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Digital Thailand: Analyzing the Impact of Broadband Connectivity on Firm Productivity

by

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Digital Thailand: Analyzing the Impact of Broadband Connectivity on Firm Productivity

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Abstract:

Using a large dataset of almost 100,000 manufacturing establishments in Thailand, this paper studies the impact of broadband internet connectivity on firms' total factor productivity (TFP). The author finds that, for micro-, small-, and medium-sized enterprises, broadband adoption can raise productivity by 23% to 54%. These results support the government's policies in building the country's broadband infrastructure. Although the results reveal substantial benefits of broadband adoption, especially for smaller-sized firms, only about 30% of firms reported adopting broadband or having any types of ICT investments. Perhaps, more could be done to encourage broadband adoptions and private ICT investments for firms of all sizes.

JEL Codes: D24, O14, O33

Keywords: Digital Economy, Broadband, ICT, Firm Productivity, Thailand

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1. Introduction

The first digital computer was built in 1940s. The technology has transformed how numbers were computed and how information was processed. It also led to many changes that happened in later years. The internet was invented in 1960s and commercialized during 1990s. The technology has completely transformed how we communicate. Many new types of goods and services became available. For businesses, digital technologies have changed not only how manufacturing activities are conducted (e.g., the use of automation), how decisions are made (e.g., the use of data-driven decision making), but also how communication and transactions are carried out (e.g., the use of internet).

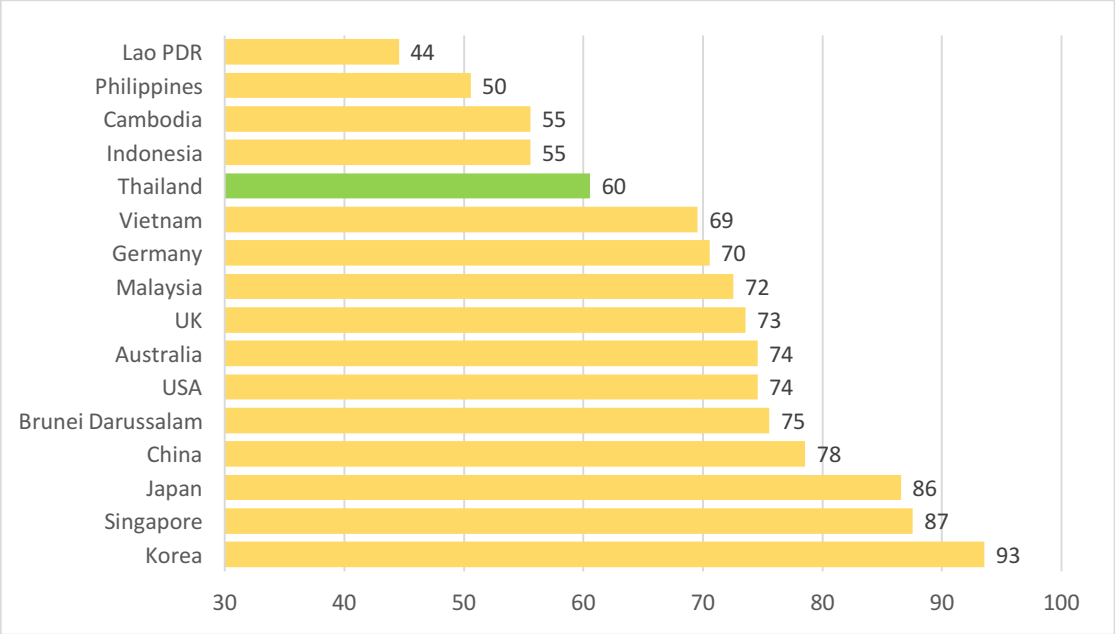
Economists have been trying to understand the impact of these technologies on our economy. Specifically, many studies have tried to investigate how ICT (Information and Communication Technology), a domain of digital technologies that focuses on how data are utilized, processed, and also transmitted via network, played a role as an engine of growth and fostered economic development (Papaioannou & Dimelis, 2007; Cardona et al., 2013).

At the cross-country level, many studies have shown that higher level of ICT development is associated with higher level of various economic measures including GDP per capita, labor productivity, etc. (See Czernich et al., 2011; Evangelista et al., 2014; Hagsten, 2016; Gal et al., 2019; for further discussions.)

For developed countries, in which productivity and ICT adoption data are readily available at the firm level, researchers were able to conduct better estimates to investigate the issues. Brynjolfsson and Hitt (2003), using the data of US firms, documented positive effects of computerization on productivity and output growth. Hempell (2005) studied German enterprises and confirmed that ICT adoption raised firm output. Later studies have also tried to explore the impact of a specific type of ICT, namely the broadband internet, on productivity. Grimes et al. (2012) found that broadband internet adoption increased productivity of firms in New Zealand by 7% to 10%. Akerman et al. (2015), using Norwegian datasets, discovered that broadband internet improved productivity of skilled workers in firms. On the other hand, DeStefano et al. (2018) and Haller and Lyons (2015) found no statically significant impact of broadband on firm productivity in the United Kingdom and Ireland, respectively.

At the time of this writing, firm-level ICT analyses, especially on how broadband connectivity can be linked to firm productivity, hardly existed for developing countries. This is possibly due the lack of appropriate data. Figure 1 presents the World Economic Forum's ICT Adoption Index for selected countries. The figure reveals that developed countries and developing countries are at different stages in terms of ICT adoption. Therefore, conclusions based on firm-level analyses of advanced countries may differ from those of developing countries. This calls for the need of more firm-level ICT research using developing countries' data so that we can better understand the importance of ICT and its impact on firm productivity under different environment.

Figure 1: ICT Adoption Index 2019



Source: Data from World Economic Forum, Figure Prepared by Author

This paper aims to fill this gap by investigating the impact of a specific type of ICT, namely the broadband internet, on firm productivity in Thailand. The empirical analyses at the firm level are made possible by combining Thailand's 2017 Industrial Census with the ICT Establishment Survey. The merged dataset contains almost 100,000 manufacturing establishments with both productivity-related variables and ICT-related variables, allowing the author to conduct in-depth analyses to tackle the issues. Thailand is an interesting case study because it is an emerging economy with many traditional Micro, Small, and Medium

enterprises (MSMEs) wanting to transform digitally. In addition, the Thai government has been promoting the "Digital Thailand" scheme in which the digital technology and innovation are encouraged as tools to get the country out of the middle-income trap. Several projects were implemented to build broadband infrastructure, to equip citizens with digital-technology related skills, and to encourage businesses to adopt digital technology. It would be interesting to see whether the effort in trying to transform Thailand digitally would actually have a concrete impact on productivity.

The remainder of this paper is organized as follows. Section 2 provides an overview of the digital landscape in Thailand. Section 3 explains the datasets. Section 4 outlines the empirical models. Section 5 discusses the results. Finally, Section 6 concludes the research and discusses policy implications.

2. Thailand's Digital Landscape

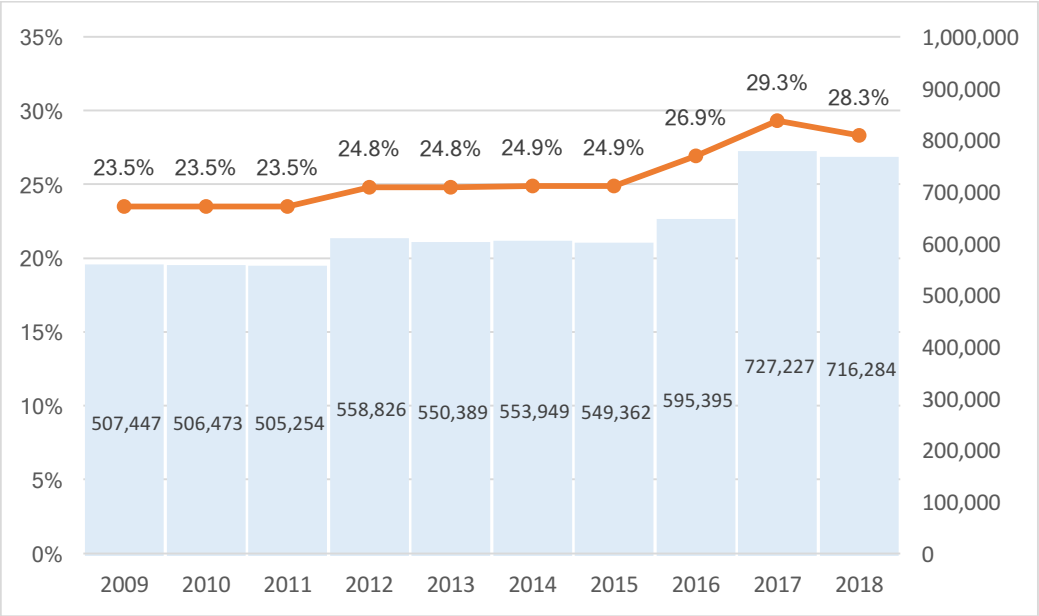
In Thailand, the Ministry of Information and Technology was established in 2002. It was later restructured and renamed to the Ministry of Digital Economy and Society in 2016. The Ministry's vision is to promote the use of digital technology and innovation to drive Thailand forward. The Ministry's most recent strategies (2020-2024) involve (i) developing the country's digital infrastructure, (ii) improving the country's competitiveness by using digital technology and innovation, (iii) raising the people's living standards by using digital technology, (iv) providing public services via digital government, (v) developing digital workforce, and (iv) building the society's trust in using digital technology. (See MDES, 2019; ONDE, 2019; for further discussions.)

Currently, the internet penetration rate of individuals in Thailand is considered high. According to the official statistics from the National Statistical Office's 2018 ICT Household Survey, about 61% of the population (aged 6 and older) use internet. The rate is as high as 94% and 88% for people aged 15-24 and aged 25-34, respectively. According to the most recent data from We Are Social (2020), Thailand's internet penetration rate is 75%.

However, for firms, the computer usage and the internet penetration rates are low or at most moderate. According to the National Statistical Office's 2018 ICT Establishment Survey, only 28% of the establishments reported using computers, and 30% reported using internet.

Figure 2 illustrates the percentage and the number of establishments reported using computers during 2009-2018. Although the figure reveals an increasing trend, it is rather flat. Figure 3 displays the percentage of establishments reported using computers by sector.[2] It appears that besides private hospitals and the information and communication sector, the usage of computers is moderate-to-low in other sectors. The manufacturing sector has the lowest rate of computer usage.

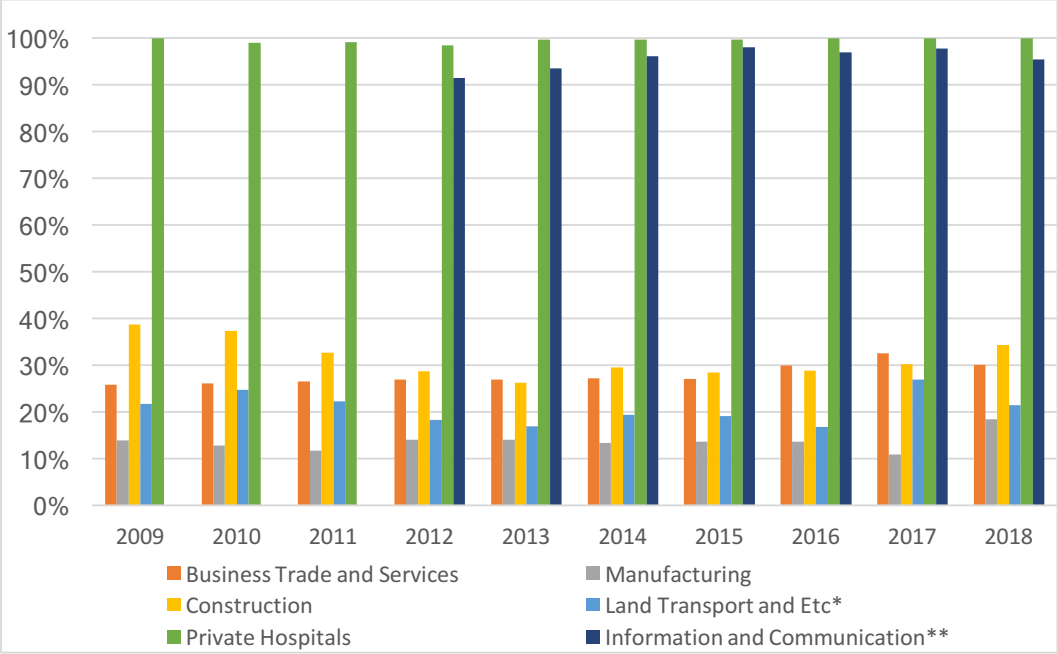
Figure 2: Percentage and Number of Establishments Using Computers (All Sectors)



Source: Data from National Statistical Office, Figure Prepared by Author

[2] For 2017, the manufacturing sector was excluded from the regular survey. Therefore, the author imputed the 2017 manufacturing statistics based on the ICT establishment questions asked to the manufacturing establishments under the Industrial Census (to be discussed in detail in Section 3). Prior to 2012, the Land Transports and Etc. Sector covered Land Transports and Travel Agencies. However, from 2012 onwards, this sector covered Land Transports and Storages. The Information and Communication Sector was added in 2012.

Figure 3: Percentage of Establishments Using Computers (by Sector)

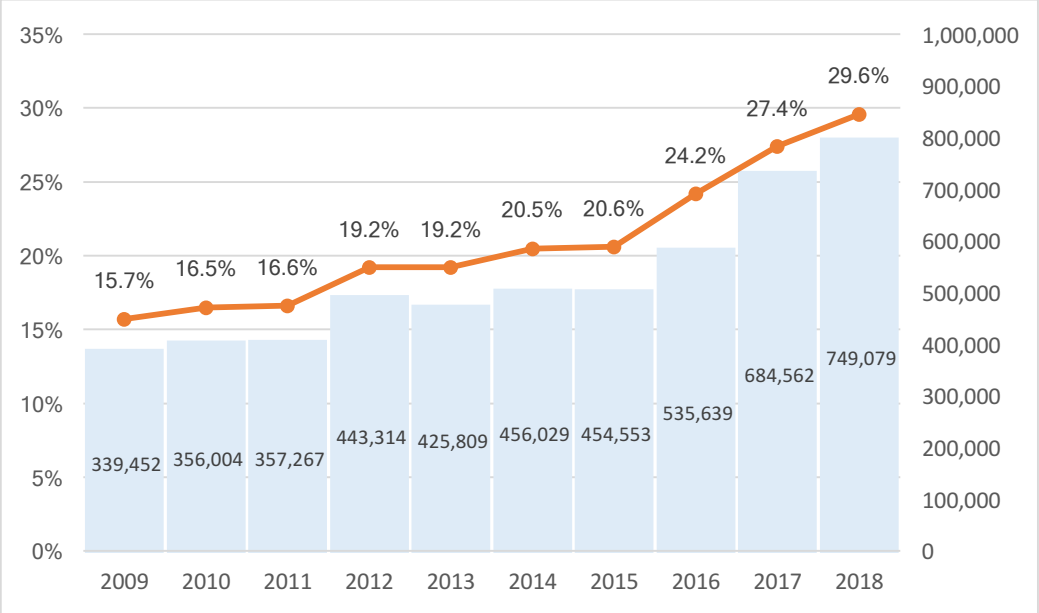


Source: Data from National Statistical Office, Figure Prepared by Author

Figure 4 illustrates the percentage and the number of establishments reported using internet during 2009-2018. There is an obvious increasing trend in which the percentage of establishments using internet almost doubled in the past 10 years. However, the adoption rate of 30% in 2018 is still considered low. Figure 5 displays the percentage of establishments reported using internet by sector.[3] Similar to the case of computer usage, for most sectors, the internet adoption is moderate-to-low, with the manufacturing sector having the lowest adoption rate.

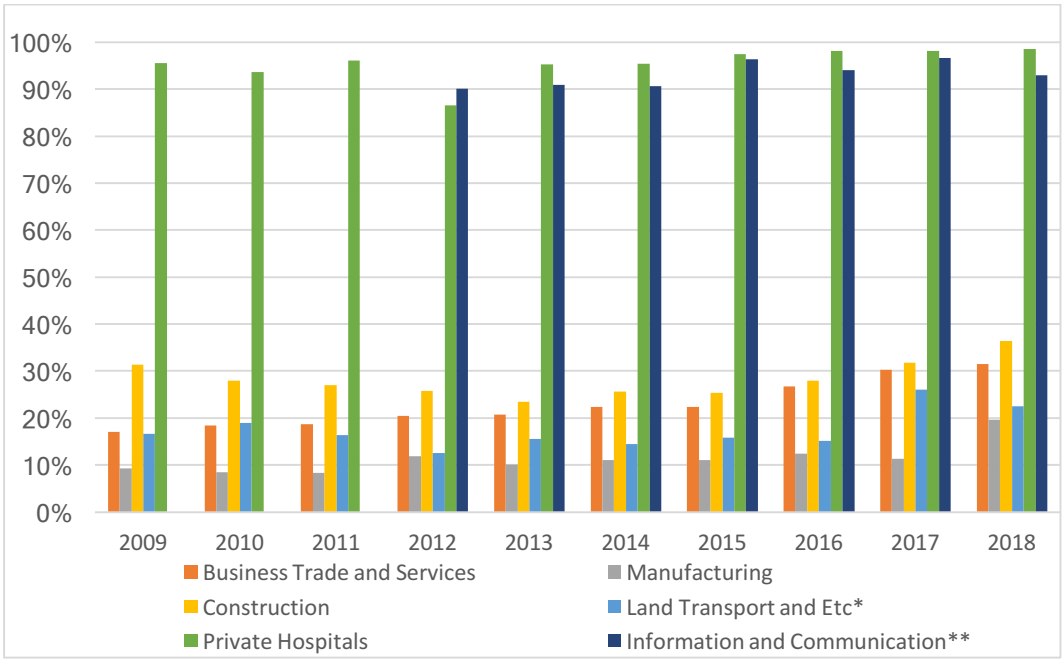
[3] Ibid.

Figure 4: Percentage and Number of Establishments Using Internet (All Sectors)



Source: Data from National Statistical Office, Figure Prepared by Author

Figure 5: Percentage of Establishments Using Internet (by Sector)



Source: Data from National Statistical Office, Figure Prepared by Author

Thailand has been promoting the "Digital Thailand" scheme in which the digital technology and innovation are strongly encouraged by the government. At the time of this writing, it appears that the internet access level is high for individuals. The internet penetration rate is almost universal for people aged 15-24. However, for firms, the actual computer usage and internet access rates are only moderate-to-low, with the manufacturing firms having the lowest usage rates.

Manufacturing is one of the most important sector in Thailand's economy. Looking into the 10 targeted industries promoted by the government, at least 5 of them, namely, (i) Digital Industry, (ii) Automation and Robotics, (iii) Aviation and Logistics, (iv) Smart Electronics, and (v) Next-Generation Automotive, are directly related to manufacturing. This paper aspires to reveal convincing evidence on how technologies can improve manufacturing firms' productivity. Perhaps these recognizable benefits can raise awareness and bring more attention to the issues regarding why only about 28% and 30% of manufacturing firms are using computers and internet, respectively. In addition, the results may convince more firms to invest and adopt relevant technologies.

3. Data

This paper utilizes two main datasets, namely, (i) Thailand's ICT Establishment Survey, and (ii) Thailand's 2017 Industrial Census. Both datasets are administered and maintained by the National Statistical Office (NSO). The sub-sections below discuss each of the datasets and the selected statistics of the merged dataset.

3.1 The ICT Establishment Survey

The ICT Establishment Survey contains detailed questions regarding ICT adoptions and investments by establishments in Thailand. The Survey has been conducted by the NSO since 2004. The stratified two-stage systematic sampling method was used with regions as stratum and industries and sizes as sub-stratum. For most years, the survey was conducted independently and the covered sectors were (i) Business Trade and Services, (ii) Manufacturing, (iii) Construction, (iv) Land Transport and etc., (v) Private Hospitals, and (vi)

Information and Communication.[4] However, for 2017, the manufacturing sector was excluded from the regular survey and the ICT questions for the manufacturing sector were asked to the manufacturing establishments in the 2017 Industrial Census. Therefore, the sampling method for the manufacturing establishments in 2017 followed the that of the Industrial Census (to be discussed below).

The aggregated statistics of the ICT Establishment Survey from 2009 to 2018 (with the 2017 manufacturing statistics imputed by the author) were used in Section 2 of this paper. The 2017 ICT questions for the manufacturing establishments will be merged with the 2017 Industrial Census and will be used in the main empirical analyses of this paper.

3.2 The 2017 Industrial Census

The Industrial Census was conducted by the NSO to obtain detailed information about the manufacturing establishments in Thailand. It was conducted in 1964, 1997, 2007, 2012, and 2017. The information collected includes basic characteristics of the establishments (legal form, size, age, location, etc.), employees and remuneration, revenues, costs, assets, etc.

This paper focuses on the 2017 Industrial Census.[5] For establishments with 11 persons or more, all of them were enumerated. For establishments with 1-10 persons, the stratified two-stage systematic sampling method was used with provinces as stratum and industries and sizes as sub-stratum. The 2017 census year is special in the sense that the questions from the ICT Establishment Survey were also asked to these manufacturing enterprises.

[4] Prior to 2012, the Land Transports and Etc. Sector covered Land Transports and Travel Agencies. However, from 2012 onwards, this sector covered Land Transports and Storages. The Information and Communication Sector was added in 2012.

[5] The census questionnaire asked for previous year's information. Therefore, the 2017 census asked questions about the operation in 2016.

3.3 Summary Statistics of the Merged Dataset

For the main empirical analyses, the paper utilizes the merged dataset of the 2017 Industrial Census and the ICT Establishment Survey. Originally, there were 118,639 observations but after some cleaning steps, about 86,296 observations remained.[6]

Table 1 shows how the observations are categorized by legal forms and sizes. The majority (67%) of the establishments are individuals or unregistered partnerships. Registered companies (both public and private) account for about 19% of the sample. (Registered) juristic partnerships comprise 5% of the sample. The remaining 9% belong to other types (e.g., government agencies, state enterprises, cooperatives, community enterprises, associations, foundations, etc.) Regarding sizes, the majority (58%) are micro enterprises (1-5 persons), about 35% are small enterprises (6-50 persons), approximately 5% are medium enterprises (51-200 persons), and the remaining 2% are large enterprises (more than 200 persons).

Table 2 shows the summary statistics of selected variables. The average firm age (i.e., years in operation) is 13.2 years. The proportions of firms having foreign investment, receiving Thailand's Board of Investment's (BOI) incentives, exporting products, and importing inputs are 2.4%, 2.3%, 2.6%, and 3.9%, respectively. The average share of skilled workers is 38%.

Table 1: Observations by Legal Form and Size

		N	%
No. of Observations		86,296	100.00%
Legal form	Indiv. & Unreg. Partnership	57,943	67.14%
	Juristic Partnership	4,476	5.19%
	Registered Company	16,010	18.55%
	Other	7,867	9.12%
Size	Micro (1-5 Persons)	49,751	57.65%
	Small (6-50 Persons)	30,510	35.36%
	Medium (51-200 Persons)	4,152	4.81%
	Large (> 200 Persons)	1,883	2.18%

[6] 4,740 observations were dropped due to industry code misclassification (they did not belong to ISIC 15-37). Another 27,603 were dropped because they could not be enumerated (i.e., they were transferred/not found, closed down, demolished, not willing to cooperate, temporarily closed.)

Table 2: Summary Statistics of Selected Variables

		N	Mean	SD
Years in Operation		86,296	13.15	10.75
Foreign Investment	(0=No; 1=Yes)	86,296	0.024	0.152
Receive BOI	(0=No; 1=Yes)	86,296	0.023	0.148
Export Products	(0=No; 1=Yes)	86,296	0.036	0.186
Import Inputs	(0=No; 1=Yes)	86,296	0.039	0.193
Share of Skilled Workers		86,296	0.378	0.383
ICT Investment	(0=No; 1=Yes)	86,296	0.294	0.456
Broadband	(0=No; 1=Yes)	86,296	0.234	0.423
No. of Computers per Hundred Employees		86,296	8.39	32.68

The remaining three variables in Table 2 are ICT-related variables from the ICT Establishment questionnaire. The ICT investment variable is equal to one if the establishment reported either (i) using any types of computers (including tablet PCs and servers), (ii) using any types of software (self-developed, package, tailor-made, open-source, software-as-a-service (SaaS)), or (iii) having any types of network systems (intranet, extranet, LAN), at the establishment. The fact that any of these devices/systems are available for use at the establishment indicates that some investments were made by the establishment to acquire or rent them. The broadband variable is equal to one if the establishment reported having access to (i) xDSL (ADSL, SDSL, VDSL), (ii) leased line, (iii) cable modem, (iv) frame relay or VPN, (v) satellite, FTTX, Fixed Wireless, WLAN, WiMAX, or (vi) cellular network of 3G or better. The number of computers (including tablet PCs and servers) per a hundred employees is calculated as such and can also be called the ICT density variable. As the table reveals, the proportions of firms having any types of ICT investments and adopting broadband, are 29% and 23%, respectively. The average number of computers per a hundred of employees is 8.4.

The ICT-related variable of interest in this paper is the broadband variable. In the main analysis, the author will investigate whether firms that adopt broadband have higher productivity compared to others that do not adopt broadband. The other two ICT-related variables will be used for robustness test. Specifically, in the full model, these two variables will be added to the regression analysis to check whether the impact of broadband remains robust.

Tables 3-1, 3-2, and 3-3 display these ICT-related variables by firm size and years in operations. It appears that larger firms are more likely to invest in ICT and adopt broadband. In addition, larger firms (and in some cases, older firms) have higher number of computers per a hundred of employees. These tables also reveal that, although on average the ICT investments and adoption are low for firms in manufacturing sector (as discussed in Section 2), these results are mainly driven by smaller firms. The micro enterprises, comprising 58% of the sample, are less likely to invest and adopt. The investment and/or adoption issues are not problems for larger firms. However, large enterprises comprise only 2% of the sample.

Table 3-1: Proportion of Establishments with ICT Investments (by Size x Years)

	Micro (1 to 5 persons)	Small (6-50 persons)	Medium (51-200 persons)	Large (> 200 persons)
0 to 5 years	0.11	0.39	0.86	0.94
6 to 10 years	0.08	0.42	0.92	0.97
11 to 20 years	0.08	0.51	0.94	0.98
21 or more years	0.10	0.68	0.96	0.99

Table 3-2: Proportion of Establishments with Broadband Internet (by Size x Years)

	Micro (1 to 5 persons)	Small (6-50 persons)	Medium (51-200 persons)	Large (> 200 persons)
0 to 5 years	0.10	0.30	0.68	0.75
6 to 10 years	0.08	0.32	0.72	0.72
11 to 20 years	0.07	0.39	0.72	0.78
21 or more years	0.08	0.50	0.77	0.87

Table 3-3: Average Number of Computers per Hundred of Employees (by Size x Years)

	Micro (1 to 5 persons)	Small (6-50 persons)	Medium (51-200 persons)	Large (> 200 persons)
0 to 5 years	6.95	9.23	15.33	21.13
6 to 10 years	4.83	9.86	16.60	17.71
11 to 20 years	4.34	11.27	17.06	18.65
21 or more years	4.88	15.59	20.26	19.16

4. Methodology

This paper assumes that the firm's production function is Cobb-Douglas. The log-linear form of the production function, as illustrated below, can be estimated using OLS.

$$q_i = a_i + \alpha_K k_i + \alpha_L l_i \quad (1)$$

q_i represents (log of) firm i's output. k_i and l_i are (log of) capital and labor which are the inputs of the production function. α_K and α_L are shares of capital income and labor income. a_i is (log of) firm i's total factor productivity (TFP). From the merged dataset, the value-added information is used as output,[7] the number of workers is used as labor input, and the value of fixed assets (the average of the beginning and ending values) is used as capital input. The (log of) firm i's TFP can be estimated and will be used as the dependent variable in equation (2).[8]

To investigate the impact of broadband connectivity on firm productivity, the following equation is estimated:

$$y_i = \beta_0 + \beta_{BB} \cdot BB_i + \rho' x_i + \theta_c + \gamma_p + \varepsilon_i \quad (2)$$

y_i represents (log of) firm i's TFP. BB_i is the broadband variable. x_i is the vector of the firm's characteristics including years in operation, size, and share of skilled workers and its squared term. In addition, the vector also includes the information whether the firm has foreign investment, receives BOI, exports products, and imports inputs. θ_c's are the industry dummies. γ_p's are the province dummies. ε_i's are the error terms. All standard errors estimated in this paper are clustered by province. Since the objective of this paper is to measure the impact of broadband on firm productivity, the variable of interest is β_{BB}.

Equation (2) will be first estimated using OLS. Both the base model (without the broadband variable) and the broadband model (with the broadband variable) will be estimated. However, since the broadband variable may be endogenous, therefore, the Two-Stage Least Squares (2SLS) estimation method will also be applied. The first stage equation is as follows:

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[7] The value-added is calculated by sales (adjusted by changes in goods inventories) subtracted by raw materials costs (adjusted by changes in raw materials inventories) and subtracted by fuel and electricity costs.

[8] Note that some of the calculated value-added figures were negative. Therefore, they were automatically dropped in the regression. The number of total observations became 84,483.

$$BB_i = \mu_0 + \mu_z \cdot z_i + \lambda' x_i + \theta_c + \gamma_p + \xi_i \quad (3)$$

BB_i is the broadband variable as mentioned above. z_i is the instrumental variable. To construct the instrumental variable, the author first defines firms in the same group as belonging to the same size, industry, province, and industrial estate group.[9] z_i is the proportion of firms in the same group that have broadband connection. x_i is the vector of the firm's characteristics as mentioned above. θ_c's are the industry dummies. γ_p's are the province dummies. η_i's, ξ_i's, and ν_i are the error terms.[10]

The 2SLS methodology will be used to estimate the casual impact of broadband adoption on firm productivity. As a robustness test, the full model will also be estimated. In the full model, the ICT investment variable and the ICT density variable will be included in the vector of firm's characteristics, x_i, in the two-stage estimation.

5. Results

Table 4-1 displays the OLS estimation results for the base model (without the broadband variable). Column 1 contains the results when all observations are used. Columns 2, 3, 4, and 5 contain the results when micro (1-5 persons), small (6-50 persons), medium (51-200 persons), and large (more than 200 persons) enterprises are used, respectively. Examining the results, some clear patterns emerge: (i) larger firms have lower productivity; (ii) firms with foreign investments have higher productivity; (iii) firms with BOI have higher productivity; (iv) for smaller firms, the ones that export products or import inputs have higher productivity; (v) firms with higher share of skilled workers have higher productivity but the increment is diminishing. Most of these results are in line with the literature (Paweenawat et al., 2017; Srithanpong, 2016).

[9] Note that the size information is more detailed than micro, small, medium, and large. In addition, this group also takes into account whether the firm belongs to an industrial estate or not. Therefore, this group has more variations than the industry and the province dummies included in the second-stage regression.

[10] The author estimated the regressions using the ivreg2 command in Stata. Note that the 'partial' option was used due to the fact that some of the clusters were too small.

Table 4-1: Results (OLS-Base Model)

VARIABLES	(1) OLS Base Model All	(2) OLS Base Model Micro	(3) OLS Base Model Small	(4) OLS Base Model Medium	(5) OLS Base Model Large
years_in_operation	0.000443	-0.00300***	0.00435**	0.00303	0.00274
	(0.00107)	(0.000868)	(0.00201)	(0.00229)	(0.00195)
foreign_inv	0.152***	0.424*	0.239***	0.181***	0.103*
	(0.0540)	(0.216)	(0.0777)	(0.0418)	(0.0551)
receive_boi	0.295***	1.186***	0.357***	0.169***	0.155**
	(0.0755)	(0.267)	(0.0883)	(0.0597)	(0.0729)
export_products	0.271***	0.361*	0.398***	0.192***	-0.0508
	(0.0572)	(0.197)	(0.0773)	(0.0571)	(0.0804)
import_inputs	0.185***	0.510***	0.201***	0.0926	0.0754
	(0.0376)	(0.105)	(0.0513)	(0.0576)	(0.0732)
share_skilled_workers	1.138***	0.382***	1.532***	0.882**	0.850
	(0.178)	(0.142)	(0.274)	(0.390)	(0.615)
share_skilled_workers_sq	-1.463***	-0.247	-1.873***	-1.064***	-0.964*
	(0.250)	(0.199)	(0.321)	(0.396)	(0.568)
size_6_50	-0.226***				
	(0.0352)				
size_51_200	-0.491***				
	(0.0790)				
size_above200	-1.121***				
	(0.0755)				
Constant	0.750***	0.792***	0.399***	0.354***	-0.317**
	(0.0405)	(0.0292)	(0.0598)	(0.132)	(0.138)
Observations	84,483	48,310	30,160	4,134	1,879
R-squared	0.212	0.151	0.339	0.251	0.195
Province Dummies	Yes	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Sample	All	1-5	6-50	51-200	>200

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4-2 displays the OLS estimation results with the broadband variable. The coefficients of the broadband variable are positive and significant for all but large enterprises. For micro enterprises, adopting broadband is associated with 37% higher in productivity. For small and medium enterprises, adopting broadband is associated with 46% and 39% higher in productivity, respectively.

Table 4-3 illustrates the 2SLS estimation results. The top panel reports the second-stage results whereas the bottom panel reports the first-stage results.[11] The Kleibergen-Paap statistics, reported at the bottom of the table, are significantly large, allowing the author to reject the null hypothesis that the instrument is weak. The coefficients of the broadband variable remain positive and significant for all but large firms, with the magnitude ranging from 64% to 81%.

Table 4-4 reveals the results of the 2SLS full model with the ICT investment variable and the ICT density variable included as additional explanatory variables. The coefficients of the broadband variable remain positive and significant for micro, small, and medium enterprises. By adopting broadband, micro enterprises can increase productivity by 54%, while small enterprises and medium enterprises can increase productivity by 23% and 44%, respectively.

[11] Only the relevant variable, the group broadband variable, is shown for the first-stage results.

Table 4-2: Results (OLS-Broadband Model)

VARIABLES	(1) OLS Broadband Model All	(2) OLS Broadband Model Micro	(3) OLS Broadband Model Small	(4) OLS Broadband Model Medium	(5) OLS Broadband Model Large
years_in_operation	0.000136	-0.00263***	0.00330*	0.00275	0.00211
	(0.00110)	(0.000917)	(0.00185)	(0.00219)	(0.00206)
foreign_inv	0.145***	0.351	0.227***	0.172***	0.0921*
	(0.0514)	(0.220)	(0.0809)	(0.0422)	(0.0528)
receive_boi	0.268***	1.141***	0.312***	0.162***	0.139**
	(0.0676)	(0.277)	(0.0789)	(0.0585)	(0.0666)
export_products	0.210***	0.266	0.300***	0.180***	-0.0500
	(0.0491)	(0.194)	(0.0644)	(0.0561)	(0.0792)
import_inputs	0.124***	0.406***	0.132***	0.0776	0.0688
	(0.0392)	(0.107)	(0.0497)	(0.0606)	(0.0743)
share_skilled_workers	1.005***	0.358**	1.448***	0.710*	0.747
	(0.155)	(0.137)	(0.257)	(0.360)	(0.598)
share_skilled_workers_sq	-1.314***	-0.281	-1.763***	-0.869**	-0.847
	(0.218)	(0.192)	(0.298)	(0.354)	(0.538)
size_6_50	-0.337***				
	(0.0354)				
size_51_200	-0.712***				
	(0.0672)				
size_above200	-1.339***				
	(0.0651)				
broadband	0.485***	0.374***	0.457***	0.390***	0.219
	(0.0685)	(0.0472)	(0.0664)	(0.104)	(0.132)
Constant	0.692***	0.767***	0.230***	0.0745	-0.473***
	(0.0479)	(0.0316)	(0.0772)	(0.156)	(0.158)
Observations	84,483	48,310	30,160	4,134	1,879
R-squared	0.229	0.158	0.357	0.266	0.200
Province Dummies	Yes	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Sample	All	1-5	6-50	51-200	>200

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4-3: Results (2SLS-Broadband Model)

VARIABLES	(1) 2SLS Broadband Model All	(2) 2SLS Broadband Model Micro	(3) 2SLS Broadband Model Small	(4) 2SLS Broadband Model Medium	(5) 2SLS Broadband Model Large
SECOND STAGE					
years_in_operation	-9.16e-05	-0.00237***	0.00285	0.00245	0.00218
	(0.00114)	(0.000892)	(0.00187)	(0.00210)	(0.00198)
foreign_inv	0.139***	0.300	0.222***	0.162***	0.0933*
	(0.0495)	(0.225)	(0.0815)	(0.0431)	(0.0517)
receive_boi	0.248***	1.109***	0.293***	0.155***	0.141**
	(0.0629)	(0.286)	(0.0764)	(0.0574)	(0.0665)
export_products	0.165***	0.199	0.259***	0.168***	-0.0501
	(0.0464)	(0.206)	(0.0619)	(0.0572)	(0.0765)
import_inputs	0.0781*	0.334***	0.102**	0.0613	0.0695
	(0.0432)	(0.127)	(0.0514)	(0.0629)	(0.0710)
share_skilled_workers	0.906***	0.342**	1.412***	0.523	0.759
	(0.145)	(0.135)	(0.251)	(0.359)	(0.563)
share_skilled_workers_sq	-1.204***	-0.304	-1.716***	-0.658*	-0.860*
	(0.203)	(0.186)	(0.292)	(0.344)	(0.505)
size_6_50	-0.419***				
	(0.0409)				
size_51_200	-0.876***				
	(0.0755)				
size_above200	-1.501***				
	(0.0762)				
broadband	0.844***	0.636***	0.652***	0.814***	0.195
	(0.0846)	(0.101)	(0.0635)	(0.139)	(0.160)
FIRST STAGE					
group_broadband	0.986***	0.959***	0.973***	0.985***	0.968***
	(0.00297)	(0.00730)	(0.00501)	(0.00678)	(0.0154)
Observations	84,483	48,310	30,160	4,134	1,879
R-squared	0.080	0.035	0.113	0.064	0.028
Province Dummies	Yes	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Sample	All	1-5	6-50	51-200	>200
Kleibergen-Paap F-stat	109977	17274	37747	21085	3948

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4-4: Results (2SLS-Full Model)

VARIABLES	(1) 2SLS Full Model All	(2) 2SLS Full Model Micro	(3) 2SLS Full Model Small	(4) 2SLS Full Model Medium	(5) 2SLS Full Model Large
SECOND STAGE					
years_in_operation	-0.000292	-0.00232***	0.00176	0.00152	0.00147
	(0.00112)	(0.000880)	(0.00179)	(0.00195)	(0.00204)
foreign_inv	0.130***	0.309	0.185**	0.147***	0.0890*
	(0.0482)	(0.224)	(0.0750)	(0.0425)	(0.0483)
receive_boi	0.243***	1.079***	0.265***	0.136**	0.112
	(0.0631)	(0.279)	(0.0743)	(0.0563)	(0.0685)
export_products	0.151***	0.197	0.215***	0.131***	-0.0555
	(0.0449)	(0.198)	(0.0581)	(0.0496)	(0.0794)
import_inputs	0.0643	0.291**	0.0759	0.0468	0.0566
	(0.0414)	(0.122)	(0.0494)	(0.0622)	(0.0750)
share_skilled_workers	0.897***	0.362***	1.435***	0.398	0.680
	(0.144)	(0.135)	(0.251)	(0.333)	(0.581)
share_skilled_workers_sq	-1.195***	-0.329*	-1.716***	-0.503	-0.780
	(0.199)	(0.186)	(0.289)	(0.315)	(0.518)
size_6_50	-0.450***				
	(0.0373)				
size_51_200	-0.924***				
	(0.0701)				
size_above200	-1.532***				
	(0.0689)				
broadband	0.620***	0.540***	0.231**	0.440***	0.141
	(0.0949)	(0.191)	(0.0914)	(0.109)	(0.178)
ICT_investment	0.257**	0.0175	0.510***	1.256***	0.0389
	(0.105)	(0.141)	(0.107)	(0.447)	(0.322)
ICT_density	0.00102***	0.00161***	0.00123***	0.00139	0.00589**
	(0.000256)	(0.000588)	(0.000422)	(0.000905)	(0.00264)
FIRST STAGE					
group_broadband	0.585***	0.562***	0.569***	0.860***	0.916***
	(0.0357)	(0.0349)	(0.0401)	(0.0348)	(0.0344)
Observations	84,483	48,310	30,160	4,134	1,879
R-squared	0.097	0.038	0.143	0.136	0.045
Province Dummies	Yes	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Sample	All	1-5	6-50	51-200	>200
Kleibergen-Paap F-stat	268.3	258.7	200.9	611.5	707.8

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6. Conclusions and Policy Implications

Thailand has been promoting the "Digital Thailand" scheme in which the digital technology and innovation are encouraged as tools to get the country out of the middle-income trap. Several projects were implemented to build broadband infrastructure, to equip citizens with digital-technology related skills, and to encourage businesses to adopt digital technology.

Using a large dataset of almost 100,000 manufacturing establishments in Thailand, this paper studies the impact of broadband internet connectivity on firms' total factor productivity (TFP). The author finds that, for micro-, small-, and medium-sized enterprises, broadband adoption can raise productivity by 23% to 54%.

Although the results reveal substantial benefits of broadband adoption, especially for smaller-sized firms, only about 30% of firms reported adopting broadband or having any types of ICT investments. It is interesting to investigate further why many firms do not make use of ICT. The 2016 ICT Establishment Survey contained additional questions asking firms to provide reasons why they did not utilize computers.[12] Interestingly, the majority of firms (93%) reported that they felt the technology was unnecessary or did not fit with their business models. Other reasons were: they felt that the technology was too expensive (23%); existing workers do not have the skills (13%); they could not hire workers with the skills (5%); they felt that the technology changed too fast (5%); and they felt hesitant to adopt (2%).

The fact that most firms felt that the technology was unnecessary or did not fit with their business models is troubling. Even if their businesses are simple and small, basic computing technology can reduce redundant routine tasks and improve efficiency. Perhaps this answer reflects the lack of understanding about the technology itself and how it can be used in businesses.

As the results of this paper reveal, the benefits of ICT investments, especially the adoption of broadband, are substantial. These results support the government's policies in building the country's broadband infrastructure and encouraging businesses to adopt the relevant technology. However, as discussed above, many enterprises, especially the smaller ones, may still lack knowledge about the technology itself and what it can do, resulting in low

[12] Respondents can choose more than one answer.

adoption rate. Therefore, more efforts are needed to educate entrepreneurs and workers about the benefit of the technology and how it can be used to enhance productivity. As the costs of technology are becoming increasingly cheaper over time, the realized benefits of investing in such technology can be realized even faster and at a larger scale.

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