverage effects—the availability of financial resources. Figure 2 shows the average leverage level after 2005 on the horizontal axis and the estimated coefficients of firm size from Table 4 on the vertical axis. The figure indicates that more financially developed countries utilize economies of scale more through better use of financial resources. Therefore, it would be very important to combine better access to financing and policies to promote economies of scale. Conversely, in the energy sector, we found diseconomies of scale.

Therefore, policymakers should not recommend M&As in the energy sector. This is consistent with Pompei (2013), who found a negative effect of vertical integration on the efficiency change in the TFP of the electricity industry in the EU. This is because vertical integration creates and protects rents for energy distribution to the incumbent high-cost domestic fuel producers, thereby contributing to technical inefficiency (Newbery, 1997).

Third, it is crucial to increase the share of young firms in the network service sector. Figure 3 shows the relationship between regulatory frameworks and firm dynamism in the network industries. The horizontal axis shows the product market regulation indicators in the network industries from the OECD Network Sectors Indicators. The vertical axis shows the estimated coefficients of firm age in Table 4. Both data cover average values during the period from 2005 to 2015 for network industries in OECD countries that have available data. The figure shows that countries with fewer regulations tend to have negative coefficients of firm age, meaning that young network firms improve TFP growth faster than their peers. This evidence calls for removing any obstacles to the entry of new firms. For example, Germany has competition in the market permitted in the provision of rail passenger transport services on at least some of the routes, but France does not. In contrast, industry representatives or individual firms are involved in the enforcement of entry regulation in the sea/coastal/inland freight water transport sectors in France, but they are not in Germany. These two examples of rail/water transport sectors underscore the roles of such entry barrier regulations as a hindrance to firm dynamism in network industries.[4] Tax holidays allocated

[4] In relation to our findings in Figure 3, Crafts (2006) found that restrictive product market regulations, especially entry barriers, hinder technology transfer and negatively impact productivity. Pompei (2013) also found that the stringency of entry regulation significantly reduces

to increase competition by inducing entry or encouraging younger firms positively and significantly impact productivity growth (Aghion et al., 2015). Policymakers should also facilitate the exit of old and low-productivity network service firms from markets by improving insolvency frameworks and speeding up debt resolution plans. To foster TFP growth, inefficient and financially underperforming network service firms should be eliminated from the market owing to insolvency or liquidation.

Fourth, intangible assets are positively correlated with TFP growth in several countries, and economies of scale are amplified by intangible assets. Figure 4 shows the relationship between the average intangible assets after 2005 and the estimated coefficients of firm size from Table 4. The figure indicates that the accumulation of intangible assets such as digital technology enhances scale economies through network effects. Intuitively, larger network firms have more resources to invest in innovation activities, such as R&D and digitalization. Policymakers should carefully

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technological change in the electricity market. Similarly, Agiakloglou and Polemis (2018) found that a competitive market structure is associated with the better performance of firms in the telecommunications industry. Newcomers can also enhance incumbent network service companies' productivity growth by increasing competition (Fritsch and Changoluisa, 2017). A positive incentive for new entrants to electricity markets will stimulate competition and welfare gains by reducing consumer prices (Piacenza and Vannoni, 2009). Bastianin et al. (2018) surveyed the literature on regulatory reform, but they did not cover the utility sector. Borghi et al. (2016), Soroush et al. (2021), and Castelnovo et al. (2019) found that electricity and telecom firms can improve their performance by better quality of governance, but they did not study product market regulations.

formulate policies to enhance productive intangible investment. Fiscal incentives for intangible investment could be encouraged for countries with prudent intellectual property protection schemes (e.g., patent and licensing) as automation technology advances (Nakatani, 2022). Network service firms may license technology to enhance their new product performance in the future based on a standard related to their technology (Lichtenthaler, 2012). Patents can also incentivize firms to conduct an expensive and long-lasting research program, and patent protection influences the subsequent innovation process. The protection of intellectual property rights keeps production companies from discouraging stemming from the illegal imitation of property rights and avoids the disincentivizing effect of such abuses. This is crucial to warrant the incentives for conducting productive R&D and legally adopting productivity-enhancing technologies. Larger infrastructure companies have the capability to conduct R&D because of better access to financing, which also reflects the availability of collateral. In this regard, a well-targeted tax policy for R&D, such as R&D tax credits, can serve as a good option for stimulating R&D investment (Nakatani, 2019b; Rao, 2016). It is also crucial to review the provision of direct subsidies for the R&D needs of incumbent firms because such subsidies encourage the survival and expansion of low-productivity firms (Acemoglu et al., 2018). Schneider and Veugelers (2010) also found that subsidies were not associated with the innovation performance of young German firms. In the transportation sector, Boame and Obeng (2005) found no statistically significant relationship between government subsidies and the TFP of bus transit systems. Mizutani (1999) also found that Japanese railway companies perform more efficiently in the absence of government subsidies. Thus, policymakers should refrain from providing subsidies to the transportation sector and focus on tax incentives for R&D.

12. Conclusion

Technology-driven productivity growth in the infrastructure sector plays a key role in driving economic growth in modern economies. TFP improvements in this sector drive a social change in people's livelihoods. In the digital economy, intangible assets can significantly contribute to the productivity of infrastructure companies. Economies of scale, financing, and firm dynamics could drive TFP growth as well. Thus, this study examines these TFP drivers at the firm level across countries in the context of the utility and network services industries.

Our baseline results show no statistically significant relationship between intangible assets and TFP growth in ten out of the fourteen sampled countries. Intangible assets exhibit statistically significant positive effects on productivity growth only in four European countries. These findings provide evidence of the relatively minor role of intangible assets in TFP growth in the utility and network services sectors. However, at the same time, we find that intangible assets can improve TFP growth by amplifying economies of scale in some countries.

We also find that leverage increases TFP growth in the infrastructure industry, except in the energy industry. Thus, utility and network firms can improve their TFP growth by increasing their access to financing. The leverage effect on TFP growth is amplified by economies of scale. In this regard, it must be noted that diseconomies of scale are observed in the energy sector.

We also find that firm age and size are important for productivity development. Specifically, infrastructure firms increase their TFP more if they are larger and/or younger. The former relationship exhibits the presence of economies of scale, while the latter confirms the life-cycle hypothesis of TFP dynamics—i.e., young firms increase their productivity more rapidly than old firms through learning by operating in new markets.

Finally, our findings support the catching-up theory of productivity; infrastructure firms with low levels of TFP experience higher levels of TFP growth by adopting existing technology from the technological frontier. Our results show that productivity convergence speeds toward the technology frontiers are higher in Asian countries than in European countries.

In the utility sector, in contrast to network service sectors, we found that the life-cycle theory of firms is not applicable. Leverage is also found to be a less important TFP determinant. In contrast, we found that economies of scale are important TFP-enhancing factors in the utility sector. This is intuitive in the sense that the utility sector requires high fixed costs. Catching up with the technology frontier is found to be another TFP enabler in the utility sector.

In the energy sector, the main driver of TFP growth is productivity convergence to the technology frontier. Interestingly, we found diseconomies of scale in the energy industry of several countries, which is consistent with the findings in the extant literature. This might reflect the fact that the ownership unbundling of electricity and gas companies improves competition, which could eventually raise productivity levels. Furthermore, we found leverage is not a significant determinant of energy companies' TFP growth in many countries.

Future research can focus on the details of intangible assets in the infrastructure industry. Without data on the compositions of intangible assets, we could not investigate the different types of intangible assets. In future research, we can analyze the effects of different types of intangible assets, such as R&D, patents, brand equity, copyrights, licenses, software, and goodwill, on productivity growth. Although the literature has extensively explored the effects of R&D on productivity, there are few studies on the effects of other intangible assets, especially in the utility industry. In the era of the fourth industrial revolution, digital and automation technologies are becoming a major source of productivity development in almost all industries. It would be useful to explore intangible assets and how different intangibles influence productivity differently across sectors.

Future research could also look into a more detailed cost structure of infrastructure companies to understand how economies of scale are achieved through intangible assets and financial resources. This will decipher the specific mechanism in which the high-fixed cost sector, i.e., infrastructure sector, can attain more production efficiency through better use of financial and digital technology, taking advantage of network effects.

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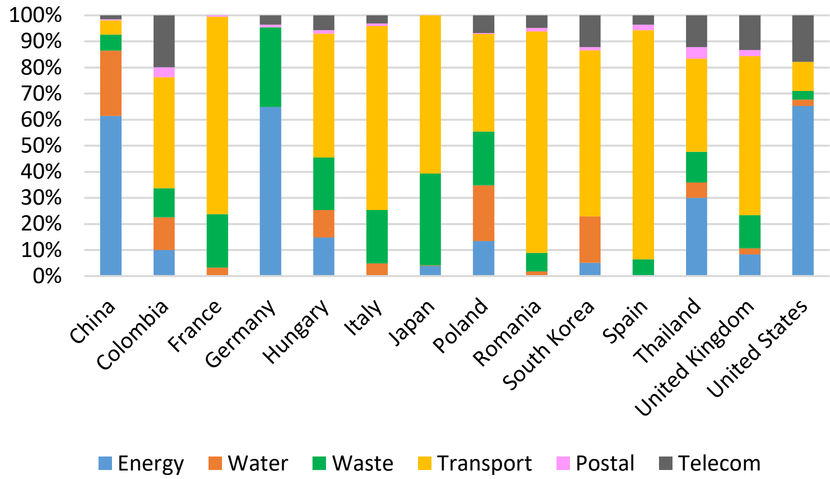

Figure 1. Industrial Composition of Our Sample Across Countries

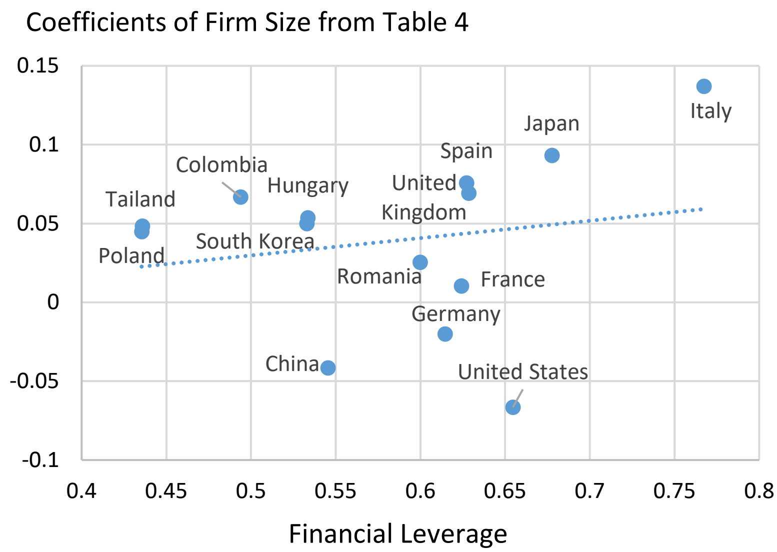

Figure 2. Economies of Scale and Financial Leverage

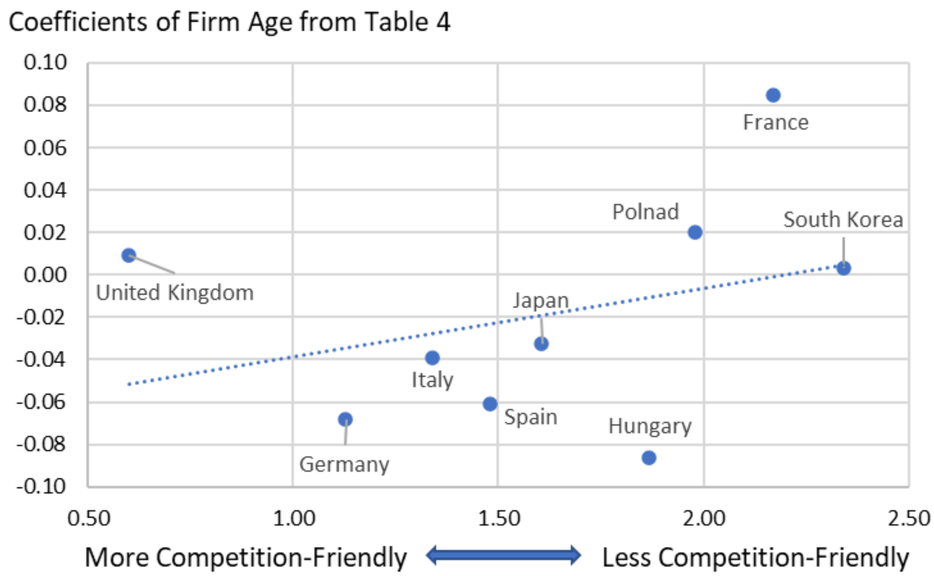

Figure 3. Product Market Regulations in Network Industries

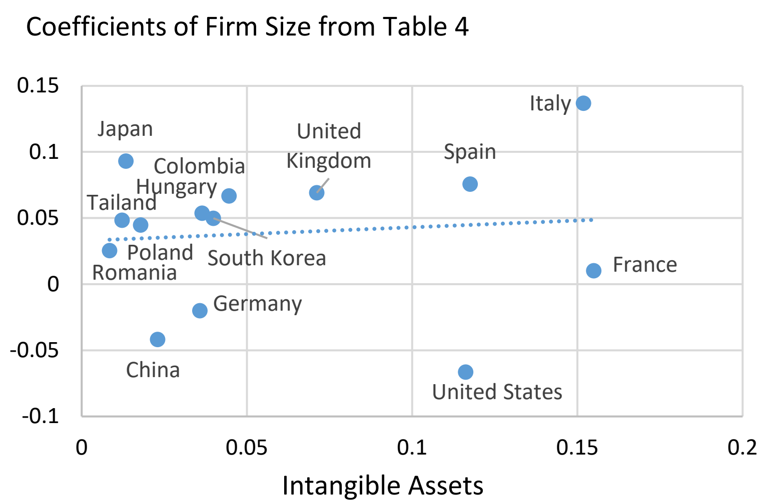

Figure 4. Economies of Scale and Intangible Assets

Table 1. Utility and Network Services Sectors in NACE

Code	Industry	Details
3500	Energy	Electricity, gas, and steam and air conditioning supply
3600	Water	Water collection, treatment, and supply
3700		Sewerage
3800	Waste	Waste collection, treatment, and disposal activities and materials recovery
3900		Remediation activities and other waste management services
4900	Transport	Land transport and transport via pipelines
5000		Water transport
5100		Airport transport
5300	Postal	Postal and courier activities
6100	Telecom	Telecommunications

Table 2. Summary Statistics

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
TFP														
Mean	3.0603	4.2836	2.5487	0.5278	2.3140	4.3286	5.6169	2.4383	2.9775	2.6668	0.1733	3.7652	4.8940	6.2761
Std. Dev.	0.5752	1.0968	3.1706	1.4441	1.1304	1.9024	1.4400	1.4354	0.9539	1.1259	1.8337	0.8915	1.2848	2.3421
Min	-0.5611	-0.4180	-10.4289	-9.9402	-4.1152	-8.1426	-0.6735	-2.8272	-5.7764	-0.9228	-10.1816	0.2668	-0.8155	-1.4407
Max	7.9837	8.3501	15.5569	8.3699	8.2260	14.5860	10.3295	7.7687	9.6893	7.5611	7.3151	6.6666	12.0528	10.7483
Leverage														
Mean	0.5455	0.4939	0.6251	0.6117	0.5335	0.7706	0.6841	0.4293	0.6145	0.5335	0.6457	0.4492	0.6356	0.6546
Std. Dev.	0.2543	0.2407	0.1985	0.2140	0.2393	0.2000	0.2393	0.2609	0.2869	0.2522	0.2382	0.2759	0.2458	0.1585
Min	0.0006	0.0000	0.0110	0.0284	0.0041	0.0000	0.0151	0.0021	0.0000	0.0015	0.0013	0.0002	0.0009	0.0174
Max	1.0000	1.0000	1.0000	1.0000	0.9967	1.0000	1.0000	1.0000	1.0000	0.9943	1.0000	1.0000	1.0000	1.0000
Size														
Mean	16.2086	14.2485	13.7273	17.2037	14.9212	14.2696	15.4229	14.4542	11.5561	14.8291	13.5808	13.8945	14.5634	21.8874
Std. Dev.	1.8874	2.1972	1.4975	1.9633	2.1584	1.4712	1.5967	1.6979	1.6703	1.8284	1.3836	2.5387	2.6664	1.9116
Min	9.6711	5.1417	8.4583	10.7146	7.8751	8.6132	9.7166	8.2180	3.9120	7.4628	8.4911	8.0236	5.6419	11.3737
Max	25.7957	22.5434	25.0064	25.7967	22.3621	25.3817	25.7685	22.2065	21.0511	24.9735	24.5427	1.0000	23.9853	26.7214
Age														
Mean	2.4189	2.4337	2.7130	2.9085	2.4735	2.4795	3.3691	2.4603	2.0586	2.4670	2.4803	2.4924	2.5386	3.4480
Std. Dev.	0.7839	0.7140	0.7729	0.8328	0.5935	0.7995	0.6410	0.6284	0.6607	0.7389	0.7033	0.6114	0.8297	1.1077
Min	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6931	0.0000	0.0000	0.0000
Max	4.6347	4.8520	5.0562	6.8002	4.9416	5.0876	4.8752	4.9127	3.2189	4.4773	4.8598	4.2485	5.1874	5.0689
Intangible Assets														
Mean	0.0230	0.0446	0.1522	0.0350	0.0364	0.1469	0.0135	0.0176	0.0088	0.0393	0.1671	0.0112	0.0599	0.1162
Std. Dev.	0.0820	0.1387	0.2463	0.1083	0.1148	0.2150	0.0485	0.0861	0.0575	0.1304	0.2707	0.0732	0.1825	0.2015
Min	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Max	0.9993	0.9835	0.9999	0.9996	0.9972	1.0000	0.9797	0.9949	0.9993	0.9998	1.0000	0.9637	1.0000	0.9766
Year														
Min	2005	2006	2000	2003	2005	1998	2002	2001	2001	2003	1996	2003	1997	2008
Max	2014	2015	2015	2014	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015

Table 3. Baseline Estimation Results

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.8645***	-0.7733***	-0.6514***	-0.5866***	-0.6858***	-0.5780***	-0.5105***	-0.5344***	-0.6344***	-0.6630***	-0.5507***	-0.5705***	-0.5844***	-0.3892***
	(0.0093)	(0.0123)	(0.0033)	(0.0098)	(0.0153)	(0.0027)	(0.0042)	(0.0090)	(0.0044)	(0.0079)	(0.0025)	(0.0140)	(0.0054)	(0.0213)
Leverage	0.0414***	0.1843***	0.0956***	0.0879*	0.0592	0.1448***	0.0416***	0.0866***	0.0594***	0.0400***	0.1685***	0.0234	0.0646***	-0.0610
	(0.0083)	(0.0428)	(0.0227)	(0.0473)	(0.0462)	(0.0226)	(0.0117)	(0.0219)	(0.0099)	(0.0130)	(0.0163)	(0.0236)	(0.0111)	(0.0827)
Size	-0.0147***	0.0668***	0.0532***	-0.0240	0.0536***	0.1137***	0.0904***	0.0426***	0.0210***	0.0485***	0.0565***	0.0508***	0.0615***	-0.0665**
	(0.0034)	(0.0148)	(0.0079)	(0.0168)	(0.0160)	(0.0069)	(0.0041)	(0.0080)	(0.0037)	(0.0050)	(0.0056)	(0.0089)	(0.0038)	(0.0273)
Age	0.0313***	0.0421	0.0109	-0.0815***	-0.0887**	-0.0243*	-0.0292***	0.0062	0.0146	-0.0522***	-0.0722***	-0.0147	-0.0122	0.0765*
	(0.0084)	(0.0452)	(0.0153)	(0.0292)	(0.0438)	(0.0133)	(0.0111)	(0.0236)	(0.0116)	(0.0112)	(0.0119)	(0.0264)	(0.0098)	(0.0433)
Intangible Assets	0.0297	0.0842	0.0962***	-0.0366	0.2654***	0.0531***	0.0365	0.0578	-0.0813*	-0.0225	-0.0220*	-0.1042	0.0792***	0.1149
	(0.0184)	(0.0530)	(0.0226)	(0.0763)	(0.0998)	(0.0173)	(0.0320)	(0.0673)	(0.0468)	(0.0250)	(0.0114)	(0.0650)	(0.0193)	(0.0943)
Constant	2.8256***	2.1910***	0.8612***	0.9057***	0.9391***	0.8502***	1.5582***	0.6045***	1.5624***	1.1738***	-0.6223***	1.4786***	1.9797***	3.6358***
	(0.0645)	(0.2316)	(0.1113)	(0.3002)	(0.2578)	(0.0990)	(0.0633)	(0.1240)	(0.0468)	(0.0731)	(0.0781)	(0.1363)	(0.0633)	(0.6031)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	15,120	7,527	93,444	11,085	4,556	114,565	46,637	12,865	64,165	14,844	142,538	6,171	33,466	1,902
R-squared	0.609	0.565	0.441	0.451	0.550	0.429	0.408	0.453	0.485	0.507	0.383	0.368	0.480	0.378

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, and ***significant at 1%.

Table 4. Robustness Check

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.8645***	-0.7733***	-0.6774***	-0.6131***	-0.6858***	-0.6416***	-0.5638***	-0.5617***	-0.6832***	-0.7045***	-0.6606***	-0.6048***	-0.6279***	-0.3892***
	(0.0093)	(0.0123)	(0.0035)	(0.0105)	(0.0153)	(0.0031)	(0.0046)	(0.0095)	(0.0051)	(0.0082)	(0.0032)	(0.0152)	(0.0065)	(0.0213)
Leverage	0.0414***	0.1843***	0.0866***	0.1283**	0.0592	0.1503***	0.0628***	0.0841***	0.0525***	0.0468***	0.1471***	0.0619**	0.0716***	-0.0610
	(0.0083)	(0.0428)	(0.0249)	(0.0537)	(0.0462)	(0.0256)	(0.0132)	(0.0232)	(0.0123)	(0.0140)	(0.0208)	(0.0263)	(0.0138)	(0.0827)
Size	-0.0147***	0.0668***	0.0103	-0.0201	0.0536***	0.1369***	0.0931***	0.0448***	0.0253***	0.0499***	0.0756***	0.0483***	0.0691***	-0.0665**
	(0.0034)	(0.0148)	(0.0089)	(0.0190)	(0.0160)	(0.0081)	(0.0048)	(0.0087)	(0.0048)	(0.0055)	(0.0080)	(0.0101)	(0.0050)	(0.0273)
Age	0.0313***	0.0421	0.0123	-0.0876**	-0.0887**	0.0017	-0.0215	0.0169	0.0087	-0.0546***	-0.0455**	0.0111	-0.0013	0.0765*
	(0.0084)	(0.0452)	(0.0172)	(0.0360)	(0.0438)	(0.0153)	(0.0133)	(0.0266)	(0.0142)	(0.0127)	(0.0181)	(0.0328)	(0.0139)	(0.0433)
Intangible Assets	0.0297	0.0842	0.1087***	-0.0440	0.2654***	0.0775***	0.0479	0.0428	-0.0678	0.0113	-0.0019	-0.0802	0.0690***	0.1149
	(0.0184)	(0.0530)	(0.0244)	(0.0820)	(0.0998)	(0.0187)	(0.0371)	(0.0708)	(0.0582)	(0.0263)	(0.0154)	(0.0675)	(0.0221)	(0.0943)
Constant	2.8256***	2.1910***	0.1087***	0.8631**	0.9391***	0.7474***	1.7843***	0.6421***	1.6678***	1.2571***	-0.9147***	1.5518***	2.0904***	3.6358***
	(0.0645)	(0.2316)	(0.0244)	(0.03430)	(0.2578)	(0.1152)	(0.0753)	(0.1341)	(0.0606)	(0.0813)	(0.1131)	(0.1581)	(0.0848)	(0.6031)
Average Convergence Speed	2.6478	3.3125	1.5099	0.3450	1.5870	2.7911	3.1696	1.3990	2.0280	3.4585	0.1181	2.2744	3.1172	2.4427
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2005-2015	2005-2014	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2008-2015
Observations	15,120	7,527	86,728	9,982	4,556	97,957	40,695	12,151	53,144	13,296	103,819	5,361	24,927	1,902
R-squared	0.609	0.565	0.454	0.466	0.550	0.466	0.455	0.466	0.510	0.533	0.438	0.398	0.499	0.378

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, and ***significant at 1%.

Average convergence speeds are calculated as the absolute values of estimated coefficients of lagged TFP levels multiplied by the average TFP levels during the data sample period in this table.

Table 5. Estimation Results for the Utility Sector

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.8578***	-0.7041***	-0.6397***	-0.5615***	-0.6700***	-0.6317***	-0.5547***	-0.5168***	-0.5826***	-0.8217***	-0.6877***	-0.6049***	-0.6537***	-0.3687***
	(0.0094)	(0.0211)	(0.0079)	(0.0109)	(0.0221)	(0.0061)	(0.0073)	(0.0117)	(0.0186)	(0.0187)	(0.0113)	(0.0209)	(0.0135)	(0.0247)
Leverage	0.0413***	0.2075***	0.1606***	0.0724	-0.0601	0.1004**	0.0845***	0.0419*	0.1072**	0.0274	-0.0031	0.0692*	0.0793**	-0.0658
	(0.0081)	(0.0399)	(0.0472)	(0.0508)	(0.0644)	(0.0428)	(0.0266)	(0.0243)	(0.0473)	(0.0268)	(0.0529)	(0.0360)	(0.0311)	(0.1409)
Size	-0.0211***	0.0304**	0.2076***	-0.0250	0.0652***	0.1442***	0.0862***	0.0010	0.0578***	0.0900***	0.1542***	0.0655***	0.0299**	-0.0592
	(0.0034)	(0.0139)	(0.0170)	(0.0181)	(0.0237)	(0.0138)	(0.0102)	(0.0092)	(0.0177)	(0.0113)	(0.0214)	(0.0135)	(0.0121)	(0.0408)
Age	0.0254***	0.0479	0.0847**	-0.0680**	-0.0865	-0.0394	-0.0327	0.0202	-0.0959*	0.0032	-0.0606	-0.0621	0.0093	0.1036*
	(0.0083)	(0.0372)	(0.0332)	(0.0337)	(0.0592)	(0.0286)	(0.0307)	(0.0268)	(0.0502)	(0.0250)	(0.0494)	(0.0400)	(0.0323)	(0.0564)
Intangible Assets	0.0213	0.0412	0.1420**	0.0387	0.4054***	0.1274***	0.0129	0.1942	-0.0271	0.0306	0.1632***	-0.1179	0.0664	0.2745
	(0.0181)	(0.0578)	(0.0568)	(0.0811)	(0.1535)	(0.0354)	(0.0873)	(0.1186)	(0.1235)	(0.0522)	(0.0503)	(0.1191)	(0.0608)	(0.1871)
Constant	2.9261***	2.1982***	1.1468***	0.8990***	0.7055*	-0.1990	2.4147***	0.7914***	0.4157*	0.7496***	-0.4350	1.2888***	2.2802***	3.6785***
	(0.0636)	(0.2333)	(0.2423)	(0.3258)	(0.3957)	(0.2086)	(0.1649)	(0.1448)	(0.2342)	(0.1589)	(0.3110)	(0.1954)	(0.2099)	(0.8963)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2005-2015	2003-2015	2005-2015	2008-2015
Observations	14,844	2,718	15,957	9,531	2,164	24,705	16,137	6,557	4,852	2,979	7,222	2,616	6,031	1,358
R-squared	0.593	0.533	0.442	0.426	0.524	0.435	0.439	0.467	0.485	0.525	0.490	0.411	0.508	0.369

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, and ***significant at 1%.

Table 6. Estimation Results for the Energy Sector

Country	China	Colombia	Japan	Germany	Hungary	Poland	South Korea	Thailand	United Kingdom	United States
Lagged TFP	-0.8390***	-0.6844***	-0.4753***	-0.3171***	-0.5792***	-0.5024***	-0.7391***	-0.6084***	-0.6668***	-0.3581***
	(0.0113)	(0.0379)	(0.0277)	(0.0115)	(0.0399)	(0.0217)	(0.0311)	(0.0252)	(0.0216)	(0.0257)
Leverage	0.0423***	0.2618***	0.0310	0.0071	-0.2481**	0.0674	0.0664	0.0917**	0.0251	-0.0810
	(0.0098)	(0.0818)	(0.0443)	(0.0372)	(0.1048)	(0.0671)	(0.0464)	(0.0402)	(0.0586)	(0.1505)
Size	-0.0111**	0.1159***	-0.0162	0.0576***	0.0113	-0.0584***	-0.0853***	0.0560***	0.0140	-0.0809*
	(0.0043)	(0.0282)	(0.0177)	(0.0135)	(0.0440)	(0.0227)	(0.0171)	(0.0148)	(0.0239)	(0.0435)
Age	0.0213**	0.2543***	-0.0341	-0.0262	-0.2447**	-0.0276	0.0651**	0.0825*	0.0354	0.1093*
	(0.0095)	(0.0821)	(0.0557)	(0.0219)	(0.1138)	(0.0617)	(0.0323)	(0.0445)	(0.0693)	(0.0570)
Intangible Assets	0.0398*	0.2896***	0.7289***	0.0106	0.1005	0.4833	0.1735	0.2482	0.2543*	0.4248*
	(0.0236)	(0.1317)	(0.1453)	(0.0553)	(0.2294)	(0.3946)	(0.1144)	(0.2125)	(0.1339)	(0.2300)
Constant	2.6305***	-0.4132	1.2846***	-0.9248***	1.1417	1.4094***	1.8310***	0.7796***	2.6980***	4.1580***
	(0.0811)	(0.4867)	(0.3449)	(0.2506)	(0.8052)	(0.3617)	(0.3074)	(0.2080)	(0.4271)	(0.9617)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2005-2015	2003-3014	2005-2015	2005-2015	2005-2015	2003-2015	2005-2015	2008-2015
Observations	9,926	825	1,519	6,607	705	1,506	673	1,639	2,197	1,250
R-squared	0.588	0.536	0.461	0.376	0.515	0.591	0.700	0.418	0.537	0.348

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, and ***significant at 1%.

Table 7. Heterogeneous Effects of Firm Age and Firm Size

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.8647***	-0.7732***	-0.6518***	-0.5870***	-0.6859***	-0.5780***	-0.5111***	-0.5338***	-0.6344***	-0.6628***	-0.5508***	-0.5706***	-0.5858***	-0.3893***
	(0.0093)	(0.0123)	(0.0033)	(0.0098)	(0.0153)	(0.0027)	(0.0042)	(0.0090)	(0.0044)	(0.0079)	(0.0025)	(0.0140)	(0.0054)	(0.0213)
Leverage × Age	-0.0074	0.0423	0.1037***	-0.0699	-0.0541	-0.0518*	0.0836***	-0.0410	-0.0070	0.0146	0.0016	0.0169	0.0406***	0.0300
	(0.0096)	(0.0574)	(0.0291)	(0.0486)	(0.0645)	(0.0266)	(0.0177)	(0.0275)	(0.0144)	(0.0167)	(0.0215)	(0.0325)	(0.0141)	(0.0642)
Leverage × Size	0.0038***	0.0055	-0.0139**	0.0166*	0.0130	0.0193***	-0.0162***	0.0124***	0.0071**	0.0004	0.0123***	-0.0020	-0.0028	-0.0073
	(0.0015)	(0.0100)	(0.0061)	(0.0087)	(0.0113)	(0.0051)	(0.0040)	(0.0047)	(0.0028)	(0.0029)	(0.0043)	(0.0061)	(0.0026)	(0.0093)
Intangible Assets × Age	-0.0564**	0.1508**	0.0629**	0.0002	0.0250	0.0440**	-0.0918***	-0.1339	-0.1047	0.0148	-0.0299*	-0.2336	-0.0168	-0.0127
	(0.0231)	(0.0749)	(0.0253)	(0.0962)	(0.1169)	(0.0222)	(0.0359)	(0.0905)	(0.0642)	(0.0324)	(0.0157)	(0.1552)	(0.0198)	(0.0770)
Intangible Assets × Size	0.0094***	-0.0184	-0.0053	-0.0016	0.0122	-0.0037	0.0202***	0.0257*	0.0106	-0.0032	0.0037	0.0311	0.0087***	0.0070
	(0.0032)	(0.0125)	(0.0053)	(0.0151)	(0.0193)	(0.0040)	(0.0072)	(0.0147)	(0.0109)	(0.0053)	(0.0029)	(0.0241)	(0.0033)	(0.0115)
Age	0.0400***	0.0102	-0.0845***	-0.0395	-0.0579	0.0110	-0.1002***	0.0254	0.0217	-0.0623***	-0.0630***	-0.0232	-0.0452***	0.0633
	(0.0103)	(0.0547)	(0.0286)	(0.0415)	(0.0590)	(0.0266)	(0.0194)	(0.0257)	(0.0165)	(0.0156)	(0.0217)	(0.0320)	(0.0155)	(0.0549)
Size	-0.0168***	0.0647***	0.0650***	-0.0352**	0.0459***	0.0993***	0.1025***	0.0368***	0.0162***	0.0485***	0.0477***	0.0524***	0.0627***	-0.0625**
	(0.0035)	(0.0158)	(0.0090)	(0.0180)	(0.0173)	(0.0080)	(0.0051)	(0.0083)	(0.0041)	(0.0054)	(0.0063)	(0.0097)	(0.0042)	(0.0284)
Constant	2.8373***	2.3010***	0.9653***	0.9787***	0.9768***	0.9660***	1.6247***	0.6427***	1.5965***	1.1972***	-0.5273***	1.4813***	2.0569***	3.5908***
	(0.0647)	(0.2338)	(0.1105)	(0.3020)	(0.2583)	(0.0983)	(0.0649)	(0.1255)	(0.0469)	(0.0739)	(0.0794)	(0.1386)	(0.0635)	(0.6075)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	15,120	7,527	93,444	11,085	4,556	114,565	46,637	12,865	64,165	14,844	142,538	6,171	33,466	1,902
R-squared	0.609	0.565	0.441	0.451	0.550	0.429	0.409	0.453	0.486	0.507	0.383	0.369	0.481	0.378

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, and ***significant at 1%.

Table 8. Heterogeneous Effects of Leverage

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.8646***	-0.7744***	-0.6514***	-0.5871***	-0.6853***	-0.5781***	-0.5112***	-0.5342***	-0.6345***	-0.6630***	-0.5508***	-0.5702***	-0.5855***	-0.3886***
	(0.0093)	(0.0124)	(0.0033)	(0.0098)	(0.0153)	(0.0027)	(0.0042)	(0.0090)	(0.0044)	(0.0079)	(0.0025)	(0.0140)	(0.0054)	(0.0213)
Leverage	0.0616**	0.4741***	0.1272	0.3734**	-0.0845	0.4719***	0.1501***	0.0250	0.1025***	0.0366	0.2227***	-0.0141	0.1638***	-0.3965
	(0.0268)	(0.1392)	(0.0860)	(0.1718)	(0.1458)	(0.0956)	(0.0378)	(0.0637)	(0.0350)	(0.0397)	(0.0554)	(0.0673)	(0.0398)	(0.2847)
Leverage × Leverage	-0.0196	-0.2947**	-0.0270	-0.2523*	0.1387	-0.2510***	-0.0923***	0.0665	-0.0399	0.0034	-0.0480	0.0412	-0.0854***	0.2959
	(0.0248)	(0.1346)	(0.0707)	(0.1460)	(0.1334)	(0.0712)	(0.0306)	(0.0646)	(0.0311)	(0.0379)	(0.0468)	(0.0691)	(0.0329)	(0.2402)
Size	-0.0147***	0.0677***	0.0532***	-0.0244	0.0531***	0.1146***	0.0910***	0.0428***	0.0211***	0.0485***	0.0566***	0.0508***	0.0615***	-0.0662**
	(0.0034)	(0.0148)	(0.0079)	(0.0168)	(0.0160)	(0.0069)	(0.0041)	(0.0080)	(0.0037)	(0.0050)	(0.0056)	(0.0089)	(0.0038)	(0.0273)
Age	0.0312***	0.0394	0.0106	-0.0831***	-0.0870**	-0.0271**	-0.0300***	0.0081	0.0135	-0.0521***	-0.0734***	-0.0150	-0.0140	0.0760*
	(0.0084)	(0.0452)	(0.0153)	(0.0292)	(0.0438)	(0.0133)	(0.0111)	(0.0237)	(0.0116)	(0.0113)	(0.0119)	(0.0264)	(0.0099)	(0.0433)
Intangible Assets	0.0294	0.0860	0.0963***	-0.0373	0.2682***	0.0546***	0.0378	0.0581	-0.0809*	-0.0225	-0.0217*	-0.1041	0.0796***	0.1362
	(0.0184)	(0.0530)	(0.0226)	(0.0763)	(0.0998)	(0.0173)	(0.0320)	(0.0673)	(0.0468)	(0.0250)	(0.0114)	(0.0650)	(0.0193)	(0.0959)
Constant	2.8218***	2.1352***	0.8529***	0.8478***	0.9713***	0.7517***	1.5305***	0.6067***	1.5560***	1.1743***	-0.6327***	1.4826***	1.9671***	3.7094***
	(0.0647)	(0.2329)	(0.1134)	(0.3021)	(0.2597)	(0.1028)	(0.0640)	(0.1241)	(0.0470)	(0.0734)	(0.0788)	(0.1364)	(0.0635)	(0.6059)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	15,120	7,527	93,444	11,085	4,556	114,565	46,637	12,865	64,165	14,844	142,538	6,171	33,466	1,902
R-squared	0.609	0.565	0.441	0.452	0.550	0.429	0.409	0.453	0.486	0.507	0.383	0.368	0.480	0.378

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, and ***significant at 1%.

Table 9. Nonlinear Effects of Firm Age

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.8649***	-0.7734***	-0.6515***	-0.5866***	-0.6860***	-0.5775***	-0.5103***	-0.5367***	-0.6339***	-0.6623***	-0.5510***	-0.5684***	-0.5837***	-0.3886***
	(0.0093)	(0.0123)	(0.0033)	(0.0098)	(0.0153)	(0.0027)	(0.0042)	(0.0090)	(0.0044)	(0.0079)	(0.0025)	(0.0140)	(0.0054)	(0.0213)
Leverage	0.0418***	0.1853***	0.0955***	0.0879*	0.0588	0.1467***	0.0427***	0.0859***	0.0569***	0.0409***	0.1635***	0.0256	0.0644***	-0.0529
	(0.0083)	(0.0428)	(0.0227)	(0.0473)	(0.0462)	(0.0226)	(0.0117)	(0.0219)	(0.0100)	(0.0130)	(0.0163)	(0.0236)	(0.0111)	(0.0828)
Size	-0.0146***	0.0646***	0.0524***	-0.0240	0.0538***	0.1133***	0.0902***	0.0427***	0.0202***	0.0483***	0.0566***	0.0516***	0.0615***	-0.0679**
	(0.0034)	(0.0148)	(0.0079)	(0.0168)	(0.0160)	(0.0069)	(0.0041)	(0.0080)	(0.0037)	(0.0050)	(0.0056)	(0.0089)	(0.0038)	(0.0273)
Age	0.0133	-0.1503	-0.1961***	-0.0823	-0.0192	-0.2453***	-0.20398***	0.0667	-0.1995***	-0.1247***	0.1669***	-0.2765***	-0.0858**	-0.0335
	(0.0168)	(0.1286)	(0.0540)	(0.0866)	(0.1147)	(0.0441)	(0.0427)	(0.0779)	(0.0353)	(0.0345)	(0.0402)	(0.8818)	(0.0360)	(0.0777)
Age x Age	0.0109	0.0843	0.0796***	0.0003***	-0.0373	0.0867***	0.0508***	-0.0253	0.1153***	0.0310**	-0.0955***	0.1160***	0.0266**	0.0490*
	(0.0087)	(0.0528)	(0.0199)	(0.0274)	(0.0569)	(0.0165)	(0.0120)	(0.0310)	(0.0179)	(0.0139)	(0.0153)	(0.0373)	(0.0125)	(0.0288)
Intangible Assets	0.0302	0.0826	0.0937***	-0.0366	0.2642***	0.0530***	0.0342	0.0587	-0.0902*	-0.0222	-0.0245**	-0.1099*	0.0788***	0.1152
	(0.0814)	(0.0531)	(0.0226)	(0.0734)	(0.0998)	(0.0173)	(0.0320)	(0.0673)	(0.0468)	(0.0249)	(0.0114)	(0.0650)	(0.0193)	(0.0493)
Constant	2.7973***	2.1388***	0.7963***	0.9056***	1.0097***	0.8075***	1.5493***	0.6200	1.4617***	1.1462***	-0.5741***	1.3446***	1.9722***	3.3881***
	(0.0684)	(0.2338)	(0.1125)	(0.3007)	(0.2794)	(0.0993)	(0.0633)	(0.1255)	(0.0493)	(0.0741)	(0.0785)	(0.1428)	(0.0634)	(0.6200)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	15,120	7,527	93,444	11,085	4,556	114,565	46,637	12,865	64,165	14,844	142,538	6,171	33,466	1,902
R-squared	0.609	0.565	0.441	0.451	0.550	0.429	0.409	0.453	0.486	0.507	0.383	0.370	0.480	0.379

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%.

Table 10. Alternative TFP Measure by De Loecker and Warzynski (2012)

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-1.0101***	-0.8457***	-0.5440***	-0.3902***	-0.6509***	-0.6263***	-0.5464***	-0.6315***	-0.7057***	-0.6814***	-0.5038***	-0.7408***	-0.6591***	-0.4102***
	(0.0064)	(0.0124)	(0.0028)	(0.0067)	(0.0140)	(0.0030)	(0.0043)	(0.0103)	(0.0039)	(0.0063)	(0.0022)	(0.0151)	(0.0060)	(0.0215)
Leverage	0.0075*	0.0373*	0.0172***	0.0134	-0.0639***	0.0046	0.0439***	0.0325***	-0.0056	0.0280***	0.0024*	0.0521***	0.0340***	0.0708**
	(0.0041)	(0.0200)	(0.0025)	(0.0087)	(0.0172)	(0.0037)	(0.0090)	(0.0094)	(0.0046)	(0.0074)	(0.0014)	(0.0192)	(0.0067)	(0.0322)
Size	0.0041**	0.0352***	0.0605***	0.0239***	0.0223***	0.0080***	0.0489***	0.0363***	0.0408***	0.0416***	0.0531***	0.0279***	0.0385***	-0.0516***
	(0.0017)	(0.0069)	(0.0009)	(0.0031)	(0.0060)	(0.0011)	(0.0031)	(0.0034)	(0.0017)	(0.0029)	(0.0005)	(0.0072)	(0.0023)	(0.0108)
Age	-0.0039	-0.0420**	0.0086***	-0.0053	-0.0145	0.0170***	-0.0181**	-0.0070	0.0164***	-0.0282***	-0.0057***	0.0535**	0.0117**	0.0157
	(0.0042)	(0.0211)	(0.0017)	(0.0054)	(0.0162)	(0.0022)	(0.0085)	(0.0104)	(0.0054)	(0.0062)	(0.0010)	(0.0214)	(0.0059)	(0.0171)
Intangible Assets	0.0226**	0.0543**	0.0266***	-0.0030	-0.0302	0.0058**	0.0457**	0.0652**	-0.0100	-0.0003	-0.0069***	0.0875*	0.0344***	0.0891**
	(0.0091)	(0.0245)	(0.0024)	(0.0148)	(0.0386)	(0.0028)	(0.0220)	(0.0259)	(0.0213)	(0.0166)	(0.0010)	(0.0526)	(0.0117)	(0.0373)
Constant	1.1438***	2.1883***	1.2294***	0.2139***	1.2236***	1.9880***	2.8059***	0.9549***	1.1975***	1.0098***	1.0026***	1.5518***	2.2232***	1.1342***
	(0.0306)	(0.1123)	(0.0143)	(0.0536)	(0.0997)	(0.0189)	(0.0526)	(0.0549)	(0.0228)	(0.0431)	(0.0085)	(0.1128)	(0.0416)	(0.2327)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	15,086	7,482	97,394	16,787	4,458	114,865	47,053	11,009	65,238	25,164	154,264	6,113	33,289	2,073
R-squared	0.831	0.671	0.514	0.453	0.693	0.542	0.449	0.651	0.582	0.509	0.553	0.447	0.502	0.473

The dependent variable is TFP growth calculated by De Loecker and Warzynski (2012) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%.

Table 11. Alternative TFP Measure by Levinsohn and Petrin (2003)

Country	France	Germany	Hungary	Italy	Poland	Romania	South Korea	Spain
Lagged TFP	-0.6137***	-0.5523***	-0.6654***	-0.4422***	-0.4967***	-0.5861***	-0.6774***	-0.5709***
	(0.0031)	(0.0074)	(0.0115)	(0.0027)	(0.0074)	(0.0040)	(0.0061)	(0.0023)
Leverage	1.6861***	38.6599*	16.3931	62.5910***	13.2304***	63.5180***	17.8009***	5.9000***
	(0.1051)	(20.0957)	(22.9445)	(18.2371)	(3.4851)	(4.4096)	(2.3903)	(0.4460)
Size	0.9673***	31.8934***	23.7066***	48.1800***	7.8858***	44.4691***	11.0913***	2.5985***
	(0.0367)	(7.0949)	(8.2619)	(5.5618)	(1.2743)	(1.6355)	(0.9443)	(0.1552)
Age	-0.0772	6.4075	-15.9771	-13.4882	1.0046	-17.3789***	-4.9162**	-1.1386***
	(0.0711)	(12.5223)	(21.8216)	(10.7133)	(3.7557)	(5.1097)	(2.0041)	(0.3247)
Intangible Assets	0.3289***	34.6906	8.4258***	20.1451	-9.6503	-0.6754	11.9118**	0.3907
	(0.1041)	(35.2088)	(55.5713)	(13.9487)	(10.7229)	(20.1881)	(5.3311)	(0.3194)
Constant	-7.6331***	-319.6476***	-135.8630	-615.0285***	-85.2715***	-379.5489***	-108.8157***	-18.8328***
	(0.5154)	(123.2183)	(130.8796)	(79.9425)	(19.5351)	(20.4811)	(13.3918)	(2.1641)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2000-2015	2003-2014	2005-2015	1998-2015	2001-2015	2001-2015	2003-2015	1996-2015
Observations	96,926	16,782	4,264	114,865	13,007	65,324	24,235	154,264
R-squared	0.478	0.404	0.749	0.452	0.496	0.506	0.530	0.388

The dependent variable is TFP growth calculated by Levinsohn and Petrin (2003) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%.

Table 12. Generalized Method of Moments

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.0440***	-0.5906***	-0.0011**	-0.2341***	-0.3539***	-0.2261***	-0.2362***	-0.0906***	-0.6458***	-0.0118	-0.1553***	-0.2278***	-0.1433***	-0.0021
	(0.0027)	(0.0491)	(0.0015)	(0.0232)	(0.0192)	(0.0149)	(0.0141)	(0.0071)	(0.0200)	(0.0157)	(0.0159)	(0.0002)	(0.0086)	(0.0034)
Leverage	0.0789***	0.3344**	0.2861***	0.4626***	0.2946***	0.1549**	-0.1643***	0.3236***	0.3471***	0.1036***	-0.1083**	0.1744***	0.2142***	-0.1876***
	(0.0068)	(0.1310)	(0.0585)	(0.1237)	(0.0730)	(0.0640)	(0.0359)	(0.0290)	(0.0292)	(0.0364)	(0.0466)	(0.0006)	(0.0120)	(0.0077)
Size	0.0086***	0.0828***	0.0391***	-0.0832***	-0.0380***	-0.0436***	0.0620***	-0.0244***	0.0440***	0.0139*	-0.0318***	0.0081***	0.0532***	0.0352***
	(0.0008)	(0.0228)	(0.0133)	(0.0149)	(0.0106)	(0.0126)	(0.0055)	(0.0071)	(0.0078)	(0.0084)	(0.0109)	(0.0004)	(0.0028)	(0.0047)
Age	-0.0144***	-0.0554	-0.2265***	-0.0063	-0.0872***	-0.1478***	-0.1202***	-0.0041	-0.1234***	-0.0597***	-0.0514***	-0.0542***	-0.0792***	-0.0897***
	(0.0011)	(0.0445)	(0.0213)	(0.0304)	(0.0237)	(0.0192)	(0.0133)	(0.0139)	(0.0151)	(0.0117)	(0.0184)	(0.0003)	(0.0069)	(0.0058)
Intangible Assets	0.0221***	0.6379***	-0.0012	0.3249***	0.0802	0.1224***	-0.1151**	0.5800***	-0.2167**	0.0236	0.0747***	0.2362***	0.3067***	0.0811***
	(0.0020)	(0.0904)	(0.0504)	(0.1044)	(0.0583)	(0.0410)	(0.0483)	(0.0368)	(0.1046)	(0.0297)	(0.0155)	(0.0002)	(0.0086)	(0.0110)
Constant	-0.0068	1.2920***	-0.1114	1.2858***	1.4080***	1.8544***	0.8746***	0.4211***	1.4268***	-0.0735	0.6132***	0.8066***	0.0005	-0.3631***
	(0.0132)	(0.3628)	(0.1624)	(0.2272)	(0.1535)	(0.1733)	(0.1360)	(0.1009)	(0.1006)	(0.1112)	(0.1207)	(0.0052)	(0.0332)	(0.1044)
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	17,028	8,512	96,610	11,842	4,999	118,918	48,121	13,726	70,398	15,761	147,645	6,415	36,016	1,945
Wald Chi2(5)	10740.52	198.03	213.92	132.65	426.01	631.16	852.36	543.11	1679.46	80.75	197.92	6.38e+07	1883.45	565614.68

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%.

Table 13. Number of Employees as a Proxy for Firm Size

Country	China	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.9262***	-0.6636***	-0.5668***	-0.7445***	-0.5742***	-0.5049***	-0.5835***	-0.6335***	-0.7230***	-0.5664***	-0.7516***	-0.5009***	-0.3854***
	(0.0097)	(0.0050)	(0.0105)	(0.0176)	(0.0031)	(0.0042)	(0.0156)	(0.0044)	(0.0096)	(0.0026)	(0.0888)	(0.0073)	(0.0253)
Leverage	0.0264***	0.1012***	0.1414***	0.0823	0.1519***	0.0766***	0.1439***	0.0559***	0.0541***	0.2154***	0.0403	0.0127	-0.6416
	(0.0084)	(0.0342)	(0.0497)	(0.0551)	(0.0249)	(0.0116)	(0.0381)	(0.0100)	(0.0157)	(0.0171)	(0.1227)	(0.0138)	(0.0958)
Employees	0.0556***	0.0184	-0.1197***	0.0055	0.0205***	0.0492***	-0.0124	0.0346***	0.0334***	-0.1376***	0.1847**	0.0995***	0.0378
	(0.0051)	(0.0120)	(0.0171)	(0.0155)	(0.0589)	(0.0032)	(0.0207)	(0.0042)	(0.0054)	(0.0055)	(0.0821)	(0.0050)	(0.0360)
Age	0.0286***	0.0555**	-0.0595*	-0.1269**	0.0161	0.0152	0.0610	0.0117	-0.0290**	-0.0099	-0.3103	-0.0244**	0.1050*
	(0.0087)	(0.0236)	(0.0306)	(0.0551)	(0.0147)	(0.0110)	(0.0442)	(0.0116)	(0.0133)	(0.0128)	(0.2250)	(0.0119)	(0.0564)
Intangible Assets	0.0131	0.0000	-0.0704	0.2811**	0.0435**	0.0178	0.2229**	-0.0736	-0.0617*	-0.0095	0.2717	0.0658***	0.0537
	(0.0184)	(0.0352)	(0.0818)	(0.1121)	(0.0192)	(0.0321)	(0.1087)	(0.0466)	(0.0321)	(0.0122)	(0.1955)	(0.0120)	(0.1009)
Constant	2.5046***	1.6621***	0.8712***	1.9295***	2.3146***	2.5769***	1.1545***	1.7569***	1.9169***	0.2517***	3.0033***	2.3465***	1.7071***
	(0.0429)	(0.0736)	(0.1201)	(0.1573)	(0.0438)	(0.0420)	(0.1368)	(0.0281)	(0.0428)	(0.0354)	(0.7847)	(0.0519)	(0.3402)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	14,461	42,056	9,429	3,665	94,195	46,243	4,877	62,496	10,742	128,730	261	17,450	1,489
R-squared	0.622	0.489	0.466	0.574	0.436	0.405	0.528	0.487	0.546	0.398	0.589	0.455	0.382

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%.

Table 14. Additional Variable of Cash Flow

Country	China	Colombia	France	Germany	Hungary	Italy	Japan	Poland	Romania	South Korea	Spain	Thailand	United Kingdom	United States
Lagged TFP	-0.9206***	-0.8019***	-0.6396***	-0.5860***	-0.6777***	-0.5730***	-0.7042***	-0.5237***	-0.6275***	-0.7133***	-0.5507***	-0.6808***	-0.5771***	-0.3899***
	(0.0894)	(0.0478)	(0.0033)	(0.0098)	(0.0155)	(0.0027)	(0.0172)	(0.0090)	(0.0045)	(0.0094)	(0.0025)	(0.0467)	(0.0055)	(0.0213)
Leverage	0.1066	0.0458	0.0858***	0.0514	0.0648	0.1426***	-0.0588	0.0766***	0.0693***	0.0494***	0.1702***	0.0766	0.0644***	-0.0565
	(0.1334)	(0.0804)	(0.0237)	(0.0487)	(0.0475)	(0.0233)	(0.0467)	(0.0223)	(0.0107)	(0.0152)	(0.0166)	(0.0951)	(0.0111)	(0.0839)
Size	0.1290***	0.0154	0.0525***	-0.0274	0.0491***	0.1148***	0.0894***	0.0398***	0.0168***	0.0473***	0.0568***	0.0118	0.0637***	-0.0673**
	(0.0361)	(0.0244)	(0.0079)	(0.0168)	(0.0162)	(0.0069)	(0.0134)	(0.0079)	(0.0037)	(0.0056)	(0.0056)	(0.0319)	(0.0038)	(0.0274)
Age	-0.0934	0.0987	0.0103	-0.0790***	-0.9276**	-0.0270**	-0.0760*	0.0067	0.0187	-0.0394***	-0.0729***	0.0341	-0.0082	0.0801*
	(0.0988)	(0.0844)	(0.0153)	(0.0292)	(0.0440)	(0.0132)	(0.0448)	(0.0233)	(0.0119)	(0.0130)	(0.0119)	(0.1602)	(0.0098)	(0.0437)
Intangible Assets	0.0270	-0.2580***	0.0926***	-0.0276	0.2689***	0.0520***	0.0301	0.0583	-0.0526	-0.0477*	-0.0225**	-0.0865	0.0783***	0.1263
	(0.1282)	(0.0592)	(0.0225)	(0.0764)	(1.0011)	(0.0172)	(0.0977)	(0.0667)	(0.0482)	(0.0284)	(0.0114)	(0.0971)	(0.0192)	(0.0973)
Cash Flow	-0.1739	0.0320	-0.0358	-0.2190***	0.0276	0.0278	0.0594	-0.0166	0.0447***	-0.0517**	-0.0003	0.1375*	-0.0049	0.0511
	(0.2193)	(0.0894)	(0.0265)	(0.0710)	(0.0507)	(0.0335)	(0.0541)	(0.0268)	(0.0092)	(0.0263)	(0.0229)	(0.0786)	(0.0040)	(0.1238)
Constant	0.7921	2.6508***	0.8544***	1.0023***	0.9938***	0.8200***	2.8125***	0.6250***	1.5715***	1.3175***	-0.6264***	2.4990***	1.9087***	3.6417***
	(0.7441)	(0.4783)	(0.1109)	(0.3018)	(0.2624)	(0.0989)	(0.2371)	(0.1231)	(0.0484)	(0.0846)	(0.0782)	(0.7672)	(0.0635)	(0.6051)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	2005-2014	2006-2015	2000-2015	2003-2014	2005-2015	1998-2015	2002-2015	2001-2015	2001-2015	2003-2015	1996-2015	2003-2015	1997-2015	2008-2015
Observations	298	819	93,188	11,083	4,527	112,927	4,977	12,723	59,105	11,411	142,354	884	32,701	1,896
R-squared	0.724	0.598	0.434	0.452	0.543	0.430	0.619	0.457	0.490	0.531	0.383	0.412	0.481	0.377

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%.

Table 15. Pooled Sample

Industry	Infrastructure	Utility	Energy	Transport	Telecom	Postal
Lagged TFP	-0.5783***	-0.5519***	-0.4797***	-0.5773***	-0.7159***	-0.6466***
	(0.0013)	(0.0026)	(0.0056)	(0.0015)	(0.0074)	(0.0124)
Leverage	0.1251***	0.0808***	0.0322***	0.1371***	0.1759***	0.1415**
	(0.0068)	(0.0110)	(0.0122)	(0.0086)	(0.0347)	(0.0589)
Size	0.0472***	0.0738***	0.0111**	0.0335***	0.1578***	0.0605***
	(0.0023)	(0.0037)	(0.0046)	(0.0029)	(0.0119)	(0.0226)
Age	-0.0623***	-0.0490***	-0.0137	-0.0631***	-0.1131***	-0.0444
	(0.0052)	(0.0084)	(0.0098)	(0.0064)	(0.0364)	(0.0549)
Intangible Assets	0.0461***	0.1089***	0.1110***	0.0403***	0.0167	0.0561
	(0.0064)	(0.0144)	(0.0289)	(0.0075)	(0.0366)	(0.0578)
Constant	1.0251***	1.1238***	0.9417***	0.9207***	1.3672***	1.4720***
	(0.0327)	(0.0571)	(0.0790)	(0.0400)	(0.1812)	(0.2945)
4 Digit Industry-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	569,251	139,140	29,123	401,206	21,727	7,178
R-squared	0.412	0.393	0.410	0.413	0.480	0.444

The dependent variable is TFP growth calculated by Gandhi et al.'s (2020) method. Standard errors are in parentheses. *significant at 10%, **significant at 5%, ***significant at 1%.