

FDI and Efficiency convergence, the case of Vietnamese Manufacturing industry

Nguyen Khac Minh^{1*}, Nguyen Viet Hung², Ha Quynh Hoa³, Pham Van Khanh⁴

¹Member of the scientific council, National Economics University (NEU), 207 Giai Phong Street, Hai Ba Trung District, Hanoi, Vietnam.

The Department of Economics, Water Resources University, 175 Tay son Street, Dong Da District, Hanoi, Vietnam

²Faculty of Economics, National Economics University (NEU), 207 Giai Phong Street, Hai Ba Trung District, Hanoi, Vietnam

³Faculty of Economics, National Economics University (NEU), 207 Giai Phong Street, Hai Ba Trung District, Hanoi, Vietnam

⁴Faculty of Information Technology, Military Technical Academy (MTA), 236 Hoang Quoc Viet Street, Cau Giay District, Hanoi, Vietnam

ABSTRACT

The scope of this study is twofold. We aim to test efficiency convergence hypothesis among firms in Vietnamese manufacturing industryⁱ, and to analyze the influence of foreign direct investment (FDI) on efficiency and efficiency convergence. Technical efficiency measures are derived for a sample of Vietnamese manufacturing firms during 2000-2012 using nonparametric data envelopment analysis (DEA). The approach to find the impacts of FDI on efficiency and efficiency convergence through **horizontal and vertical spillover effects**ⁱⁱ is to construct the linkages from dynamic input - output tables. The way to test **unconditional convergence in the two technical efficiency measures from DEA** is used the regression in the form of the Barro equation. The same approach is employed in order to test the influence of FDI as conditioning factor over firms' efficiency. We find the evidence that increase foreign presence within an industry rises the speed of convergence, and impact of FDI on efficiency and efficiency convergence through channels and time are quite different.

Keywords: Data envelopment analysis (DEA); Free disposal hull (FDH); Manufacturing; efficiency; foreign direct investment (FDI); Convergence.

1. INTRODUCTION

The literature investigating the relationship between FDI and technical efficiency has been focusing on technological spillover effects resulting from foreign direct investment. In some case, the contribution of FDI to technical efficiency and TFP via spillovers have been

confirmed while in others, it has been rejected, depending on the nature of the data used and also on specific empirical methodologies.

Our objective, beyond presenting evidence of technical inefficiency and FDI's spillover effects via horizontal and vertical linkages, is to investigate whether technical efficiency convergence process occurred in the presence of FDI through spillover effects in some sub-industries of Vietnamese manufacturing industry.

Cross-country productivity convergence have received attention both at the country level (Dorwick and Nguyen (1989) [6]; and at the industry level (Bernard and Jones (1996) [2]). It should be noted that the growth of a country results from the growth of industries, which comes from the growth of firms. Ultimately, the improvement in technical efficiency is an important aspect of the process of growth. However, there has been little empirical work at the firm level on technical efficiency convergence (Alam and Sickles, 2000 [1]).

Our methodology proceeds in three steps. First, we construct an empirical representation of the frontier technology and set out the models for analyzing the influence of foreign direct investment on speed of convergence for a given set of sub-industries. Second, we discuss the results on a statistical base in order to see if FDI spillover effects on technical efficiency. Finally, we estimate convergence regressions to determine the degree of firms' technical efficiency convergence and firms' technical efficiency convergence in the presence of spillover effects from FDI through horizontal and vertical spillovers.

We apply this methodology to the total sample of sub-industries in Vietnamese manufacturing industry (sub-industries include (1) food products and beverages and tobacco products (F); (2) textiles and wearing apparel (T); (3) footwear (W) and (4) wood and wood products (WD)) and the sample of domestically owned firms in those sub-industries.

This paper is organized into four sections as follows. The next section sets out the theoretical framework underlying the empirical analysis and results. Section 3 describes the data, reports the estimation results of the models and discusses the results obtained, with special emphasis on the contributions of FDI to increase the speed of convergence. The final section concludes the paper.

2. METHODOLOGY

2.1 Efficiency Measurement

The production technology H^t for the transformation of inputs, $x_t \in R_+^N$ into outputs, $y_t \in R_+^K$, at for each time period $t=1,2,...,T$ can be defined as:

$$H^t = \{(x_t, y_t) : x_t \text{ can produce } y_t\},$$

where H^t is assumed to satisfy certain axioms to define meaningful output distance functions. The efficiency scores are the distances from the frontier. An output-based distance function can be defined as:

$$D(x, y) = \min\{\theta : (x, y/\theta) \in H\} = \left\{ \max\{(\lambda, \theta y) \in H\} \right\}^{-1} = [D(x, y)]^{-1}.$$

The distance function is defined as the inverse of the maximal proportional increase of output vector y , given input x . It is also equivalent to the reciprocal of Farrell's (1957) measure of output efficiency. An output – inefficient firm has $D(x, y) < 1$. In the case of the non-parametric method, we use the methods of data envelopment analysis (DEA), especially Charnes, Cooper and Rhodes (CCR) model and free disposal hull model to define the boundary of H .

2.1.1 Data Envelopment Analysis

DEA creates an “envelop” of observable production point (Charnes, Cooper and Rhodes(1978) [3]). DEA is based on linear programming techniques. It provides for flexible piecewise linear approximations to model the “best practice” reference technology. The output–based efficiency score is obtained from the following linear programming problem for each sub-industry.

$$\begin{aligned}
 [D(x, y)]^{-1} &= \text{Max} \theta_{it} \\
 \text{subject to} \\
 \theta_{it} y_{kit} &\leq \sum_{i=1}^N \lambda_{it} y_{kit}, \quad k = 1, 2, \dots, K \\
 \sum_{i=1}^N \lambda_{it} x_{jit} &\leq x_{jit}, \quad j = 1, 2, \dots, J \\
 \lambda_{it} &\geq 0, \quad i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T
 \end{aligned} \tag{1}$$

θ is level technical efficiency and denoted by TE and the model is called the CCR model.

2.1.2 Free Disposal Hull models

The Free Disposal Hull (FDH) is first formulated by Deprins, Simar and Tulkens (1984) [5] and developed and extended by Tulkens and others. The basic motivation is to ensure that efficiency evaluations are affected only by observed performances. The FDH Frontier is obtained by replacing the last line in the model above, it means that the model can be as follows:

$$\begin{aligned}
 [D(x, y)]^{-1} &= \text{Max} \theta_{it} \\
 \text{subject to} \\
 \theta_{it} y_{kit} &\leq \sum_{i=1}^N \lambda_{it} y_{kit}, \quad k = 1, 2, \dots, K \\
 \sum_{i=1}^N \lambda_{it} x_{jit} &\leq x_{jit}, \quad j = 1, 2, \dots, J \\
 \sum_{i=1}^N \lambda_{it} &= 1, \quad \lambda_{it} \in \{0, 1\} \quad i = 1, 2, \dots, N; t = 1, 2, \dots, T
 \end{aligned} \tag{2}$$

$\lambda_j \in \{0, 1\}$ means that the components of λ are constrained to be bivalent. It can explain as : they must all have values of zero or unity so that $\sum_{i=1}^N \lambda_{it} = 1$, one and only one of the performance actually observed can be selected (see Bardhan et al (1996)).

θ is level technical efficiency and denoted by TE and the model is called FDH model.

The efficiency results obtained from CCR and FDH models will be regressed on variables presenting channels of FDI's spillover effects on domestic firms in the second –stage regression..

2.1.3 Second –Stage Regression

To examine the impact of foreign presence on firms' efficiency, the efficiency results obtained from (1) and (2) are regressed on the variables capturing different aspects of foreign presence through some spillover channels. We estimate the following equation:

$$TE_{i,t} = \gamma_0 + \gamma_1 fs_{ij,t} + \gamma_5 hor_{j,t} + \gamma_2 back_{jt} + \gamma_3 forw_{j,t} + \gamma_4 sback_{j,t} + \alpha_t + \alpha_i + \varepsilon_{it} \quad (3)$$

Where subscripts i and t refer to firm and time respectively. α_t capture time and α_i firm specific fixed effects. The above model is estimated using Ordinary Least Square Method (OLS) with time and fixed effects.

fs_{ijt} (Foreign share) is define as the share of firm i 's total equity owned by foreign investors, and X_{ijt} is its real output, for i^{th} firms in sector j at time t .

As in Javorcik(2004), the variable Horizontal (hor_{jt}) captures the extent of foreign presence in subsector j at time t and is defined as a foreign equity participation averaged over all firms in the sector, weighted by each firm's share in sectoral output . In other words,

$$hor_{j,t} = \frac{\sum_{j \in J} fs_{ij,t} * X_{ij,t}}{\sum_{j \in J} X_{ij,t}}$$

Backward ($back_{jt}$) is a proxy for the foreign presence in the industries that are being supplied by the sector to which the firm in question belongs and thus is intended to capture the extent of potential contacts between domestic suppliers and foreign – owned firms. It is defined in the following way:

$$back_{j,t} = \sum_{k \text{ if } k \neq j} \gamma_{jk,t} hor_{k,t}$$

where $\gamma_{jk,t}$ is the proportion of sector j 's output supplied to sourcing industry k at time t taken from the input-output tables at the two-digit level. The proportion is calculated excluding products supplied for final consumption but including imports of intermediate products. As the formula above, inputs supplied within the sector are not included, since this effect is already captured by the Horizontal variable.

The same way, we define the forward spillover variable $forw_{jt}$ as

$$forw_{j,t} = \sum_{l \text{ if } l \neq j} \delta_{jl,t} hor_{l,t}$$

Where the Input - Output tables reveal the proportion δ_{jl} of industry j 's inputs purchased from upstream industries l . Inputs purchased within the industry ($l=j$) are excluded, since this is captured by Horizontal.

Supplybackward (denoted by $sback_{jt}$) which captures the hypothesis of Markusen and Venables is defined as:

$$sback_{j,t} = \sum_{i \text{ if } i \neq j} \delta_{jl,t} back_{i,t}$$

Where $\delta_{jl,t}$ -the proportion of industry j 's inputs is purchased from upstream industries l that in turn supply the downstream industries of foreign firms as measured by variable $back_{j,t}$.

2.2 Efficiency convergence among firms

In this part, we present the models for testing unconditional convergence and conditional convergence.

2.2.1 Unconditional convergence

Empirical tests of convergence hypothesis (e.g., Baumol, 1986; Barro, 1991; Barro and Sala-i-Martin, 1995; De Long, 1988; Islam, 1995; and Mankiw et al; Alam IMS., Sickles RC,2000) determine whether or not there is a closing of the gap between inefficient and efficient firms over time. One of approach is to regresses the log of firms' average growth rates in technical efficiency on the log of the firms' efficiency scores at the beginning of the sample period. The basic form of the equation of unconditional convergence is:

$$\frac{1}{T}[\ln TE_{i,final} - \ln TE_{i,initial}] = \alpha + \beta \ln TE_{i,initial} + \varepsilon_t \quad (4)$$

where T is number of years considered; TE is technical efficiency on the designated year for the firm i and catch-up is denoted by a negative coefficient of β . The speed of caching up is: $\lambda = 1 - (1 + \beta T)^{1/T}$

2.2.2 Conditional convergence

To consider whether technical efficiency (from CCR and FDH models) convergence occurred in the presence of FDI through spillovers to domestic firms. Since, it may take more time before FDI's spillovers effects on domestic firms' technical efficiency, we include lagged foreign share (*fs*), Horizontal (*hor*), Backward (*back*), Forward (*forw*) and supplybackward (*sback*) linkage measures into the model . The new equation of conditional convergence is:

$$\begin{aligned} \frac{1}{T}[\ln TE_{ij,final} - \ln TE_{ij,initial}] = & \alpha + \beta \ln TE_{ij,initial} + \sum_{t=2000}^{2011} \delta_{1,t} fs_{j,t} + \sum_{t=2000}^{2011} \delta_{2,t} hor_{j,t} + \sum_{t=2000}^{2011} \delta_{3,t} back_{j,t} \\ & + \sum_{t=2000}^{2011} \delta_{4,t} forw_{j,t} + \sum_{t=2000}^{2011} \delta_{5,t} sback_{j,t} + \varepsilon_t \end{aligned} \quad (5)$$

$t = 2000, 2001, \dots, 2011; j \in J = \{F, T; W; WD\}$ where subscripts i , and t refer to firm and time respectively.

3. RESULTS AND DISCUSSION

3.1 Data

Our analysis is based on the data from annual enterprise survey conducted by the Vietnam General Statistical Office. The survey covers both manufacturing and non-manufacturing firms. Industry data is available at a 4-digit level. From this survey, we develop a longitudinal panel data set for the years from 2000 to 2011. We drop the firms from our sample set for which the firm-age (the year of the survey minus the year of establishment), total wages, tangible assets, and/or the number of workers are not positive and in cases with incomplete replies. We also drop firms' which enter or exit between year 0 and year T . We select "survivor" firms being survivors that continue to stay in the market between year 2000 and year 2011. The number of firms in our sample is 1038 observations and the sample of domestic firms is 907 observations for each year. To avoid a bias, we estimate efficiency using CCR and FDH models for the total sample, denoting CCRT and FDHT models,

respectively and estimate efficiency using CCR and FDH models for sample of domestically owned firms, denoting CCRD and FDHD models, respectively.

3.2. Testing the effects of FDI spillovers on firms' technical efficiency

Table 1 shows the results of estimating models (CCRT, FDHT, CCRD and FDHD models). A fixed-effects regression is used to assess the impact of the spillover effects of FDI on domestic firms' inefficiency. Technical efficiency measures from CCR and FDH models are regressed on *fs*, *hor*, *forw*, *back* and *sback*. Columns (2)-(3) show the results using the total sample. Columns (4)-(5) present the results using the sample of domestic firms. Foreign share (*fs*) bears a significant and positive sign (in CCRT models) but insignificant and negative sign (in FDHT models). *Hor* coefficients in two cases (FDHT and FDHD models) are positive and statistically significant at 1% and 5% level for the total sample of sub-industry and domestic firms, respectively. While *hor* coefficients in the rest of cases are negative and statistically significant at 5% level in the CCRT model but insignificant in the CCRD model. Positive and significant coefficients on *Back* are found for four models CCRD, CCRT, FDHD and FDHT models. Backward spillovers go from the foreign firm to its upstream local suppliers. In these models, domestic firms draw apparently more benefits from their linkages to foreign firms. *forw* coefficients are statistically significant at least 10% level for all cases but they have the opposite sign. *Forw* coefficients are positive and statistically significant at 5% level in the cases of FDH models. *sback* coefficients are positive for all cases but *sback* coefficients of FDH models are insignificant. The results obtained from CCR models are similar to those in the literature. Javorcik (2004) estimates backward spillovers to be positive and forward spillovers to be negative but not statistically significant.

Table 1. Testing the Effects of FDI spillovers On Firms' Technical efficiency

Dependent variable	Fixed-effects regression			
	TE from total sample of sub-industry sample		TE from domestic	
	CCRT model	FDHT model	CCRD model	FDHD model
γ_0	0.029*** (0.010)	-0.005 (0.014)		
γ_1	-0.040** (0.015)	0.053*** (0.020)	-0.020 (0.017)	0.048** (0.023)
γ_2	0.080*** (0.016)	0.095*** (0.021)	0.134*** (0.018)	0.091*** (0.023)
γ_3	-0.086*** (0.025)	0.071** (0.033)	-0.055* (0.029)	0.095** (0.037)
γ_4	0.117*** (0.026)	0.041 (0.035)	0.085*** (0.030)	0.035 (0.039)

	0.127***	0.315***	0.123***	0.326***
_cons	(0.005)	(0.007)	(0.006)	(0.008)
/sigma_u	0.144	0.242	0.145	0.236
/sigma_e	0.150	0.201	0.158	0.207
Rho	0.479	0.591	0.459	0.565

Note: 1) standard errors are given in the parenthesis;

2) */**/** Denotes significant at the 10, 5 and 1 percent levels, respectively.

Comparing foreign spillover effects on technical efficiency between CCR and FDH models

Two models used here to measure the foreign spillover effects on firms' technical efficiency for the total sample of sub-industry and domestically owned firms of this sub-industry are based on nonparametric data envelopment analysis in the forms of CCR and FDH models. The impacts of foreign presence on firms' technical efficiency through *hor*, *back*, *forw* and *sback* variables are the same sign in CCRT, CCRD models (but difference in magnitude). To explain the differences in effects of FDI on firms' technical efficiency derived from the CCR and FDH models is that the set of constraints of CCR model is convex set, while the set of constraints of FDH model is not convex (Deprins et al. (1984)), since FDH model imposes one fewer restrictions on the data. Thus technical efficiency from FDH model is relative to an observed point on the frontier.

Comparing foreign spillover effects on efficiency between CCR and FDH models

Two models used here to measure the foreign spillover effects on firms' efficiency for the total sample of sub-industry and domestically owned firms of this sub-industry are based on nonparametric data envelopment analysis in the forms of CCR and FDH models. The impacts of foreign presence on firms' technical efficiency through *hor*, *back*, *forw* and *sback* variables are the same sign in CCRT, CCRD models (but difference in magnitude). To explain the differences in effects of FDI on firms' technical efficiency derived from the CCR and FDH models is that the set of constraints of CCR model is convex set, while the set of constraints of FDH model is not convex (Deprins et al. (1984)), since FDH model imposes one fewer restrictions on the data. Thus technical efficiency from FDH model is relative to an observed point on the frontier.

3.3 Estimated results of unconditional convergence

Table 2 displays the cross-sectional OLS estimates of unconditional convergence for the total sample of sub-industry and the sample of domestically owned firms in Vietnamese manufacturing industry (theoretical model 4 in section 2.2).

The coefficients of initial technical efficiency from models 4.1T, 4.2T, 4.1D and 4.2D are -0.0769, -0.0627, -0.0798, -0.0644, respectively and significantly different from zero at 1%, confirming the presence of unconditional convergence during the period of 2000-2011. The speed of convergence of those model are 15.63%, 10.09%, 17.39%, 10.59%, respectively.

Table 2: Unconditional convergence (2000-2011)

Dependent variable: <i>The average year to year growth in the technical efficiency scores</i>	Speed of Half-catching up line
(a) Total sample of sub-industry	

Model 4.1T (TE from CCR model)	$DLnCCR_{i,2011} = - \overset{***}{0.2217} - \overset{***}{0.0769} LnCCR_{i,2000}$ (0.0091) (3.61E- 06)	15.63%	8.66
	$R^2 = 0.43; DW = 1.79; \text{Number of Observations} = 1038$		
Model 4.2 T (TE from FDH model)	$DLnFDH_{i,2011} = \overset{***}{-0.0892} - \overset{***}{0.0627} LnFDH_{i,2000}$ (0.0043) (0.0022)	10.09%	10.7
	$R^2 = 0.44; DW = 1.83; \text{Number of Observations} = 1038$		
(b) Domestically owned firms in the sub-industry			
Model 4.1D (TE from CCR)	$DLnCCR_{i,2011} = \overset{***}{-0.0234} - \overset{***}{0.0798} LnCCR_{i,2000}$ (0.0097) (0.0029)	17.39%	8.33
	$R^2 = 0.45; DW = 1.82; \text{Number of Observations} = 907$		
Model 4.2D (TE from FDH)	$DLnFDH_{i,2011} = \overset{***}{-0.0895} - \overset{***}{0.0644} LnFDH_{i,2000}$ (0.0043) (0.0023)	10.59%	10.41
	$R^2 = 0.46; DW = 1.71; \text{Number of Observations} = 907$		

Note: 1) standard errors are given in the parenthesis;

2) */**/** Denotes significant at the 10, 5 and 1 percent levels, respectively.

3) Model 4.1T is model 4 in section 2.2, where TE estimated from CCR model and estimated using total sample; Model 4.2T is model 4 in section 2.2, where TE estimated from FDH model and estimated using total sample; Model 4.1D is model 4 in section 2.2, where TE estimated from CCR model and estimated using sample of domestic firms; Model 4.2D is model 4 in section 2.2, where TE estimated from FDH model and estimated using sample of domestic firms;

3.4 Estimated results of conditional convergence

To investigate whether there exist impacts of FDI's spillover effects on technical efficiency convergence, we estimate the unconditional convergence models with adding spillover variables. Table 3 presents the cross-sectional OLS estimates of conditional convergence for the total sample of sub-industries and the sample of domestic firms. We estimate 4 models for the total sample of sub-industry and sample of domestic firms. 60 variables conditioning in these models are $hor_{2000}, hor_{2001}, \dots, hor_{2011}, forw_{2000}, \dots, forw_{2011}$ variables.

Table 3: Conditional convergence (2000-2011)

(a) For total sample of sub-industry with number of observations =1038	
(5.1T)	$\Delta \ln CCRT_{ij,2011} = -0.1532^{***} - 0.0836^{***} LnCCRT_{ij,2000} - 0.8835^{**} back_{j,2000} + 0.0896^{**} hor_{j,2001}$ (0.0264) (0.0026) (0.4384) (0.0398) $+ 0.2357^{**} back_{j,2001} + 0.3062^{**} forw_{j,2001} - 0.5397^{***} sback_{j,2001} - 0.4663^{***} forw_{j,2001}$ (0.1034) (0.1370) (0.1268) (0.1238) $+ 0.1024^{***} hor_{j,2005} - 0.1559^{***} back_{j,2005} + 0.025^{***} fs_{j,2008} + 0.055^{***} back_{j,2009}$ (0.0395) (0.0453) (0.0145) (0.0306) $+ 0.089^{***} fs_{j,2010} + 0.135^{***} forw_{j,2011}$ (0.0145) (0.014) $R^2=0.5$ $DW=1.92$ Speed of catching up =22.92% ; Half-line= 7.94

(5.2T)
$$\Delta \ln FDHT_{ij,2011} = -0.2366^{***} - 0.0832^{***} \ln FDHT_{ij,2000} + 0.4873^{***} + sback_{j,2000} - 0.021^{***} hor_{j,2005}$$

$$+ 0.017^{*} back_{j,2008} + 0.028^{*} back_{j,2009} - 0.049^{***} forw_{j,2009} - 0.023^{*} hor_{j,2011} - 0.024^{***} back_{j,2011}$$

$$+ 0.273^{***} forw_{j,2011}$$

$$R^2=0.89; DW =1.86$$
Speed of catching up =22.43% ; Half-line= 7.98

(b) For domestically owned firms of sub-industry with number of observations: 907

(5.1D)
$$\Delta \ln CCRD_{ij,2011} = -0.1151^{***} - 0.0823^{***} \ln CCRD_{ij,2000} + 0.2398^{**} back_{j,2000} + 0.089^{**} hor_{j,2000}$$

$$+ 0.4011^{**} forw_{j,2000} + 0.4507^{**} sback_{j,2000} - 1.0611^{***} back_{j,2000} - 0.2823^{***} forw_{j,2004}$$

$$- 0.1515^{***} back_{j,2006} + 0.1026^{**} hor_{j,2006} - 0.2066^{*} forw_{j,2007} + 0.0616^{**} back_{j,2011}$$

$$R^2=0.52; DW =1.92$$
Speed of catching up =21.42%;Half-line= 8.07

(5.2D)
$$\Delta \ln FDHD_{ij,2011} = -0.0813^{***} - 0.0755^{***} \ln FDHD_{ij,2000} + 0.1448^{**} back_{j,2000} + 0.0706^{***} hor_{j,2001}$$

$$- 0.2195^{***} back_{j,2003} - 0.0875^{***} forw_{j,2003} + 0.738^{***} back_{j,2009} - 0.2527^{***} sback_{j,2010}$$

$$+ 0.0848^{***} back_{j,2011} - 0.0966^{***} hor_{j,2011} + 0.0944^{**} forw_{j,2011}$$

$$R^2=0.52; DW =1.79$$
Speed of catching up =16.13% ; Half-line= 8.83

Note: 1) standard errors are given in the parenthesis;

2) */**/** Denotes significant at the 10, 5 and 1 percent levels, respectively.

3) Model 5.1T is model 5 in section 2.2, where TE estimated from CCR model and estimated using total sample; Model 5.2T is model 4 in section 2.2, where TE estimated from FDH model and estimated using total sample; Model 5.1D is model 4 in section 2.2, where TE estimated from CCR model and estimated using sample of domestic firms; Model 5.2D is model 4 in section 2.2, where TE estimated from FDH model and estimated using sample of domestic firms;

Estimated results of conditional convergence of technical efficiency from CCRT and FDHT , CCRD and FDHD models are given in Table 3. It allows us to draw some conclusions. The coefficients of initial technical efficiency from those models are negative and significant at 1%, showing there is evidence for convergence. Most of the conditional variables (representing impacts of FDI) were jointly insignificant, and some variables are significant . Such as, in equation 5.1T coefficients of hori₂₀₀₀, hori₂₀₀₅ are positive and significant at 5% and 1%, respectively while coefficients of back₂₀₀₀, back₂₀₀₅... are negative and significant... The coefficients of variables fs₂₀₀₈ and fs₂₀₁₀ are positive and significant at 1%, thus the expected spillover effect of FDI on efficiency convergence is confirmed. Considering total effects of FDI on technical efficiency convergence can be seen in Table 4.

Comparing the speed of convergence from unconditional convergence models

Table 4. Comparing the speed of convergence from unconditional convergence models and conditional convergence models

	Unconditional convergence models				conditional convergence models (Impact of FDI on speed of convergence)			
	TE from total sample		TE from sample of domestic firms		TE from total sample		TE from sample of domestic firms	
	Model 4.1T	Model 4.2T	Model 4.1D	Model 4.2D	Model 5.1T	Model 5.2T	Model 5.1D	Model 5.2D
Speed of convergence	15.63 %	10,09%	17,39%	10,59	22,92%	22,43%	21,42%	16,14%
Half line	8.66	10,7	8,33	10,41	7.94	7.98	8.07	8.83

Table 4 displays the results of comparing the speed of unconditional convergence models and conditional convergence models. Columns 2, 3, 4, 5 report the results of speed of convergence and half-line of unconditional models. Columns 6, 7, 8, 9 present the results of speed of convergence and half-line of conditional models. The results show that the speed of conditional convergence models through channels of FDI effects must be faster than those from unconditional convergence models.

4. CONCLUSION

This study analyzed horizontal and vertical productivity spillovers of foreign direct investment on technical efficiency convergence in Vietnamese sub-industries from 2000 to 2011. Dynamic I-O tables (2000 and 2005) were used to construct the linkages between domestic and foreign firms and to set out the model in which several channels through which FDI could affect efficiency and efficiency convergence of the domestically owned firms. Using a panel dataset covering sub-industries in Vietnamese manufacturing firms from 2000 to 2011, We found the existence and the nature of the effect of FDI on firms' efficiency and efficiency convergence at firms levels in the sub- industries: (1) there were impact of FDI on domestic firms' efficiency score and convergence at a firm level; (2) the presence of FDI increased the speed of efficiency convergence in domestically owned firms.

REFERENCES

1. Alam IMS., Sickles RC. Time Series Analysis of Deregulatory Dynamics and Technical Efficiency: The Case of the U.S. Airline Industry. International Economic Review. 2000; 41(1): 203-218.
2. Bardhan, I., Bowlin, W.F., Cooper, W.W; and Sueyoshi, T. 1996. Models and Measures for Efficiency Dominance in DEA. Journal of Operations Research Society of Japan. 1996, 39: 322-332
3. Barro, R.J. Economic growth in a cross section of countries. Quarterly Journal of Economics. 1991; 106, 407-443.
4. Barro, R.J., Sala-i-Martin, X.X. 1995. Economic Growth. McGraw Hill, New
5. BAUMOL, W.J. 'Productivity Growth, Convergence and Welfare: What the Long Run Data Show. American Economic Review 76. 1986: 1072-1085.
6. Bernard AB., Jones CI. Comparing Apples to Oranges: Productivity Convergence and Measurement Across Industries and Countries. American Economic Review. 1986; 86 (5): 1216-1239.

- 352 7. Blomstrom, M., A. Kokko. Multinational Corporation and Spillovers. *Journal of Economic*
353 *Survey*. 1998;12 (2):247-277.
- 354 8. Charnes A., Cooper WW., Rhodes E. Measuring the efficiency of decision-making units,
355 *European Journal of Operational Research*. 1978; 2(6): 429-444.
- 356 9. Cornwell C., Schmidt P., Sickles RC. Production Frontiers with Cross Sectional and Time
357 Series Variation in Efficiency Levels. *Journal of Econometrics*. 1990; Vol 46, No 1-2: 185-
358 200.
- 359 10. Deprins D., Simar L., Tulkens H. Measuring Labor-Efficiency in Post Offices, in: M.
360 Marchand and et al (eds). *The Performance of Public Enterprises: Concepts and*
361 *Measurement*. Amsterdam, North Holland; 1984; 243-267.
- 362 11. De Long, J.B. Productivity growth, convergence, and welfare: comment. *American*
363 *Economic Review*. 1988; 78: 1138-1154.
- 364 12. Dorwick S., Nguyen DT. OECD Comparative Economic Growth 1950-85: Catch-Up and
365 Convergence. *American Economic Review*. 1989; 79 (5): 1010–1031.
- 366 13. Farrell MJ. The measurement of Productive Efficiency. *Journal of the Royal Statistical*
367 *Society*. 1957; 120: 253 - 281.
- 368 14. Haddad M., Harrison A. Are there Positive Spillovers from Direct Foreign Investment?
369 Evidence from Panel Data for Morocco. *Journal of Development Economics*. 1993; Vol.42,
370 No.1: 51-74.
- 371 15. Islam, N., 1995. Growth Empirics: a panel data approach. *Quarterly Journal of Economics*
372 110: 1127-1170.
- 373 16. Javorcik, B.S. Does foreign direct investment increase the productivity of domestic
374 firms? In search of spillovers through backward linkages, *American Economic Review*.
375 2004; 94(3): 605-627.
- 376 17. Mankiw, N.G., Romer, D., Weil, D.N.. A contribution to the empirics of economic growth.
377 *Quarterly Journal of Economics*. 1992; 107: 407-437.
- 378 18. Schmidt P., Sickles CR. Production Frontiers and Panel Data. *Journal of Business &*
379 *Economic Statistics*. 1984; Vol.2, No. 4: 367-374.

380 **Acknowledgements**

381 Funding from Vietnam National Foundation for Science and Technology Department
382 (NAFOSTED), under grant number II 2.2-2012.18 is gratefully acknowledged

383 We would like to send special thank to researchers who commented on our paper at the
384 12th International Conference on Data Envelopment Analysis (DEA2014) in Malaysia on 14-
385 17 April 2014

386 This manuscript has also benefited from comments by the editor and two anonymous
387 referees.

ⁱ Vietnamese manufacturing sector is the most important sector in the country in terms of its contribution to economic growth. Four sub-industries: food products and beverages and tobacco products; textiles and wearing apparel; footwear and wood and wood products have contributed about more than 40% of Vietnamese manufacturing industries' total output during 2006-2013.

ⁱⁱ Horizontal spillovers run from a foreign firms to a local firms in the same industry. On the other hand, vertical spillovers refers to local firms that may be able to improve their productivity (efficiency) as a result forward or backward linages with foreign firms (see Blomstrom and Kokko (1998))