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Impact of Trade Liberalization and Technology Advancements on Productivity: Evidence From Thai Manufacturing Sector

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Abstract

This study investigates the impact of trade liberalization and technology advancements on firm's productivity by employing alternative trade (input and output tariff) and technology variables (ICT and industrial robot). Three latest Thai industrial censuses are used with panel random effect model. Firm's productivity is computed by means of alternative measurement, i.e. value added per worker, Olley-Pakes (1996) and Levinsohn & Petrin (2003). The key finding is that trade liberalization and technology advancements can spur Thai firms' productivity, however, technology advancements show more robust positive impact. For trade liberalization aspect, higher trade liberalization on input side, i.e. lowering input tariff shows higher positive impact on firm's productivity than output side. However, Thai firms are likely to consider input and output tariffs simultaneously so that effective rates of protection (ERP), with and without water in tariffs are introduced. The results confirm a crucial role of trade liberalization, through a simultaneous decline in both input and output tariffs, in promoting firms' productivity. Regarding proxies of technology, ICT use tends to encourage greater firms' productivity improvement than industrial robot uses due to its longer engagement in all manufacturing industries.

Keywords— Productivity, Trade liberalization, Technology advancement.

Introduction

Enhancing firms' productivity is one of the crucial elements in promoting sustainable economic growth. In boosting productivity, two areas are widely discussed in the literatures, one is trade openness and the other one is using technology advancement. Trade theories, both traditional (Ricardian model and Heckscher-Ohlin model) and new ones (Krugman, 1979; Helpman and Krugman, 1985; Melitz, 2003) tend to support trade openness in inducing higher growth and productivity. A number of empirical studies (e.g. Bernard et al 2006; Gries et al, 2012; Miller; 2010) also showed that trade openness could lead to higher economic growth and productivity improvement. For firm' production process, trade can help increase access unavailable varieties and higher quality of imported inputs that can generate productivity growth from embed technology and technology transfer from high to low-tech countries. In addition, trade could induce firm improve existing production process resulting from higher competitive pressure (Muendler, 2004). International organization, e.g. World Bank, IMF, and OECD regularly advice that trade openness would generate favorable impact on economic growth and productivity.

In term of technology advancement, traditional theoretical aspects (i.e. Neoclassical theory) state that sustained long-term economic growth arises from technological progress in addition to appropriate inputs, i.e. capital and labour. Later, several theoretical studies (i.e. Helpman, 1991; Martinez et al, 2018) confirm that countries with progress in technology will enjoy higher rate of productivity and economic growth than those with low technology progress. Technologies can lead to both product and process innovation or even innovation in business model thereby improving firms' productivity. Over the last three decades, firms, especially ones in developed countries, have attempted to upgrade their production technology to deal with higher costs of production. In developing countries, many have tried to push their economies towards industry 4.0.

Interestingly, although issues of trade liberalization and technology advancements in enhancing productivity and growth are crucial, empirical evidence is still limited. There has been no study that examines the role of trade

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openness and technology advancement on productivity (or economic growth) simultaneously. For the role of trade openness, most studies examine the impacts of trade openness only from output point of views, i.e. impacts of trade liberalization arising from finish products. Only few studies do examine liberalization from both outputs and inputs simultaneously. Amiti & Konings (2007) and Luong (2011) are exceptions. The results from these studies indicate that reducing input tariff has higher positive impact on firm-level productivity. In terms of technology advancements, especially ones moving economies towards industry 4.0, most previous studies examine such impacts using developed countries as case studies. Evidence from developing countries is sparse. For example, Kromann et al (2011) studied industrial robot uses for 11 EU countries, Dauth et al (2017) studied effect of both ICT uses and industrial robot uses for Germany. Moreover, so far there has been no study that examines the role of trade openness and technology advancement on productivity (or economic growth) simultaneously. In fact, the relative importance of these two variables are crucial.

With unfulfilling points in the literature, this study aims to examine the impacts of both trade liberalization and technology advancement all together on firms' productivity using Thailand as a case study. Thailand is a good case study at hand for two key reasons. First, Thailand has implemented trade liberalization policies for long periods since the early 1990s. Input and output tariffs have been reduced substantially, but at different rate. Second, Thailand is moving towards Thailand 4.0 where innovation/ technologies, including automation and industrial robots, are expected to play a big role in Thai manufacturing sector.

This study investigates the impact of trade liberalization and technology advancements by employing various alternative trade and technologies variables via 3 latest Thai industrial census. Firm's productivity is computed by means of alternative measurement, i.e. value added per worker, Olley-Pakes (1996) and Levinsohn & Petrin (2003). Trade liberalization, in this study, are proxied by various measurements including tariffs, both nominal and effective rate of protection (ERP). Computer uses, so far, has used as proxy of technologies advancements while in this study also uses industrial robot which expect to play big role in Thai manufacturing during Thailand 4.0 era.

Literature Review

Empirical studies of trade liberalization

Trade openness has a positive effect on productivity and economic growth and in macroeconomic view, many of empirical evidence showed that more open economies will grow faster, and it reconciled to microeconomic findings. Evidence from industry-level also present positive effect of trade liberalization. Bernard et al (2006) investigated the relationship of international trade and economic efficiency or the effect of declining trade cost and plant outcome from U.S. manufacturing during 1977 to 2001 with OLS regression. Furthermore, there are some literatures investigating import- penetration's effect of specific country especially China since it is one of the most interested countries for empirical studies and it is a major exporter both intermediate goods and final good. However, there are some scholars who doubt about the role of trade openness in promoting productivity and growth. For example, Rodriguez & Rodrik (2000) argued that relationship of trade openness and economic growth is ambiguous depending on characteristic of country and type of trade openness policies used in the empirical studies.

If we consider specifically the effect of trade liberalization from import side, import can affect firm's productivity from better quality and variety of input and intermediate goods. Previous empirical studies analyzed impact of trade liberalization on productivity of firm-level and industry level by considering the effect of import penetration, import input or intermediate goods and reducing inputs' tariff on productivity. Almost of empirical investigating impact of trade liberalization on input found that imported input and input tariff have positive effect to productivity. Reducing input tariff, therefore, can induce firm import intermediate goods and lead to productivity changes. Fernandes (2003) and Amiti & Konings (2007) investigated from plant-level and firm's productivity in Columbia and Indonesia in 1991-2000 respectively with OLS plant fixed effect and they found similar results that imported intermediate good can affect and involve to productivity. Alternatively, there are some studies use effective rate of protection as representative of trade policy and trade liberalization to find its effect on productivity (ERP) for the case of Thailand, e.g. Jongwanich & Kohpaiboon (2017). The results for these studies indicate that higher cross-border protection have lower productivity, in the other word, protection can dilute productivity improvement. Interestingly, for panel-data analysis during in the case of Thailand, Jongwanich&Kohpaiboon (2020), who applied ERP to reflects industry policy, found negative impact of higher protected industries. This study also suggests using ERP, which consider the effect input and output simultaneously, is better illustrate the impact of liberalization than input and output tariff on firm-level productivity.

Empirical studies of technology advancements

Technology advancement have been focused as one of the important factors to enhance productivity at firm-level, industry-level, and country-level. In first stage of empirical related literatures, technology advancements have been considered as capital accumulation and nowadays, industrial robot, and artificial intelligence (A.I.) will be consider for proxies of technology advancement. Moreover, office, computing and accounting machinery, communication equipment science and engineering equipment as high-tech share capital (Feenstra et al, 1997). Furthermore, Bartel et al (2007) identified technology advances that are using a computer numerically controlled (CNC), and flexible manufacturing system (FMS) can reduce inspection time in quality control.

Dauth et al (2017) studied the impact of the change in the number of industrial robots per thousand workers in German manufacturing firms with 2SLS method. The result can be concluded that industrial robots can raise labor productivity or every additional industrial robot per thousand workers can raise the growth rate of GDP per employed worker by 0.5365 percent. Graetz et al (2018) investigated impact of industrial robot on employment and change of TFP by using panel data of 17 developed countries with OLS and 2SLS technique. Both of OLS and 2SLS results suggested that most of the labor productivity comes from increasing of using industrial robot. Nevertheless, there are limited empirical studies that examine both trade liberalization and technology simultaneously on growth and productivity. There is only Autor et al (2015) who applied to trade and technology examined the impact on employment in US local labour markets during 1980 to 2007 but not productivity. This study suggested that the effect of trade and technology can be observed separately and simultaneously by using OLS and 2SLS. On the other hand, some of previous empirical studies also investigated the relationship between other technologies advancement variables and growth. Interestingly, Van Ark et al (2003) found that during 1995 to 2005 faster productivity growth in services industries using ICT intensive can cause U.S. productivity has grown faster than in EU by analyzing labor productivity growth in 51 countries in European countries and U.S. with shift share method. The growth in U.S. gains from both adoption ICT using and the production of ICT.

Empirical Analysis

The model

In this study, plant-level productivity will be considered to determine the impact of trade liberalization and technology advancements. The control variables include both firm and industry-level specific characteristic factors.

For firm-specific factors, the control variables are as follows ratio of output exported of firm $(expout_{ijt})$. Foreign ownership, $(forown_{ijt})$, the ratio of blue-collar labor to employment $(highL_{ijt})$, firm age (age_{ijt}).

Regrading industry-specific factors in this study, trade liberalization variable $tradelibre_{jt}$, which is our key interest variable, is included in the model. Trade liberalization is proxied here, including tariff rates, both nominal and effective rate of protection (ERP) For nominal tariff rates, they are divided into output tariff $(outputtariff_{jt})$ and input tariff $(inputtariff_{jt})$. Input tariff can be computed as weighted average of the output tariffs by using information from input-output table. The concordance between input- output table and ISIC classification is developed to obtain the input and output tariffs in each industry The formula to calculate is as follows:

$$inputtariff_i = \sum_{i=1}^{n} a_{ij} t_i \quad (3.1)$$

where

t_i is nominal tariff on industry i[th]

$\sum_{i=1}^{n} a_{ij}$ is the sum of share of intermediate input (1, ... , n) in the output value product j[th]

ERP across industries can be calculated by using data of the weighted average of tariff and the formula is shown as follows.

$$ERP\_no_{jt} = \frac{t_j - \sum_{i=1}^{n} a_{ij} t_i}{1 - \sum_{i=1}^{n} aij} \quad (3.2)$$

where t_j = nominal tariff on output j^{th},

t_i = nominal tariff on input i^{th},

$\sum_{i=1}^{n} a_{ij} t_i$ = the sum of the shares of intermediate inputs (1, …, n) in the output value of product j^{th}

Moreover, ERP can be adjusted to capture a possible water in tariffs that output tariff become ineffective. The ineffective tariff can occur from exporting firms improve their productivity (Jongwanich&Kohpaiboon,2020). The ERP with water in tariff is calculated as in equation 3.3

$$ERP\_total_{jt} = (1 - \alpha_{jt}) ERP_{no_{jt}} + (\alpha_{jt}) ERPexport_{jt} \quad (3.3)$$

where α_{jt} is the share of exports of output of industry j at time t, $ERPexport_{jt}$ is treat at market interest (Jongwanich&Kohpaiboon,2020) since tariff on final goods and intermediate good become ineffective in protecting producer and exporter can draw back tariff on raw material. Exporters should pay tariffs in advance before applying for drawback, thus, market interest can represent opportunity cost and ERP for exporting.

Technology advancements are also included as an industrial-specific factor. two variables are used to proxy technology advancements, namely ICT uses (ICT_{jt}) and industrial robot $(robot_{jt})$.

All in all, the empirical model used in this study is shown in equation 3.4,

$$lnY_{ijt} = \gamma_0 + \beta_1 lnK_{ijt} + \beta_2 lnL_{ijt} + \beta_3 lnK_{ijt} lnL_{ijt} + \beta_4 (lnL_{ijt})^2 + \beta_5 (lnK_{ijt})^2 + \\ + \gamma_1 expout_{ijt} + \gamma_2 highL_{ijt} + \gamma_3 age_{ijt} + \gamma_4 forown_{ijt} + \gamma_5 tradelibre_{jt} + \gamma_6 tech_{jt} + \varepsilon_{ijt} \quad (3.4)$$

Data source and variable measurement

To determine effects of trade liberalization and technology advancements on firms (plants)'level data, Thailand Industrial Census in year 2007 to 2017 from the National Statistical Office of Thailand, are employed. Industrial census data can be matched to be panel data by matching ID No. that refer to the same firms. Therefore, the panel data of 9,211 observations from Thailand Industrial Census in year 2007, 2012 and 2017 are used. For each year of census, duplicate observations by detecting key variables including total workers, initial fixed assets, ending fixed assets, registered capital, sale value, and input values. The data set are cleaned by dropping unreliable observation for example, dropping firm having negative value added, low value added (less than 10,000), and low fixed asset (less than 10,000). The firm defined as small/micro enterprise or having less than 10 workers were excluded from observation since their performance might be difference from larger plants. Additionally, identification of ISIC 3 at 4 digits-level of each observation are also check and firm having difference in 3 years census were excluded. Finally, industries, that serve niches in domestic market (e.g. processing of nuclear fuel, and manufacture of weapons and ammunition), in the service sector (e.g. building and repairing of ships, manufacture of aircraft and spacecraft, and recycling) or are obviously preserved local businesses (e.g. manufacture of coke oven products, manufacture of ovens, furnaces and furnace burners) Thus, after data cleaning process there are 2,842 firms from 3 latest industrial censuses and 4,254 firms for 2 latest industrial censuses are valid for analyzing in this study.

Plant-level productivity will be estimated through using standard measure, i.e. value add per worker, and specific model, i.e. Olley-Pakes (1996) and Levinsohn & Petrin (2003) Both of the OP and the LP techniques decompose error term in traditional OLS into two terms including productivity shock that can be observed by firm and white noise error. In the OP method, investment is used as a proxy for observable productivity shock term, while the LP uses intermediate input or material used instead investment since Investment is not valid for plant reporting zero investment and these will be excluded from observations.

The data of import and export are gathered form UN Comtrade Data base. Six-digits product level of trade data classified in HS 2002 are extract from this database and changed into TSIC industry-level. Tariff used in this study are gathered from World Trade Organization tariff data and reported in six-digits HS code. Consequently, tariff data and import data on six digits HS code were match to four-digits ISIC Rev.3 and TSIC. Furthermore, output of each manufacturing sector is from Office of the National Economic and Social Development Council (NESDC). For industrial robot, data are from International Federation of Robotics (IFR), which provides information both in country and industry level. The data is available from 2005 to 2017. Furthermore, ICT uses data of each TSIC industry-level are from Digital Economy Promotion Agency (DEPA) including computer uses and software and it is available from 2012 to 2018

All in all, the empirical model used in this study is shown in equation 3.5 with theoretically expected sign attached to each controlling variable.

$$lnY_{ijt} = \gamma_0 + \beta_1 lnK_{ijt} + \beta_2 lnL_{ijt} + \beta_3 lnK_{ijt} lnL_{ijt} + \beta_4 (lnL_{ijt})^2 + \beta_5 (lnK_{ijt})^2 + $$
$$+\gamma_1\, expout_{ijt} + \gamma_2 highL_{ijt} + \gamma_3 age_{ijt} + \gamma_4 forown_{ijt} + \gamma_5 tradelibre_{jt} + \gamma_6 tech_{jt} + \varepsilon_{ijt} \quad (3.5)$$

where

lnY_{ijt} = Value added /or productivity measured by value added, the OP and the LP techniques in time t, lnK_{ijt} = Fixed asset of local plant *i* in industry *j* in time t, lnL_{ijt}= Number of workers of local plant *i* in industry *j* in time t, $expout_{ijt}$ = Percentage of import raw material of local plant *i* in industry *j* (+), $highL_{ijt}$ = Ratio of production (bule-collar) workers to total workers of local plant *i* in industry *j* in time t, (-), age_{ijt}= Age of local plant *i* in industry *j* in time t (+), $forown_{ijt}$ = Foreign equity of firm *i* in industry *j* in time t (+),

$tradelibre_{jt}$ = Proxy of trade liberalization variables at industry-level including $outputtriff_{jt}$ or Output tariff industry *j* (-), $inputtariff_{jt}$ or Input tariff industry *j* (-), ERP_no_{jt} or effective of protection with no export tariff of industry *j* (+/-), ERP_water_{jt} or effective of protection without export tariff of industry *j* (-),

$tech_{jt}$ = Proxy of technology advancements variables at industry-level including $robot_{jt}$ or density of industrial robot per workers or ratio of industrial robot per worker using in time t of industry *j* (+), ICT_{jt} or ICT uses of industry *j* in time t (+),

ε_{ijt} = A stochastic error term omitted in the model and productivity measurement

The results and discussion

Equation 3.5 is estimated using panel data model with time dummy variable as time fixed effect that also included in empirical studies regarding trade liberalization i.e. Amiti & Konings (2007). Random effect is chosen for estimation since some of our interest variables, which are industrial variables, adjust slowly over the periods, especially technology and trade policy variables. All regression results pass 1 percent level of the overall significance. Results when value-added per worker is used as a dependent variable are similar to those when the LP method is employed. By contrast, results when the OP method is employed to obtain firms' productivity are vastly different from those when the LP or value added per worker are employed. As mentioned earlier, the OP productivity measurement uses investment to control for unobserved firm's productivity process, which is valid only for firm having non-zero investment. These reasons are widely used to support using the LP productivity measurement instead of the OP. In particular, Fernandes, A. (2003), Topalova et al (2011) argued that the OP can cause bias since many samples are not included for Chilean and Indian manufacturing sectors, respectively. The OP method does not seem to be well suitable for the Thai data set in which large portion of observations are truncated. In other words, productivity measured by the LP method and value-added per worker is more appropriate so that results discussed later in this chapter are based on these two measures.

The effect of trade liberalization on firm-level productivity

Evidence of negative effect of only input tariff or output tariff on firm-level productivity are found in thesis. The coefficients corresponding $outputtriff_{jt}$ and $inputtariff_{jt}$ are negative and statistically significant as exhibited in table 4.1. This finding reveals reducing input tariff and output tariff has positive impact on firm's productivity which in line with our expectation sign as discussed earlier. However, when tariff is included in the model separately, a reduction of input tariffs shows more powerful in raising firm-level productivity in Thai manufacturing sector. Our results are similar to Amiti & Konings (2007).

Interestingly, after combining the impact of output tariff and output tariff on productivity the estimation result is shown in column (3) of table 4.1. The outcome exhibits the coefficients corresponding to input tariff 's $(inputtariff_{jt})$ are statistically significant while output tariff $(outputtriff_{jt})$ coefficients are statistically insignificant. This finding is consistent with Jongwanich & Kohpaiboon (2020) which discovered negative, but statistically insignificant of output tariff reduction. Nevertheless, the insignificant impact of output tariff reduction raises some concern in considering input and output tariffs separately in the empirical model. It is likely that Thai firms consider both input and output tariff simultaneously for their business operation (Jongwanich&Kohpaiboon, 2020).

Table 4.1

Impact of input and output tariff on productivity

	(1) Only input tariff			(2) Only output tariff			(3) Both input and output tariff		
Variables	Value added per worker (A)	OP (B)	LP (C)	Value added per worker (D)	OP (E)	LP (F)	Value added per worker (G)	OP (H)	LP (I)
expp	0.583***	0.396***	1.320***	0.543***	0.375***	1.252***	0.542***	0.375***	1.253***
	(0.078)	(0.057)	(0.090)	(0.086)	(0.064)	(0.097)	(0.086)	(0.065)	(0.097)
age	0.131***	0.157***	0.333***	0.129***	0.197***	0.346***	0.135***	0.198***	0.352***
	(0.031)	(0.027)	(0.038)	(0.034)	(0.028)	(0.042)	(0.034)	(0.281)	(0.042)
forp	0.445***	0.556***	1.014***	0.482***	0.533***	1.011***	0.485***	0.534***	1.014***
	(0.088)	(0.064)	(0.104)	(0.095)	(0.071)	(0.110)	(0.095)	(0.072)	(0.111)
highl	-0.282***	-0.127***	-0.343***	-0.273***	-0.130**	-0.343***	-0.282***	-0.132**	-0.350***
	(0.053)	(0.050)	(0.215)	(0.058)	(0.055)	(0.060)	(0.058)	(0.055)	(0.064)
inputtariff	-1.729***	-0.483	-1.657***				-2.592***	-0.596	-2.450***
	(0.440)	(0.425)	(0.608)				(0.506)	(0.574)	(0.774)
outputtariff				-0.410***	-0.86	-0.747**	-0.049	0.028	-0.313
				(0.233)	(0.164)	(0.307)	(0.268)	(0.181)	(0.348)
con	11.067***	11.470***	9.514***	10.724***	11.348***	9.507***	10.725***	11.353***	9.528***
	(0.786)	(0.085)	(0.114)	(0.832)	(0.087)	(0.131)	(0.834)	(0.092)	(0.130)

Note: *, **, *** represent 1,5, and 10 percent significant level respectively; OP = Olley-Pakes (1996) and Levinsohn & Petrin = (2003) productivity measurement

Source: Author's calculation

To take into account a possible simultaneous effect of input and output tariffs, effective rate of protection (ERP) is employed to represent trade liberalization**.** ERP is measured by two alternatives; one is without considering water in tariff while the other includes such impact. The results reveal the negative coefficient corresponding to ERP with no water in tariff (ERP_{jt}_no) and ERP water in tariff (ERP_{jt}_total) (Table 4.2). This reflects that The negative and significant results shown here is consistent with the previous studies, e.g. Jongwanich & Kohpaiboon (2017) who discovered that industry protection can slowdown productivity generating process in the case of Thai manufacturing and Topalova et al (2011) who found less productive firms are in higher protected industry in the case of Indian manufacturing sector. Interestingly, our results show that ERP with water in tariff shows greater negative impact on firm-level productivity than ERP with no export tariff. This outcome consists with Jongwanich&Kohpaiboon (2020) who found the impact of ERP with water in tariff has strongest impact among four alternatives and reveal that reducing input and output tariff simultaneously stimulus firm's productivity enhancing. All in all, the negative and statistical significance of both ERP implies Thai firms consider both input and output tariff concurrently for their business operation**.**

Table 4.2

Impact of effective rate of production on productivity

	ERP with no water in tariff			**ERP with water in tariff**		
Variables	**Value added per worker**	**OP**	**LP**	**Value added per worker**	**OP**	**LP**
expp	0.581*** (0.077)	0.391*** (0.057)	1.318*** (0.089)	0.591*** (0.077)	0.393*** (0.057)	1.328*** (0.089)
age	0128*** (0.030)	0.157*** (0.027)	0.330*** (0.038)	0.128*** (0.030)	0.157*** (0.027)	0.329*** (0.038)
forp	0.452*** (0.088)	0.559*** (0.064)	1.018*** (0.104)	0.443*** (0.088)	0.560*** (0.064)	1.007*** (0.104)
highl	-0.260*** (0.053)	-0.124*** (0.035)	-0.363*** (0.589)	-0.261*** (0.053)	-0.124*** (0.050)	-0.3245** (0.059)
ERP	-0.326*** (0.059)	-0.029 (0.057)	-0.363*** (0.082)	-0.518** (0.086)	-0.073 (0.084)	-0.604*** (0.116)
con	11.186*** (0.781)	11.454*** (0.038)	9.517*** (0.115)	11.242*** (0.785)	11.459*** (0.085)	9.539*** (0.115)

Note: *, **, *** represent 1,5, and 10 percent significant level respectively; OP = Olley-Pakes (1996) and Levinsohn & Petrin = (2003) productivity measurement

Source: Author's calculation

The effect of technology on firm-level productivity

The effect of technologies, which are proxied by industrial robot uses in production process $(robot_{jt})$ and firm's computer using (ICT_{jt}) at industry-level, are presented in table 4.3. The coefficient corresponding to $robot_{jt}$ and ICT_{jt} are statistically significant at 1 percent level for all productivity measurements. The coefficient corresponding to ICT_{jt} is remarkably greater than $robot_{jt}$ for all productivity measurements. It reflects higher positive impact on firm-level productivity from ICT adoption than industrial robot adoption. The finding could arise from the fact that ICT uses are related to both inbound and outbound business activities such as whereas industrial robot uses are mostly related to internal production process (Jongwanich&Kohpaiboon, 2019). Another reason is ICT has been widely using in business while industrial robot has been introduced in business just few years ago so that its effect might not be well recognized. In Thai manufacturing sector, ICT uses seem to increase from 2012 to 2017 in almost all industries and it has covered for all industries before 2012. By contrast, industrial robot had just adopted in

Thailand since 2012 and has been concentrated in some sectors, especially in automotive, electronics, and plastic & chemical products. Therefore, productivity improvement generated by ICT tends to be higher than that generated by industrial robot use.

Table 4.3

Impact of technology advancement on productivity

Variables	**Value added per worker**	**OP**	**LP**
expp	0.610*** (0.076)	0.407*** (0.057)	1.347*** (0.088)
age	0.123*** (0.030)	0.153*** (0.027)	0.323*** (0.038)
forp	0.400*** (0.087)	0.529*** (0.064)	0.936*** (0.103)
highl	-0.274*** (0.052)	-0.128** (0.050)	-0.338*** (0.059)
robot	0.009*** (0.003)	0.006** (0.002)	0.021*** (0.004)
ict	2.145*** (0.179)	0.521*** (0.167)	2.503*** (0.219)
con	10.980*** (0.778)	11.395*** (0.043)	9.165*** (0.117)

Note: *, **, *** represent 1,5, and 10 percent significant level respectively; OP = Olley-Pakes (1996) and LP = Levinsohn & Petrin (2003) productivity measurement

Source: Author's calculation

Combining the effects of trade liberalization and technology advancements

As discussed in 4.2, ERPs show significant effect to firms' productivity, thus they are chosen to be representative of trade liberalization. When trade and technology are combined in the empirical model as presented in table 4.4, technology advancements show higher positive impact. Furthermore, ICT which have widely using in Thai manufacturing exhibits greater positive impact on firm-level productivity than industrial robot. The stronger positive impact of technology than trade could arise from (1) Tariffs (especially nominal ones) have been relatively low. Tariff reform in 1990s substantially brought down nominal tariff rates in all sectors in Thailand. (2) Costs of accessing in some technology like ICT are likely to be cheaper than those of participating in international market.

Table 4.4

Impact of effective rate of protection and technology advancement on productivity

	ERP with no water in tariff			ERP with water in tariff		
Variables	**Value added per worker**	**OP**	**LP**	**Value added per worker**	**OP**	**LP**
Expp	0.617*** (0.076)	0.407*** (0.057)	1.354*** (0.088)	0.620*** (0.076)	0.408*** (0.057)	1.357*** (0.088)
Age	0.124*** (0.001)	0.153*** (0.027)	0.322*** (0.038)	0.123*** (0.030)	0.153*** (0.027)	0.322*** (0.379)
Forp	0.400*** (0.087)	0.529*** (0.064)	0.935*** (0.103)	0.397*** (0.087)	0.528*** (0.064)	0.936*** (0.103)
Highl	-0.266*** (0.052)	-0.128*** (0.050)	-0.330*** (0.059)	-0.273*** (0.052)	-0.128*** (0.50)	-0.338*** (0.059)
ERP	-0.214*** (0.060)	-0.011 (0.057)	-0.235** (0.084)	-0.283*** (0.089)	-0.021 (0.02)	-0.324*** (0.370)
Robot	0.009*** (0.003)	0.006** (0.002)	0.021*** (0.004)	0.009*** (0.003)	0.512** (0.002)	0.021*** (0.004)
ict	2.038*** (0.182)	0.516*** (0.127)	2.385*** (0.223)	2.000*** (0.184)	0.512*** (0.171)	2.338*** (0.226)
con	11.107*** (0.779)	11.397*** (0.087)	9.220*** (0.119)	11.118*** (0.779)	11.399*** (0.088)	9.166*** (0.117)

Note: *, **, *** represent 1,5, and 10 percent significant level respectively; OP = Olley-Pakes (1996) and Levinsohn & Petrin = (2003) productivity measurement

Source: Author's calculation

Regarding other control variables for all cases, all variables are statically significance and follow expected signs. The sign of coefficients corresponding to $expout_{ijt}$,age_{ijt}, and $forown_{ijt}$ are significantly positive for all cases. The finding regarding firm's characteristic reveal exporting, older, and foreign firms are likely to generate higher productivity. The outcome of positive effect of exporting on firm's productivity is consistent with learning by exporting hypothesis and exporting firms face more competitive pressure. Such pressure can drive them to generate higher productivity than domestic firms.

Firm's age is found to be a positive effect on productivity, i.e. older firms tend to be more productive than younger firms. Older firms have more experience and expertise in production process and the marketing thereby generating higher productivity. The role of foreign ownership with productivity improvement found in this study is resemble to previous empirical studies e.g. Amiti & Konings (2007) and Tantratananuwat (2015) etc. where foreign firms tend to have higher productivity than indigenous firms. Many studies (e.g. Griffith et al, 2014) indicated that there are knowledges spillover through foreign affiliates. Therefore, foreign firms can adopt or imitate advanced technologies, transfer expert workers and efficiency production process.

The coefficient of $highL_{ijt}$ turn to be negative or show that firms that employ less bule-collar in total employment exhibit the higher firms' productivity. This outcome is consistent with theoretical expected sign and empirical studies of Thai manufacturing sectors e.g. Jongwanich & Kohpaiboon (2020) that examine effect of this factor on firm's productivity with panel data of industrial census. A high proportion of bule-collar workers hired by firm can reflect low application of efficient production process practice, for example, Kaizen or just in time system. These production practice can save blue-collar labor hiring to hire more white-collar labors thereby improving firms' productivity.

Conclusion

The key finding is that trade liberalization and technology advancements can spur Thai firms' productivity, however, the latter shows more robust positive. For trade liberalization aspect, lowering either input or output tariffs can stimulus firms' productivity. The outcomes become ambiguous when both input and output tariffs are included together. Particularly, the latter becomes statistically insignificant. This could be because Thai firms likely to consider both input and output tariff simultaneously for their business operation. To take into account a possible simultaneous effect of input and output tariffs, effective rate of protection (ERP) with and without water is employed, instead of nominal tariffs (both input and output). The results reconfirm the role of trade liberalization in generating firms' productivity. Furthermore, ICT which have widely using in Thai manufacturing exhibits greater positive impact on firm-level productivity than industrial robot. Older firm, higher ratio of white-collar workers, foreign firms tend to be more productive than indigenous, all other things remaining constant. Two policies inference can be introduced from this study. First, while promoting trade liberalization remains crucial, policies emphasizing on fostering technology advancements in the country should be prioritized. Second, our findings raise policy awareness issues regarding overemphasizing input tariffs solely in performing trade policy reform. Where the trade policy reform process is concerned, both input and output tariffs must be jointly taken into consideration. Third, our study supports global integration (e.g., exporting products, foreign participation) as it potentially promotes productivity enhancement.

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