International R&D Transfer and Technology Absorption: Technical Efficiency in the Asian Countries 1994-2011

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Abstract

This paper estimated semi-translog stochastic frontier production functions using an unbalanced panel of the 13 Asian developing countries during 1994 and 2011. The empirical results suggest that the productivity of Asian country depends on not only the physical capital but also its technical knowledge transferred from the developed countries. The transferred technical knowledge of the US R&D is a driver for the output efficiency in the Asian countries. As a result, the country with the US technical knowledge keeps high efficiency, the country with changing the technical knowledge to the US improves efficiency.

Keywords: International R&D; Technology Transfer; Asian Technical Efficiency; US or Japan Technology.
JEL Classification Numbers: O47; O57

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1. Introduction

As a large body of researches pointed out, the 'technical knowledge (called as the stock of R&D) made by advanced countries has been embodied in manufactured products, which is traded on international markets. The technical knowledge would be transferred by importing manufactured products from advanced countries to developing countries. Thus, the productivity growth of a developing country would depend on the physical capital but also its imported 'technical knowledge', symmetrical to the relation between labor and human capital. In fact, the empirical study by Coe et al.(1997,p.147) reported, "On average, a 1 % increase in the R&D capital stock in the industrial countries raises output in the developing countries by 0.06 %". Then, the R&D stock by advanced countries has been internationally transferred, which increases productivity growth in developing countries which undertake little domestic R&D and have few domestic sources of new technology. See (Tybout et al:1991, Coe et al:1997, Griffith et al:2004, Cameron et al:2005, Kneller and Stevens:2006 and Henry et al:2009, Coe et al:2009, and Fracasso and Vittucci Marzetti :2015).

In International R&D Transfer, we focus on recent contribution on 'Technology Absorption'. Kneller and Stevens (2006) produce the technical knowledge in terms of weighting the advanced country' machinery stock of R&D by physical distance from developing country itself, while Henry et al. (2009) weighted its stock of R&D by share of its developing country's machinery imports in its advanced country GDP. By using the stochastic frontier analysis, both papers firstly found important influence of the international transferred technical knowledge for the physical capital in output frontier. Secondly, Henry et al. (2009) found the importance for the level of the imports from advanced countries in the degree of absorbing technical knowledge and Kneller and Stevens (2006) for the level of human capital. The higher degree of absorbing knowledge improves the 'efficiency' (the distance of actual output from output frontier).

The previous papers including Coe et al.(1997) and Henry et al. (2009) deal with the same production frontier until 1971-1990 for 77 developing countries and until 1970-1995 for 57 developing countries. However, as the Asian economy continues to greatly grow up to the present, compared with the other developing countries (around 10% annual growth rate for the Asian developing countries, around 2% for OECD members and around 3% for the rest of the world [1]), we isolate the Asian production frontier from the others and have to consider it. If we do so, we also meet

[1] See the 'World Development Indicators'.
http://databank.worldbank.org/data/views/reports/tableview.aspx

an idiosyncratic view point for the Asian economy in efficiency effects. Lessons from business-world researches show the same cultural-oriented sources of absorption for 'technical knowledge' transferred through imports (familiar to manipulation of machines): see Leal-Rodríguez et al (2014). In fact, the specific company-oriented source of absorption in knowledge, 'Toyota Production System by Japan', is also popular over the Asia: see Monden (1983). However, as Figure 1 show, from early 1990 to the present, the imports of machine and equipment (representing 'technical knowledge' transferred) from Japan and the US to the Asian countries occupied 90% out of total amounts by G7 countries. However, the Japanese ratio (amounts by Japan / total amounts by G7) decreases gradually, while the ratio of the US increases. Does the Japanese 'technical knowledge' become now unpopular?

[Insert Figure 1]

The purpose of this paper is to estimate semi-translog stochastic frontier production functions using an unbalanced panel of the 13 Asian developing countries during 1994 and 2011. By using this model, this paper investigates the effects of technical knowledge transferred from developed countries on the output frontier of the Asian economy, identify who is a driver for the output efficiency with higher degree of absorbing knowledge (the distance of actual output from output frontier), imports of Japanese R&D or the US R&D and find how much more efficient the Asian countries become corresponding to the import of the driver. The findings are as follows. The productivity growth of Asian country depends on not only the physical capital but also its technical knowledge transferred from the advanced countries. The transferred US R&D stock (the US technical knowledge) is better absorbed and a driver for the output efficiency in Asian countries, which robustness was confirmed by evaluating only amounts of the US R&D, comparing the ratio between both amounts of the US R&D vs Japan R&D, and the US import dummy variable (1,0) where '1' means the country with more imports from the US than Japan. Most of the Asian countries improve the output efficiency period by period by the increase of the US imports. These results seem to suggest that the Japanese 'technical knowledge' has not been improving the output efficiency more than the US, that is, not better absorbed and the Japanese 'technical knowledge' become now unpopular. In section 2, we sketch the methodology, in section 3 describe the formulation and the data, and in section 4 discuss the empirical results. Section 5 contains concluding remarks.

2. Methodology

To do the stochastic frontier analysis of the Asian countries, we apply the following stochastic frontier production function:

$$Y_{it} = f(X_{it})\exp(V_{it} - U_{it}), \quad where\ f(X_{it}) \equiv f(K_{it}, L_{it}, H_{it}, RD_{it}^{m}) \qquad (1)$$

where i (i=1,2,..,N) indexes country and t (t=1,2,..,T) indexes time, Y is GDP, K is the stock of physical capital, H is the stock of human capital, L is the labour force, RD^m is the stock of foreign technical knowledge. The V_{it} s are *iid* $N(0,\sigma_V^2)$ random errors, and independent from the U_{it} s. The U_{it} s are *iid* $|N(\mu_{it},\sigma_U^2)|$ random variables associated with technical inefficiency for production (distance from the production frontier), where $|N(\mu_{it},\sigma_U^2)|$ denotes the normal distribution with mean μ_{it} and variance σ_U^2 that is truncated at zero, and

$$\mu_{it} = Z_{it}\phi \qquad i = 1,..,N\ . \qquad (2)$$

The Z_{it} is a $1\times$M vector of variables which influence the inefficiency for the *i-th* country, and ϕ is an M$\times 1$ vector of constant coefficients.

The model specified in (1) and (2) was developed by Battese and Coelli (1995) for analyzing the panel data. The parameters in the equation (1) are the same for all countries. However, the inefficiency effects are permitted to come from truncated normal distributions that might have different means. Kneller and Stevens (2006) and Henry et al. (2009) have specified the production form in (1) with a second-order linear approximation around data mean for the general form. The μ_{it} is a key parameter of our model in the sense that it determines the distribution of inefficiency depending on the Japanese R&D or the US R&D.

Technical Inefficiency

Battese and Coelli (1988, p.389) define the technical efficiency of production for the *i-th* country at the *t-th* period as a ratio of its mean production to the corresponding mean with $U_{it} = 0$:

$$TE_{it} \equiv \frac{E(Y_{it} \mid U_{it}, X_{it})}{E(Y_{it} \mid U_{it} = 0, X_{it})} = \exp(-U_{it}) \quad . \tag{3}$$

That is, when $\exp(-U_{it})$ =0.75, only the 75% of frontier production at $U_{it} = 0$ can be realized because of inefficiency $U_{it} \neq 0$. Alternatively, the technical inefficiency is defined by $TIE_{it} = 1 - TE_{it}$. Then, it is,

$$TIE_{it} = 1 - \exp(-U_{it}), \tag{4}$$

which is a random variable taking the values between zero and one. We simply call TIE_{it} the technical inefficiency for production as well as U_{it} (distance from the production frontier). There should be no confusion.

Although Battese and Coelli (1995) model has been widely applied, it implicitly makes the strong assumption that the inefficiency effect (i.e., the mean parameter μ_{it} in our equation (2)) is positively related to technical inefficiency TIE_{it} in production. Wang (2002) analytically confirmed the assumption made by Battese and Coelli, which are important because he provides a theoretical justification for the model's assumption used by Battese and Coelli (1995). [2] In section 4, we check whether the coefficient for the stock of foreign technical knowledge in (1) is significantly positive, whether the coefficient for both import amounts of the US R&D vs Japan R&D in (2) is significantly negative, and how much is the inefficiency for each Asian country in a view point of time series.

3. Formulation and Data

[2] There are many papers based on Battese and Coelli 's approaches: see Tsukuda and Miyakoshi (2003,2006) and Miyakoshi and Tsukuda (2004).

Formulation

The estimation of equation (1) is important in the functional form of the production frontier. As Kneller and Stevens (2006) has pointed out, the popular form of Cobb–Douglas production function may be misspecified because its form is very restricted compared with constant elasticity of substitution function and a translog function. In fact, Kneller and Stevens (2003) has rejected the restriction that the stochastic frontier is Cobb–Douglas. Therefore, we follow Kneller and Stevens (2006) in using a semi-translog specification (i.e. translog in L and K), which provides a better approximation to a broader class of production functions. The equation (1) actually estimated is therefore given by:

$$y_{it} = \beta_{0t} + \beta_1 l_{it} + \beta_2 k_{it} + \beta_3 h_{it} + \beta_4 rd_{it}^m + \beta_5 l_{it} l_{it} + \beta_6 k_{it} k_{it} + \beta_7 l_{it} k_{it} + V_{it} - U_{it} \quad (5)$$

where lower case letters represent logarithms: $l_{it} = Log(L_{it}), k_{it} = Log(K_{it}), h_{it} = Log(H_{it})$ and $rd_{it}^m = Log(RD_{it}^m)$. The distance from the production frontier, U_{it}, explicitly appears.

The key variable in this paper is RD^m in (1) and (5), is the stock of foreign technical knowledge transferred. Given that most developing countries undertake little domestic R&D, the stock of 'foreign technical knowledge' is assumed to depend on the stock of imported foreign R&D. The measure of 'foreign technical knowledge' used in this paper builds on Henry et al. (2009, p.241). We measure its stock of 'foreign technical knowledge' as the stock of machinery R&D, RD_j, in OECD countries j. To capture the transfer RD^m of foreign technical knowledge to developing countries i we weight this stock of machinery R&D of 5 OECD countries j, RD_j, by the share MM_{ij}/Y_j of a developing country i's machinery imports MM_{ij} from 5 OECD countries j in each of 5 OECD country j's GDP Y_j. The stock of foreign technical knowledge RD_i^m via imports by developing country i is therefore given by

$$RD_i^m \equiv \sum_{j \neq i} \frac{MM_{ij}}{Y_j} RD_j \quad (6)$$

We want to use only G7 OECD countries for R&D suppliers because of data availability and large volume of imports. However, the data base is only available from 2007-2012 and 2009-2012 for France and UK. As seen in Figure 1, imports from the US and Japan exceed France and the UK by ten times and dominate 90% over summed imports from G7 OECD countries. Then, we can omit two countries. Thus, the 5 OECD countries used to generate this measure are Canada, Germany, Italy, Japan and the United States. See Appendix in detail.

Another formulation is the mean level μ_{it} of inefficiency in (2). Henry et al. (2009, p.242) stressed the trade volume of machinery import from 5 OECD countries, where the larger these imports the wider the scope and deepness for technical knowledge. The variable of import volume means sources of the 'inefficiency'. However, when we distinguish import volume from Japan and the US, each of import volumes means many potential sources of the 'inefficiency' oriented from Japan and the US respectively: the familiarity to the technology (i.e., the same cultural-oriented) and the easy repair for machine (i.e., the close distance-oriented). Then, we pick up independently each of two country import volumes. This investigation focusing on only Japan and the US is rationalized because both countries occupied 90% out of total amounts of imports by G7 OECD (or 5 OECD) countries to the Asia, as seen in Figure 1. We also used the Sachs and Warner (1995) indicator (1 or 0 dummy variable) of openness to international trade, updated by Wacziarg and Welch (2003), as well as a dummy variable that takes the value of 1 if the developing country has a tropical climate and 0 if it does not. These sources were statistically significant in Henry et al. (2009). Then, we can formulate the mean level of inefficiency in (2) as

$$\mu_{it} = \phi_0 + \phi_{SW} SW_{it} + \phi_{TR} TROP_{it} + \phi_{ALL} KM_{it}^{ALL} + \phi_{US} (KM_{it}^{US} - KM_{it}^{JP}) + \sum_{k=1} \lambda_k D_{it} \qquad (7)$$

where $SW_{it}(1,0)$ the Sachs-Warner openness index, $TROP_{it}(1,0)$ the tropical index , $KM_{it}^{ALL}, KM_{it}^{JP}, KM_{it}^{US}$ the machinery imports from 5 OECD countries, Japan and the US, discussed above.[3]

Thus, if the machinery import volume promotes the absorption of technical

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[3] Note AY_{it} the share (%) of agriculture in GDP, is not included as the coefficient is never significant in Henry et al. (2009,p.250). Equation (7) corresponds to model (3) in this text.

knowledge and openness increases competition, Henry et al. (2009) expect to find negative coefficients on ϕ_{SW} and ϕ_{ALL}, that is, they reduce the inefficiency (distance from the frontier). In contrast, if a tropical climate increases inefficiency, ϕ_{TR} would be positive. [4] As well as Henry et al. (2009), we include the year dummies $D_{it} = 1\ if\ t = k$ and 0 if otherwise, which will provide the same effects on all of the Asian countries like the Asian currency crisis 1997-2002.

However, different from Henry et al. (2009), we introduce new variables of imports from Japan and the US: KM_{it}^{JP}, KM_{it}^{US} and our interest is on those coefficients ϕ_{JP}, ϕ_{US}.

We can write the log likelihood function log L and can determine the parameter θ in (5) and (7) together with the parameter of distribution (σ^2, γ) where $\sigma^2 \equiv \sigma_V^2 + \sigma_U^2, \gamma \equiv \dfrac{\sigma_U^2}{\sigma_V^2 + \sigma_U^2}$ to maximize it.

$$\begin{aligned} &\underset{\theta}{\mathrm{Max}} \log L(\theta : \varepsilon_{it}):\ L(\theta : \varepsilon_{it}) \equiv \Pi_{i=1}^{N} \Pi_{t=1}^{T} f(\varepsilon_{it} : \theta) \\ &where\ \varepsilon_{it} \equiv V_{it} - U_{it} \end{aligned} \tag{8}$$

By using these estimated parameters, we can get $\hat{\varepsilon}_{it}$ together with production frontier (5) and efficiency effect (7) and then $E\left(\exp(-U_{it} | \varepsilon_{it})\right)$ in Battese and Coelli (1993, p.20).

This estimated $E\left(\exp(-U_{it} | \varepsilon_{it})\right)$ is $\exp(-\hat{U}_{it})$ which is an estimator for $\exp(-U_{it})$ in (3).

Data

The sample period for the thirteen countries is from 1994-2011, though there is little different among Bangladish (BGD), Sri Lank(LKA), Cambodia(KHM), China(CHN), Hong Kong(HKG), India(IND),Indonesia(IDN), South Korea (KOR), Malaysia (MYS), Philippines (PHL), Singapore (SGP), Thailand (THA) and Vietnam(VNM), depending data availability.

In equation (5), the data on developing country are GDP Y_i, physical capital K_i and labor force L_i. The data is in constant 2005 US$. The capital stock data were

[4] Henry et al. (2009, p.242) introduce the tropical index which is intended to capture the effects of climate on public health, and then to capture the utilization and productivity of human resources.

constructed using the perpetual inventory method, as described in Appendix A. Human capital H is measured by mean years of schooling in the population aged 25 and over and is taken from Barro and Lee (2010). R&D investment data RD_j and advanced country GDP Y_j in (6) on machinery for the 5 OECD countries were taken from the OECD's ANBERD Database.[5] Data on machinery imports MM_{ij} for our sample of developing countries were extracted from the United Nations COMTRADE Database. Hence RD^m in (1) can be computed. All these data are measured in US$ PPP.

In (7), the Sachs–Warner, SW (1,0) were given by Sachs and Warner (1995) and Wacziarg and Welch (2003,p.35). Note there are no data of SW (1,0) for KHM and VNM and then we set 0 for two countries. The tropical indexes, TROP(1,0), were obtained from the following definition. The tropical countries (based on a biggest city's latitude in the country) are defined as the country between 23.5 degrees North and South latitude. Countries between these latitudes have tropical climates all year. Such countries are the BGD, LKA, KHM, HKG, IND, IDN, MYS, PHL,SGP, THA and VNM. The KM_{it}^{ALL}, KM_i^{JP} KM_i^{US} are the machinery imports from 5 OECD countries, Japan and the US, which are the same as MM_{iJP} and MM_{iUS} in (6). Appendix A provides greater detail of explanation for data.

Summary statistics for data

The data estimated for the model is from 13 countries and 18 year annual data from 1994-2011. The total number of available observation is 219 depending on the data availability for each country. Then, the data set is an unbalanced panel data. Table 1 shows the summary statistics for data, where all variables including numbers of people and educational year are in logs for US$, except SW dummy, TROP dummy and D year dummy in (7). Comparing the '*Table A1'* seen in Henry et al. (2009,p.250) who deal with 57 developing countries over the world, we find for 13 Asian countries that the

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[5] The item in OECD's ANBERD is 'machinery and equipment'. Henry et al. (2009) recognized that machinery imports is important in the amounts of technology diffused, rather than imports of the broader class of capital goods. We follow Henry et al. (2009).

mean, minimum, and maximum of GDP, capital, and labor force, human capital, and R&D stocks are much larger and the standard deviations for those variables are much less that their numbers in Henry et al. (2009,p.250). That is, the Asian economies grown up greater and the difference among the Asian countries become smaller. Then, as we have already suggested at section 1, we have to isolate the Asian production frontier from the other developing countries. Finally, except for human capital (educational years), the interval between mean $\pm$ 2-standard deviation covers the maximum and the minimum values and then if the data follow the normal distribution, we think that the data used in analysis had no abnormal data.

[Insert Table 1]

4. Empirical Results

Estimated Coefficients in Production Frontier

The results of our estimation are presented in Table 2. The models are differentiated by the assumptions for inefficiency effects, i.e., depending on how the import transferring the R&D stocks from Japan and the US is formulated. The Model (1), a benchmark model, assumes that the model incorporate no difference of imports between Japan and the US, while only total 5 OECD imports of machinery and equipment in logarithm, KM_{it}^{ALL}, are incorporated. This model is the same as that of Kneller and Stevens (2006) and Henry et al. (2009). However, the Model (2) adds only the separated import of the US in the logarithm, KM_i^{US} to the Model (1)[6], the Model (3) the ratio of the US import / Japan import in the logarithm, LN(US/JP import), and the Model (4) the US_import dummy, where the US's accumulated imports during analytical periods is larger than that of Japan and then the US import dummy is equal to 1 and zero otherwise. All of models (1) to (4) includes the year dummy and then the Model (5), replacing year dummy in the Model (4), investigates whether year dummy means the Asian crisis dummy (one during 1997-2002) or not?

The estimated results from model (1) in Table 2 are close to those found by

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6 We have formulated the model with both Japan and the US in the logarithm, KM_i^{Jap} KM_i^{US} to the Model (1): the coefficient for Japan is significantly positive, where the coefficients for the US and 5 OECD are not significant. Moreover, the separated import of Japan in the logarithm, KM_i^{JP} to the Model (1) is also considered, but the coefficients for Japan and 5 OECD are not significant.

Kneller and Stevens (2006, p.10) and Henry et al. (2009, p.25), while we focus on the Asian countries. In the production frontier, the coefficients of labor, human capital and R&D stock is positive, while the coefficient of physical capital is negative as well as them. Most of the parameters including the σ^2, γ shown in (8) is significant at 5%.

However, in our model (2)-(4) the coefficients of physical capital are significantly positive. Thus, we report the evidence of spillover of R&D stock (i.e., its technical knowledge) from advanced countries through import and stress the importance of international trade, as well as Kneller and Stevens (2006) and Henry et al. (2009).

[Insert Table 2]

We also check whether the production frontier is appropriately estimated by using the elasticities of output with respect to each of the inputs in (5), $E_X \ (X = L, K, H, RD)$. In Table 3, these were calculated as follows by using the mean values of input in Table 1 and the estimated parameters in Table 2

$$E_L \equiv \frac{\partial y}{\partial l} = \beta_1 + 2\beta_5 l + \beta_7 k, \quad E_K \equiv \frac{\partial y}{\partial k} = \beta_2 + 2\beta_6 k + \beta_7 l, \quad E_H \equiv \frac{\partial y}{\partial h} = \beta_3, \ E_{RD} \equiv \frac{\partial y}{\partial rd^m} = \beta_4 \tag{9}$$

Also, returns to scale (elasticity of scale: what percent point increase of output summed with one percent increase of each input) is calculated from the sum of the input elasticities as:

$$RTS \equiv \sum_X E_X \tag{10}$$

In Table 3, when we pick up the result for model (4) discussed later in detail, at the mean for each variable, the elasticity of output with respect to labor force is 0.187, for physical capital 0.772, for human capital 0.374 and for R&D 0.008. The estimated elasticity is comparable with the results of Asia (1970-1998) by Henry et al. (2009,p.243): 0.42, 0.72, 0.09, and 0.12. During 1994-2011 in our analysis, the labor and R&D elasticities decrease, while the human capital elasticity increases. Notes that the labor elasticity is not significant and inefficiency effect is different from them because of different periods. However, the model (4) is appropriate for production frontier as well as the other model (1)-(5) except for labor force input. On the other hand, the elasticity of scale (*RTS*) for model (1)-(5) are greater than unity and around the estimated RTS in Henry et al. (2009,p.243).

[Insert Table 3]

Estimated Coefficients in Efficiency Effects

In the inefficiency effects, Henry et al. (2009,p.25) found sources of efficiency effects is the Sachs- Warner (SW) market openness and is also the tropical indexes (TROP). In Table 2 of this paper, the negative signs of SW and positive sign of TROP in Model (1)-(4) roughly support their findings. However, total 5 OECD imports of machinery and equipment in logarithm KM_{it}^{ALL} has positive signs in all of models except for model (2), which cannot stress the importance of international trade volumes for 5 OECD countries in the inefficiency effects, opposed to Henry et al. (2009). It is remarkable difference when we analyze the Asia. We will mention on this difference later. Except for this point, the use of the formulation in the stochastic frontier function seems to be appropriate in a sense that the estimation results are not so different from Henry et al. (2009) dealing with the developing countries.

Our main concern is why recent Japanese import of machinery import and equipment is decreasing or unpopular in the Asian countries as seen in Figure 1. That is, who is the driver of output efficiency through transferred technology of the R&D? We investigate this question by evaluating only amounts of the US R&D in model (2), and next by comparing the ratio in model (3), and the dummy variable in model (4) and (5). In Table 2, the coefficients of the KM_{i}^{US} (negative) in model (2), the LN(US/JP import)(negative) in model (3), the US_import_dummy(negative) in model (4) and (5) show the significance at 1%. Thus, we find that more imports from the US than Japan improve the inefficiency.

These 5 models include year dummies showing the same effects on all of the Asian countries. What is the same effect? In our recognition, a big same effect is the effect of Asian currency crisis 1997-2002. The Model (5) shows that the crisis dummy (1 during 1997-2002) is significantly positive at 5%, confirming our recognition. In this sense, all models (1)-(4) including year dummies could express the characteristics of the Asian economy well, including the Asian currency crisis.

Robustness checks

We check the robustness of this result, by using a two-step procedure. See Pitt and Lee (1981) and Kalirajan and Shand (1985): the first step is the estimation of a standard model that ignores the inefficiency effect in (2), and the second step is a OLS regression of sources of efficiency. [7] Table 4 shows the results for inefficiency effects

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[7] Kumbhakar et al.(1991,p.280) pointed that the first step of the two-step procedure is biased

(inefficiency sources) in model (4) and the results in model (6) for efficiency OLS regression on the same sources used in model (4) where efficiency in model (6) with individual effects for each country *i* and each year *t* are estimated under the same truncated normal distribution for inefficiency, U_{it} : the numbers of estimated efficiency are 219. The results for both models (4) and (6) have opposite signs because of inefficiency in model (4) and efficiency in model (6). Moreover, coefficients of sources are mostly significant at 5% level and year dummies are significant from 1998-2002. Thus, we have checked the robustness that the Sachs- Warner (SW) market openness, the US_import dummy improve efficiency, while total 5 OECD imports of machinery and equipment in logarithm KM_{it}^{ALL} and the TROP reduce efficiency. Thus, we have confirmed the estimated results of model (4) by using model (6). The reason why we use model (4) as a representative model for model (1)-(5) with the same results has mostly the same likelihood as model (2) with the same number of parameters and the maximum likelihood and has the sake of convenience in classifying the countries by 'the US import dummy' at section of 'Time series of efficiency'.

[Insert Table 4]

How do we confirm that the US import's increase improve efficiency and the 5 OECD import's increase reduce efficiency?

In Table 2, why do total 5 OECD imports reduce efficiency in the Asian countries, in spite of the results of all developing countries over the world by Henry et al. (2009)? However, this result is similar to Kneller and Stevens (2006,p.10) where the positive efficiency effect by R&D level (or imports from advanced country) is not robust. The increases of the US import improve efficiency and improve better than the Japan import, considering the results in model (1)-(5). At section of 'Time series of efficiency', we found that India is the major imported country from the US and is mostly at a production frontier for the Asian economy during the whole period. Considering the fact, we imagine that India is always improving efficiency by the US imports. However, the

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for the regression parameters if inefficiency sources and the inputs are correlated and Kneller and Stevens (2006,p.3) also pointed that in the second step, inefficiency are assumed to be a function of these sources, implying that inefficiency are not identically distributed. We use the two-step procedure as an approximation to this problem.

positive coefficient of 5 OECD import reduces efficiency in all models. Imports from various technical knowledge by 5 OECD country diversify the degree of absorption in the same cultural oriented technical knowledge. More investigation is needed.

Time series of efficiency

We investigate how the US technical knowledge absorption through imports improves the output efficiency in the Asian economy from viewpoint of time series, by using model (4). Figure 2 classifies each country in three categories: (A) country with BGD, VNM, KOR, HKG, LKA,CHN,IDN,THA trying Japanese technical knowledge absorption:US_import dummy=0 which shows the accumulated imports from Japan is larger than that of the US, (B) country with IND,SGP trying the US technical knowledge absorption: US_import dummy=1, (C) country with KHM,MYS,PHL trying to change to the US technical knowledge absorption: US_import dummy=0 which means that as seen in Figure1, recent 10 years the US import share dominate Japanese one. Figure 2 shows efficiency of each country at each period computed by model (4). The efficiency of each country in category (A) is decreasing or low, suggesting that the Japanese technical knowledge is not well absorbed (see the results of Table 2).[8] The efficiency of each country in category (B) is increasing or high, suggesting that it is well absorbed. The efficiency of each country in category (C) is increasing, suggesting that those countries are changing to the US technical knowledge absorption. Thus, these results suggest that the non-well absorbed Japanese technical knowledge cannot improve efficiency and then gradually are changing to the US technical knowledge.

[Insert Figure 2]

5. Concluding Remarks.

The Asian economies grew up rapidly and the difference among the Asian countries becomes smaller. Then, we have to isolate the Asian production frontier from the other developing countries, as opposed to Kneller and Stevens (2006) and Henry et al. (2009). As well as the results for other developing countries, the productivity of Asian country depends on not only the physical capital but also its technical knowledge transferred from the advanced countries. However, we have to meet an idiosyncratic view point for the Asian economy. The transferred technology of the US R&D is a

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8 As we described at the robustness check in Section 4, we recognize that when the imports from Japan is increasing, the imports from the US is decreasing. Then, the well-absorbed US technology decreases, which decreases the output efficiency.

driver for the output efficiency in the Asian countries, which robustness was confirmed by evaluating only amounts of the US R&D, comparing the ratio between both amounts of the US R&D vs Japan R&D, and the US import dummy variable (1,0). In addition, the 5% significant Asian crisis dummies (1 during 1997-2002) support that these models are appropriate for the Asian economy. Also, we confirmed the driver source of efficiency by using two step procedure used by Pitt and Lee (1981) and Kalirajan and Shand (1985) is the US import.

As a result, the country with the US technical knowledge improve output efficiency, the country with changing the technological knowledge from Japan to the US improve output efficiency, while the country with the Japanese technical knowledge reduce output efficiency in contrast to the increases of production frontier by the country with the US technical knowledge and keep low efficiency. Why did the Japanese technical knowledge not improve efficiency recently, despite that previously it improved well seen in Figure 2 and its popularity was well introduced by Monden (1983) ? This investigation is future research.

Appendix A

Data construction

France and UK have no data for no data for R&D investment until 2005 and then both countries are omitted in analysis.

R&D stock transferred RD_i^m *, R&D stock in advanced countries* RD_j *, Import* MM_{ij} *.*

The data for R&D stock, RD_j , in advanced countries are from the OECD's ANBERD Database:

http://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV4#.

by setting STAN R&D expenditures in Industry (ISIC Rev. 4), D28: Machinery and equipment n.e.c., and US$ current PPPs. Using the product field data for the amounts in R&D is recommend, as seen in 'THE OECD ANBERD DATABASE, August 2, 2013 (http://www.oecd.org/sti/inno/Anberd_full_documentation.pdf)' as a manual of this data base. However, in Rev.3 and 4, only France and the UK have *the 'product field' data* from 1990-2012 and 1990-2009 respectively, while most of the other countries has not.[9] Then, we have to use main activity data. All OECD 5 countries has *the 'main activity' data* for in the Rev.4 and the Rev.3 from 1990-2013, while France has the main activity data only from 2007 to 2012 and the UK only from 2009 to 2012. The

[9] See the definition of the 'product field' data which exist around page 30 and of the 'main activity' data around page 82 in Frascati Manual (2002,OECD).

amounts in the product field data are less by about 50% than the amounts in the main activity data, which is supported by *the 'product field' data* in Italy which has this data for the first time from 2007-2012 in Rev.4. Moreover, Table 1 shows that the imports from OECD 5 countries for the Asian countries dominate the imports from France and the UK. In particular, the imports from US and Japan overcome both countries by about ten times. Then, we exclude France and UK in analysis. The advanced country GDP Y_j is also extracted by setting Gross domestic product (annual) in US$ current PPPs.

The data on machinery imports for developing country i from advanced country j, MM_{ij}, were extracted from the United Nations COMTRADE (Commodity Trade) Database.

http://comtrade.un.org/data/

by setting SITC Rev.2, Section 7 (machinery and transport equipment), reporter (import developing country), partner (exporting developing country) and US$ current PPPs. The version Rev.2 selected by this paper is old version, compared with the present version Rev.4, while the data span of new version is very short. Then, we can compute *R&D stock transferred*, RD_i^m, in (5)

GDP Y_i ***, Labor Force*** L_i ***, Physical Capital*** K_i ***, the share of agriculture*** AY_i ***and Human Capital*** H_i

These data for developing country are from World Development Indicators (WDI):

http://databank.worldbank.org/data/views/reports/tableview.aspx#

by setting constant 2005 US$. The share of agriculture in GDP is measured in %. The human capital data from 2010 are extrapolated forward by assuming that the rate of growth was the same as the average over the sample period by using Barro and Lee (2010). The gross capital formation compiled is converted to Physical Capital by using a perpetual inventory method as well as Kneller and Stevens (2006) and Henry et al. (2009).

$$K_{it} = (1-\Delta)K_{it-1} + I_{it-1} : K_{i0} = \frac{I_0}{(g_i + \Delta)}$$

The rate of depreciation (Δ) is set to equal 10% in the equation, while the initial capital stock is estimated in the usual way (where the term g_i is the average annual growth rate of investment over the period).[10]

[10] We assume that the growth rates of investment I_{i0} and stock K_{i0} in the initial period are equal to each other: $K_{i1}/K_{i0} = K_{i2}/K_{i1}$.

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Table1. Summary statistics of variables used in estimation of stochastic production frontier

Variable	Mean	Std. deviation	Minimum	Maximum
LN(GDP)	25.757	1.413	22.116	29.066
LN(L)	17.235	1.701	14.366	20.478
LN(K)	26.296	1.575	22.034	29.823
LN(H)	1.890	0.346	1.165	2.463
LN(RDm)	30.228	1.691	25.140	33.692
SW(1,0) dummy	0.639	0.481	0.000	1.000
LN(5OECD Machinery imports)	22.997	1.680	17.861	26.175
TROP(1,0) dummy	0.836	0.371	0.000	1.000
LN(US machinery import)	22.265	1.700	17.587	25.443
LN(JP machinery import)	21.660	1.903	15.375	24.472
LN(Machinery imports US/JA)	−0.605	0.696	−2.511	1.011
US import dummy(1,0)	0.164	0.371	0.000	1.000

Notes: Except for SW, TROP and US import dummies, all variables are in logarithm, LN(.).

Table 2.Maximum-likelihood estimates for stochastic semi-translog production function with inefficiency component

	(1) Benchmark			(2) US import			(3)US/JP		
	Coef.	SE	t	Coef.	SE	t	Coef.	SE	t
Production frontier									
constant	11.929	2.655	4.49	11.241	2.291	4.91	3.759	0.834	4.51
l	0.888	0.231	3.84	1.038	0.198	5.25	0.799	0.074	10.74
k	−0.635	0.238	−2.66	−0.682	0.23	−2.96	0.173	0.078	2.21
h	0.562	0.057	9.8	0.536	0.054	10	0.295	0.046	6.47
rd	0.034	0.022	1.53	0.035	0.02	1.76	0.018	0.005	3.54
ll	0.12	0.008	15.41	0.114	0.007	15.77	0.091	0.004	21.23
kk	0.087	0.008	11.08	0.087	0.008	11.57	0.059	0.003	22.59
lk	−0.182	0.012	−14.85	−0.18	0.012	−15.58	−0.144	0.005	−26.84
Inefficiency effects									
constant	−3.035	0.921	−3.3	−2.588	0.691	−3.75	−1.394	0.294	−4.75
SW	−0.107	0.071	−1.5	−0.031	0.057	−0.54	−0.002	0.032	−0.06
KM_ALL	0.14	0.039	3.59	0.228	0.041	5.61	0.059	0.012	4.95
TROP	−0.081	0.069	−1.18	−0.11	0.061	−1.81	0.114	0.044	2.59
KM_US				−0.113	0.028	−4.1			
LN(US/JP import)							−0.09	0.017	−5.42
US_ import dum									
No.signifi.y	5			4			6		
Crisis dummy									
sigma	0.013	0.002	6.54	0.011	0.002	6.73	0.015	0.003	5.9
gannma	0.768	0.09	8.56	0.775	0.091	8.52	1	0.001	819.54
Log-Likelih	216.983			226.52			223.89		

	(4) US import dummy			(5)Crisis dummy		
	Coef.	SE	t	Coef.	SE	t
Production frontier						
constant	0.734	0.799	0.92	8.708	2.419	3.6
l	0.811	0.081	10.04	1.056	0.179	5.89
k	0.407	0.054	7.51	−0.51	0.191	−2.68
h	0.374	0.041	9.11	0.548	0.05	11.03
rd	0.008	0.003	2.57	0.052	0.018	2.85
ll	0.078	0.004	18.07	0.107	0.007	14.65
kk	0.048	0.002	23.13	0.08	0.006	13.07
lk	−0.126	0.005	−23.66	−0.17	0.01	−16.71
Inefficiency effects						
constant	−0.899	0.265	−3.4	−2.029	0.686	−2.96
SW	−0.052	0.037	−1.41	−0.192	0.068	−2.81
KM_ALL	0.042	0.01	4.05	0.098	0.029	3.34
TROP	0.137	0.055	2.52	−0.027	0.055	−0.5
KM_US						
LN(US/JP import)						
US_ import	−0.194	0.04	−4.87	−0.217	0.086	−2.51
No.signifi.y	4					
Crisis dummy				0.103	0.028	3.67
sigma	0.015	0.002	6.88	0.015	0.003	5.45
gannma	1	0	7.00E+04	0.841	0.074	11.31
Log-Likelih	218.14			213.386		

Notes: A benchmark model is one by Kneller and Stevens (2006) and Henry et al(2009). In the production frontier, the dependent variable is the log of GDP. All independent variables are lower case letters which represent logarithms as seen in equation (5). Year dummies included in the inefficiency component are not reported due to space constraints, while the numbers of significant dummy at 10% out of 17 year dummies are reported as 'No_signif_year dummy'.

Table 3. Elasticities (E_X) and Return to Scale (RTS) at the mean of the data.

models	EL	EK	EH	ER&D	RTS
model(1)	0.224	0.789	0.562	0.034	1.609
	0.479	0.521	0.057	0.022	
model(2)	0.215	0.799	0.536	0.035	1.585
	0.44	0.5	0.054	0.02	
model(3)	0.161	0.786	0.295	0.018	1.26
	0.217	0.183	0.046	0.005	
model(4)	0.187	0.772	0.374	0.008	1.341
	0.219	0.153	0.041	0.003	
model(5)	0.259	0.738	0.548	0.052	1.598
	0.409	0.412	0.05	0.018	

Notes: standard errors in parentheses.

Table 4. Estimated Sources of Inefficiency and Efficiency with year dummies

	(4) US import dummy					(6) OLS: Efficiency Sources		
	Coef.	SE	t			Coef.	SE	t
Inefficiency effects					Efficiency effects			
constant	−0.899	0.265	−3.40			1.367	0.121	11.29
SW	−0.052	0.037	−1.41			0.022	0.015	1.42
KM_ALL	0.042	0.010	4.05			−0.021	0.005	−4.18
TROP	0.137	0.055	2.52			−0.075	0.021	−3.61
US_ import dum	−0.194	0.040	−4.87			0.104	0.018	5.90
year dum 1995	−0.037	0.068	−0.54			0.010	0.033	0.29
1996	−0.009	0.069	−0.13			0.004	0.033	0.11
1997	−0.007	0.067	−0.10			0.002	0.032	0.07
1998	0.142	0.059	2.41			−0.077	0.032	−2.37
1999	0.135	0.061	2.22			−0.069	0.032	−2.14
2000	0.041	0.060	0.69			−0.044	0.032	−1.38
2001	0.095	0.060	1.58			−0.054	0.030	−1.78
2002	0.098	0.060	1.64			−0.053	0.031	−1.71
2003	0.065	0.061	1.07			−0.042	0.031	−1.35
2004	0.029	0.063	0.46			−0.018	0.031	−0.57
2005	−0.010	0.062	−0.16			0.000	0.031	−0.01
2006	−0.054	0.064	−0.84			0.018	0.031	0.58
2007	−0.090	0.066	−0.14			0.040	0.031	1.29
2008	−0.065	0.065	−1.00			0.033	0.031	1.06
2009	−0.010	0.021	−0.46			0.004	0.008	0.43
2010	−0.066	0.068	−0.97			0.028	0.031	0.90
2011	−0.064	0.066	−0.98			0.027	0.031	0.86

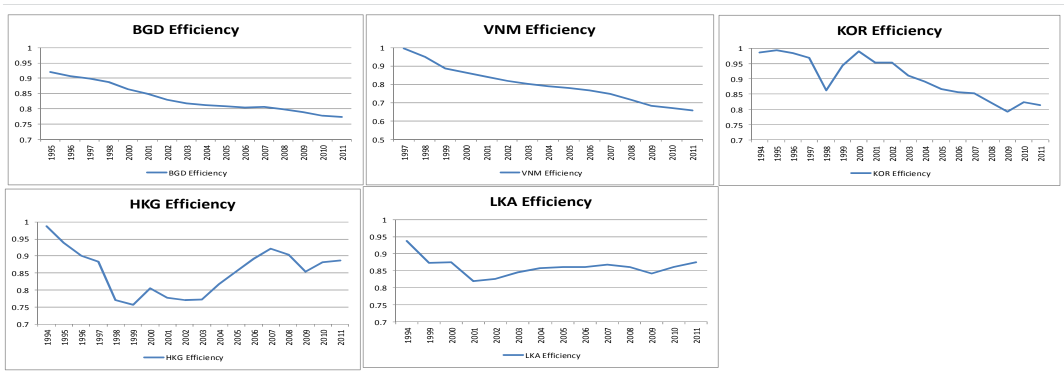
Notes: The results on left-hand side are the inefficiency effects in model (4). The results in model (6) are for OLS regression of efficiency on the same sources used in model (4), where efficiency in model (6) with individual effects for each country and each year are estimated under the same truncated normal distribution for inefficiency U_{it} .

Notes: Bangladish (BGD), Sri Lank(LKA) Cambodia(KHM), China(CHN), Hong Kong(HKG), India(IND),Indonesia(IDN), South Korea (KOR), Malaysia (MYS), Philippines (PHL), Singapore (SGP), Thailand (THA) and Vietnam(VNM). The blue line is for Japan and the red for the US. The number is the ratio: (Import from Japan or the US)/total imports of G7 OECD countries in US$.

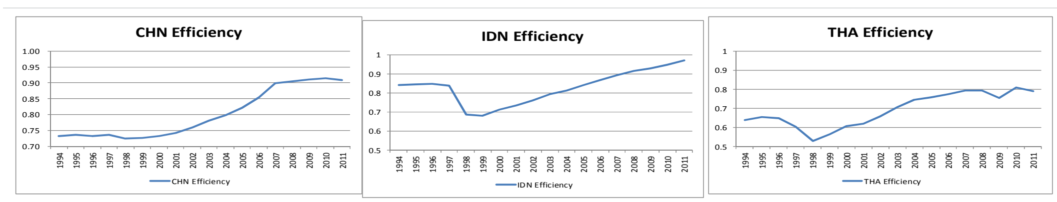
Figure 1. Import ratios of machine and equipment from Japan and the US to the Asian countries in G7 OECD countries.

A. Japanese technology absorption: US_import dummy=0

decreasing efficiency

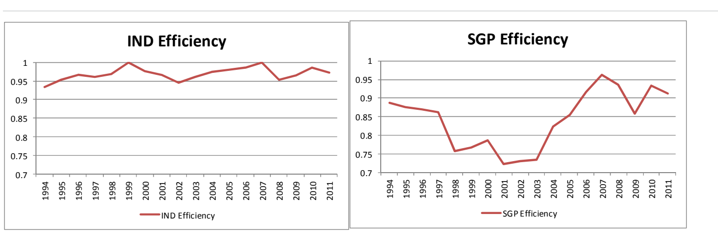


low efficiency or stagnant



B. The US technology absorption: US_import dummy=1

high efficiency or increasing



C. Changing to the US technology absorption: US_import dummy=0

increasing efficiency

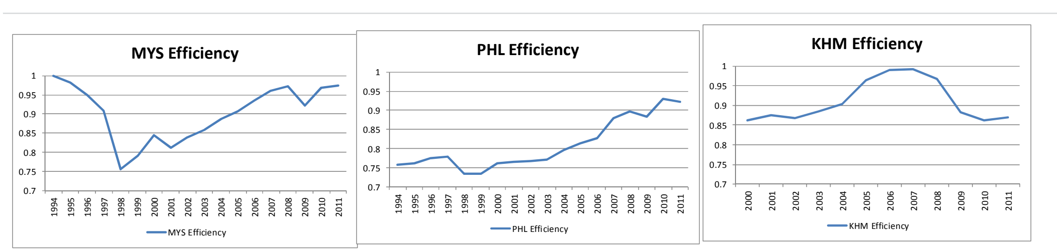


Figure 2. Imports from Japan and Inefficiency of the Asian countries.