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

Tatsuyoshi Miyakoshi*
Hosei University

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 technology of the US R&D is a driver for the output efficiency in the Asian countries. As a result, the country with the US technological knowledge keeps high efficiency, the country with changing the technological knowledge to the US improves efficiency, while the country with the Japanese technological knowledge reduce efficiency and keep it low.

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

* Correspondence: Tatsuyoshi Miyakoshi, Department of Industrial and System Engineering, Hosei University, 3-7-2, Kajino-cho, Koganei, Tokyo, 184-8584, Japan. Tel: 042-387-6352, E-mail: miyakoshi@hosei.ac.jp

1. Introduction

As a large body of researches pointed out, technical progress has been embodied in manufactured products and capital equipment, which is traded on international markets. Then, international trade allows countries to import the R&D investments made by other countries and plays greater importance for productivity growth in developing countries which undertake little domestic R&D and have few domestic sources of new technology. For recent researches, see Tybout et al. (1991), Coe et al.(1997), Han et al. (2002), 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 particular, 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 %".

The productivity of a developing country would depend on not only the physical capital but also its 'technical knowledge', symmetrical to the relation between labor and human capital. The 'technical knowledge' for the physical capital would be measured as the stock of R&D and transferred from developed countries by the international trade. In fact, Kneller and Stevens (2006) produce the knowledge in terms of weighting the developed country' machinery stock of R&D by physical distance from developed country, while Henry et al. (2009) weighted its stock of R&D by share of its developing country's machinery imports from developed country in its developed country GDP. By using the stochastic frontier analysis, both papers firstly found important influence of the knowledge for the physical capital in output frontier. Secondly, investigating source of the 'inefficiency' (the distance of actual output from output frontier), Henry et al. (2009) found the importance for the level of the international trade from advanced countries (i.e., the level of technical knowledge) in improving the inefficiency of developing countries: i.e., increasing the degree of absorption in technical knowledge.

The previous papers deal with the same production frontier until 1970-1995 for 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 meet an idiosyncratic view point for the Asian economy. Lessons from business-world researches show the same

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

cultural-oriented (familiar to manipulation of machines) sources for 'technical knowledge' transferred through imports: see Leal-Rodríguez et al (2014). Moreover, the specific company-oriented source, 'Toyota Production System', 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. Has the Japanese 'technical knowledge' not been increasing the efficiency or not been well absorbed? Does the Japanese 'technical knowledge' become now unpopular?

[Insert Figure 1]

The purpose of this paper is to investigate 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, Japanese R&D or the US R&D and find how much more efficient the Asian countries become corresponding to the import amount by 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 developed countries. The transferred technology of the US R&D is a driver for the output efficiency in Asian countries, which robustness is confirmed by comparing both amounts of the US R&D vs Japan R&D, the ratio between both amounts, and the dummy variable (1,0) where '1' means the country with more imports from the US than Japan. The most of Asian countries improve the output efficiency period by period by the increases of the US imports. These results seem to suggest that the Japanese 'technical knowledge' has not been increasing the efficiency, that is, not well absorbed and the Japanese 'technical knowledge' become now unpopular. In section 2, we sketch the methodology, in section 3 describe the variables 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:

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

where i indexes country and t indexes time, Y is GDP, K is the stock of physical capital, H is the stock of human capital, L is the labour supply, 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. Henry et al. (2009) has specified the production form 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, which means the regional or global effects. In the empirical study of Section 4, we apply two kinds of formulation for μ_i , in which Z_i takes either the set of economic variables or the set of dummy variables for the countries.

In the following explanations, we check whether the coefficient for the stock of foreign technical knowledge in (1) is significantly positive or not, whether the coefficient for the Japanese R&D in (2) is significantly negative or not and less than that of the US, and how much is the inefficiency for each country.

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 $U_{it} = 0$:

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

Alternatively, the technical inefficiency is defined by $TIE_{it} = 1 - TE_{it}$. Then, it is,

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

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} . 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. Tsukuda and Miyakoshi (2001, 2002) and Wang (2002) analytically confirmed the assumption made by Battese and Coelli, which are important because they provide a theoretical justification for the model's assumption used by Battese and Coelli (1995).[2]

3. Formulation,Variables and Data

Formulation

The estimation of equation (1) is important in the functional form of the production frontier. 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, pointed out by Kneller and Stevens (2006). Moreover, Kneller and Stevens (2003) reject the restriction that the stochastic frontier is Cobb–

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

Douglas. Therefore, we follow Kneller and Stevens (2006)'s paper 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}, is explicitly appears.

Variables

The key variable in this paper is RD^m in (1), the stock of foreign technology transfer.

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 technology to developing countries i we weight this stock of machinery R&D by OECD countries j, RD_j by the share MM_{ij}/Y_j of a developing country i's machinery imports MM_{ij} in each 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 through import to the Asia 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, each import from US and Japan overcome France and the UK by ten times and moreover dominate 90% over total imports from G7 OECD countries. We omit two countries. The 5 OECD countries used to generate this measure are Canada, Germany, Italy, Japan and the United States. See Appendix in detail.

Another key variable 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 greater these imports the greater the scope and deepness for technical knowledge. This variable means sources of the 'inefficiency'. However, when we distinguish the 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 to the Asia by G7 OECD countries as seen in Figure 1.

They 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.[3] These additional sources were statistically significant in Henry et al. (2009). Then, we formulate the mean level of inefficiency as

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

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.[4]

Thus, if the machinery import volume promotes the absorption of technical knowledge and openness increases competition, we expect to find negative coefficients on ϕ_{SW} and $\phi_{ALL}, \phi_{JP}, \phi_{US}$, respectively; that is, they reduce the inefficiency (distance from the frontier). In contrast, if a tropical climate increases inefficiency, ϕ_{TR} would be positive. We include the year dummies $D_{it} = 1\ if\ t = k$ and 0 if otherwise, which will

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3 Henry et al. (2009) introduce this variable which is intended to capture the effects of climate on public health, and by extension the utilization and productivity of human resources, following the previous researches: see Hall and Jones(1999,p.101-102).

4 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).

provide the same effects on all of the Asian countries like the Asian currency crisis 1997-2002.

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

[5] The item in OECD's ANBERD is 'machinery and equipment'. Mayer (2001) and 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 Mayer (2001) and Henry et al. (2009).

Japan and the US, which are the same as $MM_{i\,JP}$ and $MM_{i\,JP}$ 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, TROP and D 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 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. 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

The results of our estimation are presented in Tables 2. The first four models are differentiated by the assumptions for inefficiency effects where the import transferring the R&D stocks from Japan and the US is formulated. Model (1), a benchmark model, assumes that the model incorporate re 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, Model (2) introduces the separated import of Japan and the US in the logarithm, KM_i^{Jap} KM_i^{US} , together with total 5 OECD imports KM_{it}^{ALL} , Model (3) does the ratio of the US import / Japan import in the logarithm, LN(US/JP import), and Model (4) does the dummy variable, US_import dum, where the US's accumulated imports during analytical periods is larger than that of Japan, the US import dummy is equal to 1 and zero otherwise. All of model (1) to (4) includes the year dummy and then Model (5) 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 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 significantly positive, while the coefficient of physical capital is negative as well as them. However, in our model (2)-(4) the coefficients of physical capital are significantly positive. Thus, they 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 results in Model (1)–(4) of our paper.

Moreover, in the inefficiency effects, Henry et al. (2009,p.25) found sources of efficiency effects is the Sachs- Warner (SW) market openness and that of inefficiency is 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 the models except for model (2), which cannot stress the importance of international trade, opposed to Henry et al. (2009). It is remarkable difference when we analyze the Asia. We mention it in the robustness checks. Except for this point, the use of the formulation in the stochastic frontier function seems to be appropriate.

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 comparing both amount levels of the US R&D vs Japan R&D in model (2), the ratio levels in model (3), and the dummy variable in model (4). In Table 2, the coefficients of the KM_i^{Jap} :positive, 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%, where KM_i^{US} :negative is significant at both sides 30%. 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 Asian currency crisis 1997-2002. Model (5) shows that the crisis dummies (1 during

1997-2002) is significantly positive at 5%, confirming our recognition. In this sense, all models express the Asian economy well. Thus, we find that more imports from the US than Japan improve the inefficiency.

[Insert Table 2]

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. [6] Table 3 shows the results for Inefficiency effects (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) for each country and each year are estimated under the same truncated normal distribution for inefficiency. The results for both models 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 confirmed 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.

Why do total 5 OECD imports improve efficiency in Asian countries, in spite of the results of all developing countries over the world by Henry et al. (2009)? One answer for this question is as follow. The results in model (2)-(6) in Table 2 show that import from Japan reduces efficiency, while the import from the US improves efficiency. Moreover, Figure 1 show that imports from Japan dominate G7 country imports in the Asia and the increases of imports from Japan decreases import from the US. Then, the import increases of 5 OECD (increases from Japan and decreases from the US) reduces efficiency. Why does not the import increases from Japan (together

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6 Kumbhakar et al.(1991,p.280) and Wang and Schmidt (2002,p.144) pointed that the first step of the two-step procedure is biased for the regression parameters if sources and the inputs are correlated, as is well known. A less well known fact is that, even if sources and the inputs are independent, the estimated inefficiencies are underdispersed when we ignore the effect of sources on inefficiency.

with import decreases from the US) improve efficiency? That is, why is the Japanese technology knowledge not popular? This investigation is future research.

[Insert Table 3]

Time series of efficiency

We investigate how the US or Japan technology absorption through imports improve the efficiency in the Asian economy from viewpoint of time series. Figure 2 classifies each country in three categories: (1) country with Japanese technology absorption: US_import dummy=0 which shows the accumulated imports from Japan is larger than that of the US, (2) country with the US technology absorption: US_import dummy=1, (3) country with changing to the US technology absorption: US_import dummy=0. Figure 2 shows efficiency of each country at each period computed by model (4). The efficiency of each country in category (1) is efficiency by country with Japanese technology absorption which is not better absorbed than the US technology (see Table 2) and then low or is decreasing because those countries continue to import a large amount from Japan together with less import from the US. Those countries are not native speaker of English, except for BGD. The efficiency of each country in category (2) is efficiency by country with the US technology absorption which is better absorbed than Japan technology and then high or is increasing. Those countries are not native speaker of English. The efficiency of each country in category (3) is efficiency by country with Japanese technology absorption while those countries are changing the technology absorption of Japan to the US (i.e., the import ratio of the US is dominating that of Japan) and then is increasing. Those countries are native speaker of English, except for KHM. These results suggest that no-well Japanese technology absorption decreases efficiency and then gradually change Japanese technology to the US technology together with efficiency increases.

5. Concluding Remarks.

The Asian economies grown up greater and the difference among the Asian countries become 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 developed countries. However, we have to meet an idiosyncratic view point for the Asian economy. The transferred technology of the US R&D is a driver for the output efficiency in Asian countries, which robustness is confirmed by comparing both amounts of the US R&D vs Japan R&D, the ratio between both amounts, and the US import dummy variable (1,0). In addition, the 5% significant Asian crisis dummies (1 during 1997-2002) support these models are appropriate for the Asian economy. Also, we confirmed the source of efficiency by using two step procedure used by Pitt and Lee (1981) and Kalirajan and Shand (1985) is the US import, not the Japanese import.

As a result, the country with the US technological 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 technological knowledge reduce output efficiency and keep low efficiency. Why did the Japanese technical knowledge not improve efficiency? 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.[7] 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

[7] 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 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).[8]

[8] 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 dummy	0.639	0.481	0.000	1.000
LN(5OECD Machinery imports)	22.997	1.680	17.861	26.175
TROP 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	0.164	0.371	0.000	1.000

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

	(1) Benchmark			(2)JPvsUS			(3)US/JP		
	Coef.	SE	t	Coef.	SE	t	Coef.	SE	t
Production frontier									
constant	11.929	2.655	4.49	2.695	0.247	10.90	3.759	0.834	4.51
l	0.888	0.231	3.84	0.792	0.032	24.72	0.799	0.074	10.74
k	−0.635	0.238	−2.66	0.280	0.030	9.19	0.173	0.078	2.21
h	0.562	0.057	9.80	0.288	0.020	14.20	0.295	0.046	6.47
rd	0.034	0.022	1.53	0.008	0.004	2.21	0.018	0.005	3.54
ll	0.120	0.008	15.41	0.083	0.002	42.50	0.091	0.004	21.23
kk	0.087	0.008	11.08	0.053	0.002	35.38	0.059	0.003	22.59
lk	−0.182	0.012	−14.85	−0.132	0.002	−58.57	−0.144	0.005	−26.84
Inefficiency effects									
constant	−3.035	0.921	−3.30	−1.097	0.288	−3.80	−1.394	0.294	−4.75
SW	−0.107	0.071	−1.50	−0.043	0.042	−1.04	−0.002	0.032	−0.06
KM_ALL	0.140	0.039	3.59	−0.078	0.078	−1.01	0.059	0.012	4.95
TROP	−0.081	0.069	−1.18	0.133	0.040	3.36	0.114	0.044	2.59
KM_JP				0.167	0.040	4.12			
KM_US				−0.036	0.032	−1.14			
LN(US/JP import)							−0.090	0.017	−5.42
US_ import dum									
No.signifi.year dummy	5.000			6.000			6.000		
Crisis dummy									
sigma	0.013	0.002	6.54	0.017	0.003	5.93	0.015	0.003	5.90
gannma	0.768	0.090	8.56	1.000	0.000	6.E+06	1.000	0.001	819.54
Log-Likelihood	216.983			222.206			223.890		

	(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	3.60
l	0.811	0.081	10.04	1.056	0.179	5.89
k	0.407	0.054	7.51	−0.510	0.191	−2.68
h	0.374	0.041	9.11	0.548	0.050	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	0.080	0.006	13.07
lk	−0.126	0.005	−23.66	−0.170	0.010	−16.71
Inefficiency effects						
constant	−0.899	0.265	−3.40	−2.029	0.686	−2.96
SW	−0.052	0.037	−1.41	−0.192	0.068	−2.81
KM_ALL	0.042	0.010	4.05	0.098	0.029	3.34
TROP	0.137	0.055	2.52	−0.027	0.055	−0.50
KM_JP						
KM_US						
LN(US/JP import)						
US_ import dum	−0.194	0.040	−4.87	−0.217	0.086	−2.51
No.signifi.year dummy	4.000					
Crisis dummy				0.103	0.028	3.67
sigma	0.015	0.002	6.88	0.015	0.003	5.45
gannma	1.000	0.000	7.E+04	0.841	0.074	11.31
Log-Likelihood	218.140			213.386		

Notes: A benchmark model is one by Kneller and Stevens (2006) and Henry et al(2009). The dependent variable is the log of GDP. All other variables except *SW*, *TROP* and the year dummies are in logs. 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.

Table 3.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
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

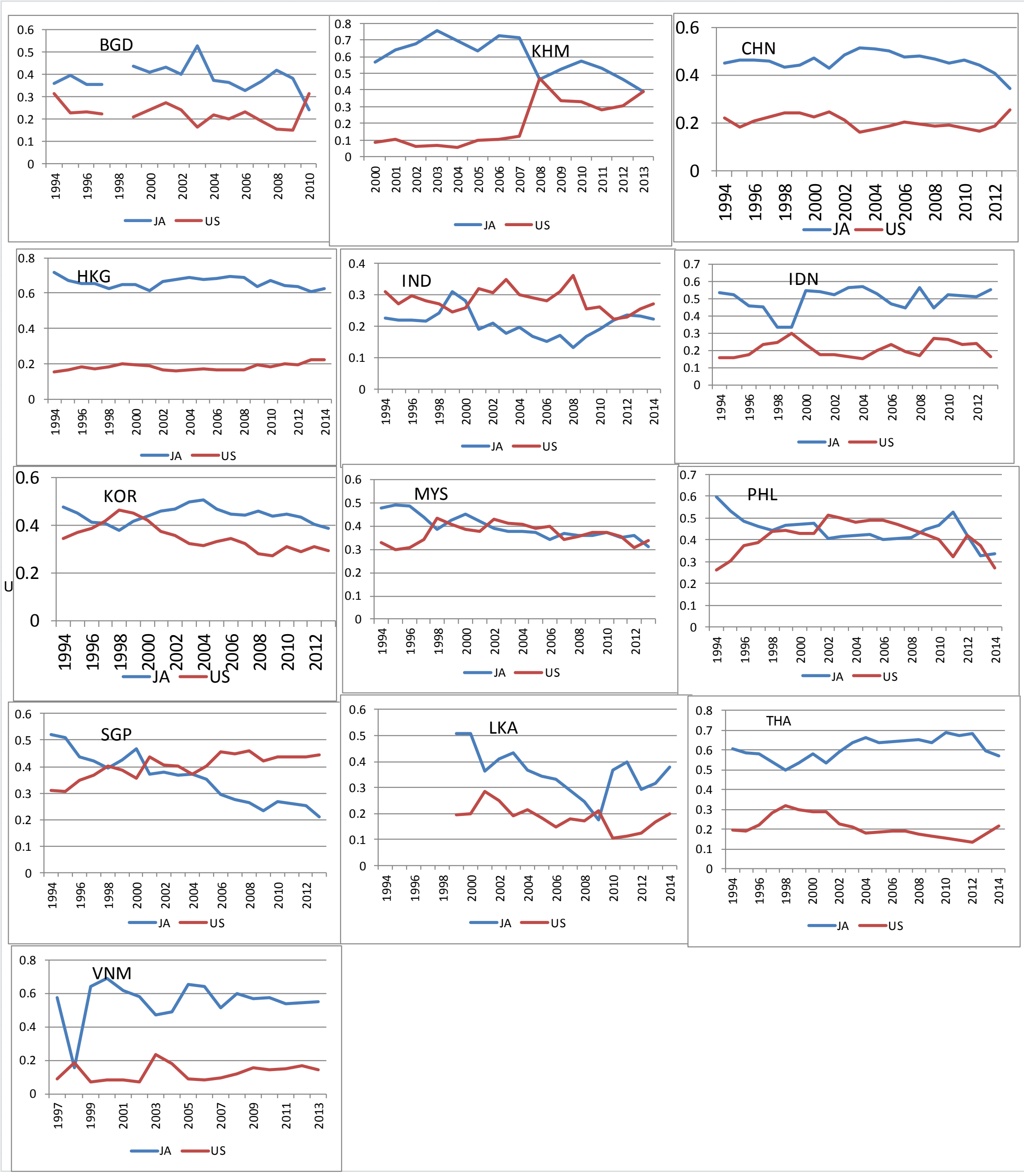
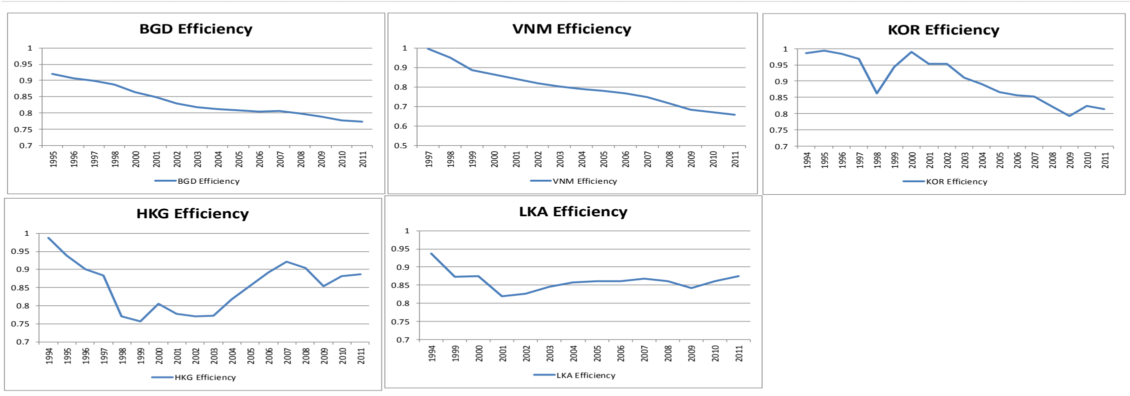


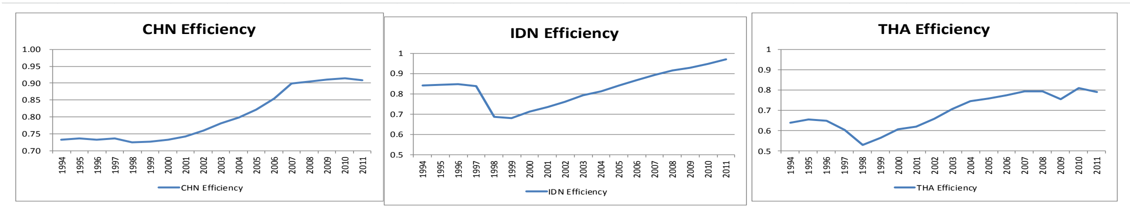
Figure 1. Import ratios of machine and equipment from Japan and the US to the Asian countries in G7 OECD countries.

Japanese technology absorption: US_import dummy=0

decreasing efficiency

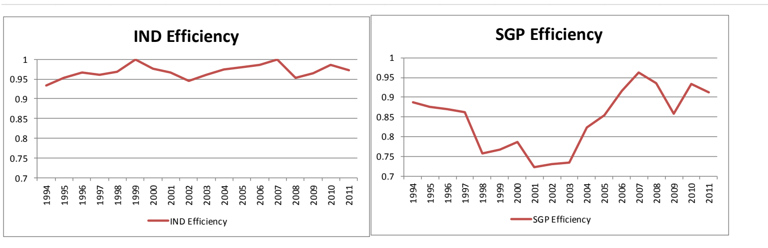


low efficiency or stagnant



The US technology absorption: US_import dummy=1

high efficiency or increasing



Changing to the US technology absorption: US_import dummy=0

increasing efficiency

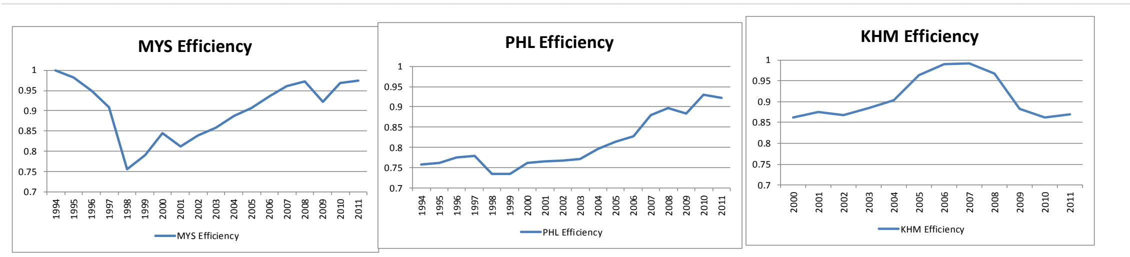


Figure 2. Import from Japan and Inefficiency of the Asian countries.