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How Does Technology Diffusion Increase Speed of TFP Convergence at Firm Level? Exploring the Effects of High Technology Firms on Linkages: Evidence from Vietnam Enterprises

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Abstract

The objective of this research is to give an explanation why low-technology enterprises can catch up with high-technology ones even when they are unable to invest in RD. The answer is the existence of technology diffusion, however, how does technology diffusion take place and can we quantify this process? To answer this question, we structure variables which represent the transmission channel of technology diffusion from high-technology enterprises to low-technology ones, then quantifying impacts of technology diffusion and applying this methodology into the analysis of impacts of technology diffusion on total factory productivity (TFP) convergence of Vietnamese enterprises. We establish two TFP series in accordance with the methods developed by Olley-Pakes [7] and extended by Levinsohn and Petrin [5]. On the basis of two constructed TFP series, we estimate the unconditional convergence model and the convergence model under the effects of technology diffusion. The estimation results of two models show that the impacts of technology diffusion occur complicatedly but the total effect of the variables representing for impacts of technology diffusion on TFP convergence is positive and the speed of convergence in the model including the variables of technology diffusion is faster than one in the model excluding this variables.

Index terms— technology diffusion, horizontal spillover, vertical spillover, TFP convergence, convergence under the technology diffusion.

1 Introduction

here have been a lot of researches exploring the productivity convergence among countries at both the national level and the firm-level. The results, however, are not consistent with each other, and in many cases they are opposite to each other. Bernard and Jones [1], for instance, could not find any evidence of the convergence in manufacturing industry. Others acquire results supporting for the convergence in countries which have low-productivity at the first stage of development but quickly grow in the subsequent periods. Nishimura e t al. [6] provides evidences of productivity convergence among Japanese enterprises. Pascual et al. [8] study the productivity convergence in manufacturing-processing industry in Europe. They analyze in detail sub-industries which belong to the manufacturing-processing industry to make a comparison among industries having similar characteristics of technology. They find out that in some industries, there exists a productivity convergence while in others as well as the whole manufacturing-procession industries, there does not exist a productivity convergence. Their results put an emphasis on the importance of making a comparison among industries having similar technologies when we analyze the productivity convergence. Minh et al. [9] studies effects of FDI spillover on efficiency convergence of Vietnamese manufacturing enterprises. They employ the dynamic input-output (I-O) tables to construct the structure of relationship between domestic and FDI enterprises through spillover effects of FDI enterprises on domestic ones. Using the data of Vietnamese manufacturing industry in the period 2000-2011, they point out the positive effects of FDI spillover on the efficiency convergence of manufacturing enterprises. However, one issue arising here is that why productivity (or technical efficiency) convergence is so important. One reason is that the technology spillover behind the productivity convergence process can create opportunities for low-technology enterprises to catch up with high technology ones, even when they could not invest into R&D or purchase new technologies due to high investment cost, especially for new market-comers and small and medium enterprises. The recent researches show that the R&D spillover is one important explanatory variable for convergence. For one nation which has international trade of goods and services, investment, exchange of information and knowledge, firms' productivity would depend on its own R&D as well as others' R&D because technology spillover is not restricted by geographical boundaries. Technology is the root cause of long-term economic growth. The economic performance of one nation has a strong relationship with the capacity of inventing new knowledge and applying these knowledge as well as the ones invented by other nations. This research would answer the question how technological knowledge spillovers from advance-technology enterprises to lowtechnology one, and how we can quantify this spillover effect.

This research is structured into five sections. The next one will present the methodology framework including models measuring total factor productivity to estimate TFP; constructing convergence model; and integrate transmission channels of technology progress into the convergence model. The third section provides data and estimation results. The conclusions would be in section 4.

2 II.

3 The Methodology Framework a) Measurement of total factor Productivity

To construct the convergence model from TFP series estimated from a unified dataset by two different methods, we will briefly present the methodology basis of the Olley-Pakes method, in which investment is used as a controlling variable. The second method is quite similar, except using the intermediate input as a controlling variable.

The efficiency estimates at the firm-level in this research are attained by using Olley and Pakes method. This method has been developed to point out the possibly simultaneous bias when estimates the production function. This can be illustrated by examining logarithm version of Cobb-Douglas function below (at point of time t for firm i):LnY t =? 0 + ? l lnL t + ? k LnK t + ? t LnI t +? t +? t (1)

In which, Y t is denoted for output, L t for labor and K t for capital, I t for intermediate inputs.

The individual error component of firm ? t , and error component follows i.i.d ? t . The component ? t has no determinant impact on firms' decisions. The productivity component, ? t , is assumed to be unobservable in the eyes of econometrists, but firms' managers have information, and this component has impact on the rule of making decision in the firm. The simultaneity problem arises when there exists simultaneous correlation, both within firm i and between periods t, between ? t and inputs of firms in separate series of firms. To show the simultaneity problem, OP employs investment as a representative for latent productivity that is serially correlated. The investment function, therefore, can be rewritten as follows:i t = i t (? t , k t)

In order to take positive value for investment, i t = i t (? t , k t) is converted to inverse function to get ? t as a function of capital and investment ? t =(i t , k t). To facilitate the analysis, we denote: y t =lnY t , l t =lnL t , k t =lnK t and i t =lnI t . Then, the first equation gives use the output as a function of observable variables:y t = ? l l t + ? k k t + ? t ? t +? t (i t , k t) +? t ,**(2)**

in which, (i t , k t)= ? 0 + ? k k t + ? t (i t , k t). The robust estimates of input variables can be attained by using the semi-parametric estimation. Assuming ? t following firstorder Markov and capital does not instantaneously respond to creativeness in productivity -in which invention in productivity can be defined as follows:? t = ? t -E[? t |? t-1]. (**3**)

With this assumption, the robust estimates of ? k can be derived from estimation of this function:y t * = y t -l t ? l -? l ? t = ? 0 + ? k k t + E[? t |? t-1]+ ? t * (**4**)

in which, y t * is the net output after eliminating the contribution of labor and ? t * =? t +? t . Because the result of the first stage is one estimate of ? t -one robust estimate of E[? t |? t-1] which can be obtained, and the estimates of the equation (3) give us the robust estimate of ? k . Total factor productivity (TFP) of firm i in year t is: (5) in which, tfp it is the logarithm of TFP (lnTFP) s and the appropriate indicators are estimates of parameters attained from production function estimation.tfp it = y it -l l it -? it -k k it

4 b) The Role of Technology Spillover in Convergence

This section is to answer this question: "How does technology diffusion from high-tech to low-tech firms take place?" We would construct several channels through which high-tech firms can have impact on productivity and productivity convergence of low-tech ones. Herein, we structure channels allowing horizontal and vertical technological spillovers.

To implement this task, we need give some assumptions at first: 1. Assumption 1: There is the relationship between firms' technology and productivity. It means that technology and productivity (TFP) of any firm have a strongly positive correlation (high-tech firm has high (TFP) productivity). 2. Assumption 2: Firm i is called a high-tech one in year t if this firm has TFP being double or more than the average TFP of that industry in the same year. We use LH it as a variable capturing the existence of firm i which has advance technology in the industry under consideration in year t, and J is a set of firms having advance technology:LH it = 1 if i J ? and LH it = 0 if i J ?**(6)**

The horizontal technology spillover variable jt LHh tells us the extent of participation of high-tech firms in that industry and it can be measured by the weight of actual output of high-tech ones in total output of the whole industry:1 it it it n jt j LH X LHh X = * = ? (7)

In which, X it is the real output of firm i, n is the number of firms in questions.

The variable jt LHb measures the backward spillover effect, exhibiting the extent of participation of high-tech firms in the downstream industry; therefore, it reflects the linkages between low-tech suppliers and high-tech clients. So, we can measure jt LHb as follows:jt jkt kt k if k j LHb LHh ? ? = * ?**(8)**

In which, ? jkt is the ratio of output of industry j selling to industry k in the period t. The values of ? can be computed from I-O table. When computing ?, we eliminate firms' inputs sold within the industry (k ? j) because this component has already been captured by kt LHh . We can avoid the endogeneity problem by using the ratio of output sold to downstream industry k with a certain level existence of foreign firms kt LHh . In a similar way, we can define the forward spillover variable LHf it as follows:jt jlt lt l if l j LHf LHh ? ? = * ?**(9)**

Herein, I-O table provides us ? jlt , the ratio of inputs of industry j purchased from the upstream industry l. Inputs purchased within the intra-industry (l ? j) are also eliminated because these are already captured by LHh.

5 c) The model of productivity convergence among firms

The simple model of productivity convergence developed by Bernard and Jones [1] has been widely used in researches of cross-country productivity convergence. This is the basis for the model of longterm average productivity growth convergence (TFP) as a function of the initial productivity, and we can specify the general model as follows:

( ), , ,**0 1 , 1 ln**

ln ln lni final i final i initial i initial i TFP TFP TFP TFP u T ? ? ? = ? = + +**(10)**

In which, T shows the length of the period, final denoted for the final year, initial for the initial year (in this sample, the initial year is 2000 while the final year is 2012). The catching-up variable can be exhibited by a negative value of the coefficient? 1 = -{1 -(1 -?) T }/T.

We assume that u it ? N(0, ?). The convergence model (10) can be applied for two TFP series computed from two distinctive methods on the same dataset. Therefor, we would two types of model to estimate convergence: model (10.1) is the model 10 in which TFP (denoted by pm) can be estimated by using Levinshon-Petrin procedure while model (10.2) is the model 10 in which TFP (denoted by pi) would be estimated by using Olley-Pakes procedure.

6 d) The impact evaluation model of technology spillover on TFP convergence

The impact evaluation model of technology spillover can be specified as follows: ? ? ? ? ? ? µ = = = = ? = ? = + + + + + + + + ? ? ? ?**(11)**

The convergence model (11) can be applied for two TFP series computed by using two different methods on the same dataset. Therefor, we would have two types of model to estimate convergence under impacts of technological spillover: model (11.1) is the model 1 in which TFP (denoted by pm) can be estimated by using Levinshon-Petrin procedure while model (11.2) is the model 11 in which TFP (denoted by pi) would be estimated by using Olley-Pakes procedure.

7 III.

8 Empirical Results

9 a) Data

The micro-data basis is derived from annual business survey undertaken by General Statistical Office (GSO) from 2000 to 2012. This research employs all firms from all industries including cultivation, animal husbandry, mining, manufacturing and service industries, however, these firms must be available in all thirteen years of GSO surveys.

The main information of firms includes type of firm, field of business, number of labors (the average number in the year), assets, capital allowance, fixed assets, labor's earnings, salary and bonus and social security contribution, financial obligations, profits (in term of VND million).

Inputs and outputs are corrected for inflation. This research uses balanced panel data, including all firms appearing in 13 years from 2000 to 2012. We eliminate firms whose age, revenue, assets, and labor do not take positive values. In this research, the added value is used to estimate total factor productivity. However, these data are not available and must be indirectly computed from other related indicators. The dataset consists of 10767 observations for each year and the whole sample period is 13 years. These observations are categorized into three sectors, namely: b) Testing assumptions of Olley-Pakes approach Before continuing our discussion about estimation of parameters of production function by OP method, we must test if the main assumptions of OP approach are satisfied, i.e. if investment monotonically increases with respect to TFP measured using strictly positive investment observations. We estimate the fixed effect model at the firm level, in which logarithm of investment and TFP and year dummy variable are used as explanatory variables and would be adjusted for group of any variables at the four-digit industry code. The estimate of logarithm of TFP ranges from 0,7 to 0,8 for the whole sample and sectors, statistically significant at 1%. The estimate implies that a 1% shock of TFP at firm-level will cause investment to increase by 0,7-0,8% in the whole sample. Thereby, with the given dataset of considered firms, using OP approach to estimate production function is an appropriate method.

c) The unconditional convergence Table 1 records estimation results of models (10.1) and (10.2). These results are derived from OLS regression. To compute the speed of convergence, we firstly estimate ?, then computing ? based on the following formula: ? 1 = -{1 -(1?) T }/T. The estimated coefficients have expected sign and are highly statistically significant. Source: the author estimates from business surveys of GSO

We can draw out two comments from the estimation results given in Table 1. Firstly, in both two groups of models, we can see a clear evidence for productivity convergence. However, the speed of convergence in cases is slightly different. The speed of convergence attained from models (10.1T), (10.1K), (10.1C) and (10.1D) are correspondingly 6,7%;8,96% ;4,7% and 7,73%. Meanwhile, the speed of convergence obtained from models (10.2T), (10.2K), (10.2C) and (10.2D) are respectively 7,55%; 8,96% ; 5,38% and 8,67%. Thereby, the speed of convergence computed from the group (10.2) are higher than ones from the group (10.1), except the case of models 10.1K and 10.2K which have a same speed at 8,96%. Secondly, the speed of convergence is higher than one obtained in the research at the nation-level. For instance, while Dorwick and Nguyen [2] reports the result of speed of convergence cross countries being around 2.5% annually, our results collected from both models 10.1 and 10.2 point out that the speed of convergence does not exceed 9%. On the other hand, these results are lower than ones provided by Nishimura et al. [6].

10 d) Impacts of technology spillover on convergence

The estimation results of two unconditional convergence models (10.1) and (10.2) prove there exists productivity convergence among firms in three sectors in Vietnam. In this section, we examine convergence under the impact of technological spillover. The estimation results of models (11.1) and (11.2) are provided in Table 2 and 3. Because results from unconditional and conditional models using two estimated productivity series by Levinshon-Petrin and Olley-Pakes algorithms tend to have the same direction and are nearly indifferent, therefore, we put focus on making a comparison impacts of technology spillover between unconditional model and conditional one using estimated productivity series by using Levinshon-Petrin algorithm. Comparing impacts of technology spillover between unconditional model and the conditional one using Olley -Pakes gives us a similar result. Table 2 gives us impacts of technology spillover on firms in three sectors, in which estimated productivity series are based on Levinshon-Petrin algorithm. Source: the author estimates from business surveys of GSO From estimation results in table 2, we have following comments. The value of ? coefficient estimated from convergence model under the impact of technology spillover variable is negative and highly statistically significant.

Most of coefficients of technology spillover in all three models are statistically significant at 1%-10%, however, their sign are different in models.

The sign of LH variable in 2001 is negative but not highly significant. It is also negative in 2003 and significant at 5%. In 2004, it is negative but insignificant while it is positive in 2010 and significant at 10%. In 2002 and 2006, it is positive and significant at 5% while it is positive and significant at 1% in **??**003, 2008, 2011, and 2012. The total impact of this coefficient is positive and statistically significant. This can explain that the technology spillover from high-tech to low-tech firms is significant.

The sign of variables Lhh, Lhb and Lhf are opposite to each other depending on the year we consider. This can be explained as follows. The horizontal technology spillover (Lhh) implies the spillover from high-tech firm to low-tech firm in the same industry. There are two main channels for this transmission: the mobility of trained labors in high-tech firm and technology imitation (positive Lhh). The presence of high-tech firms also stimulates competitiveness in the market. The stronger competitiveness will force low-tech firms to either apply high technology, new management method, or employ the existing resources more efficiently, and this is also an important channel for horizontal spillover (positive Lhh). However, none of these impacts must be positive. The movement of labor market can generate a negative spillover effects such as brain drain from low-tech to high-tech firm putting a harmful effect on productivity in low-tech firm, or paying higher wage without requiring an improvement in productivity due to the higher wage in high-tech firms. The high-tech firms can prevent costs concerned with high technology leakage from happening by restricting technology transfer or keeping know-how in secret. These policies apparently hinder opportunities for horizontal spillover through performance impact. Higher productivity in high-tech firms can put the downward pressure on the price or lower demand for products of low-tech firms (negative Lhh). If low-tech firms could not adapt with more fierce competition and raise the productivity, they could not only lag behind but also be kicked out of business due to the existence of high-tech firms.

The vertical spillover is the backward spillover from high-tech firms to low-tech firms in the upstream industries (positive Lhb). Even in the case that high-tech firms try to minimize the technology leakage to low-tech firms in the same industry (horizontal impact), they still want to support their suppliers (low-tech one) in order to help them provide good quality input and high-tech firms can benefit from this outcome (positive Lhb). In other words, if high-tech firms decide to purchase inputs from low-tech ones (possibly due to location), they can transfer technology to low-tech firms which provide them with inputs, and stimulate the spread of technology to the upstream industries to break the stagnation (positive Lhb). The impact of backward linkages also can be harmful for low-tech firms (negative Lhb).

The forward spillover (Lhf) is from high-tech firms to low-tech ones in the downstream industries. The availability of better inputs from high-tech firms can raise the productivity of firms using these inputs (positive Lhf). However, inputs produced by high-tech firms are usually more expensive and less appropriate for requirements of low-tech firms (negative Lhf). In this case, there would be a negative spillover. Source: the author estimates from business surveys of GSO Despite complexity of these effects, however, the total impact of technology spillover is positive. This can be shown by a comparison of results in table 3. It shows a strong evidence for impacts of technology spillover on productivity convergence among firms in all three sectors (because of negative ? and highly statistically significant). This once again confirms the positive impacts of technology spillover. It can be proved by the higher absolute values of coefficient ? in all three models taking technology spillover into consideration. The empirical evidence is shown in the Source: the author estimates from business surveys of GSO Following the definition given above, model (11.1) is the one in which TFP (denoted pm) is estimated by using Levinshon-Petrin procedure while model (11.2) is the one in which TFP (denoted pi) is estimated by using Olley-Pakes procedure. The results in table 5 show that the speed of convergence of convergence model under the impact of technology spillover estimated by using Levinshon-Petrin procedure is slightly smaller than one derived from Olley-Pakes procedure. This implies that these approaches can be substituted for each other.

We come to the general comments as follows. The above results show that speed of convergence when taking technology spillover into consideration is larger than the case without taking this effect into consideration. Besides, the speed of convergence at the firm-level is larger than one at the nation-level. Theoretically, we can see that the spillover of technological knowledge among firms within one nation is quicker than one across nations due to "national boundaries effect". The technology spillover behind productivity convergence can create opportunities for lagging firms to catch up with leading ones. If there does not exist technological spillover, lagging firms could not catch up with leading ones if they do not invest into R&D or purchase new technologies, patents, and costs of these investments are huge for new-market comers or small and medium firms.

However, we should notice that a quick technology spillover also can create its own problem. If this can be done easily, then no firms have incentive to invest into R&D. However, our results show that the process of technology spillover does not occur immediately but takes a quite long time to take place. Thereby, the advantage of technology of leading firms can be maintained in a certain period of time, and this can help firms have incentive to introduce more advance technology.

IV.

11 Conclusions

This paper empirically studies impacts of technology spillover on convergence among firms in three sectors of the economy: (i) agricultural, forestry, and fishery industry, (ii) manufacturing industry, and (iii) services. The results are summarized as follows. Firstly, we employ the semi-parametric method to estimate TFP. A TFP series is estimated by using Levinshon-Petrin method and the second one is estimated by using Olley-Pakes method. Using dynamic I-O table **??**2005) **??**2006) **??**2007), we construct channels of technology spillover in the horizontal and vertical dimensions and combining them with convergence model. Using two TFP series and variables of technological spillover, we examine two groups of convergence models. On the basic of specified convergence model, we estimate the group of unconditional convergence model and conditional convergence one (the condition of technological spillover). The estimation results show that the impacts of technology spillover in two dimensions-horizontal and vertical-are quite complicated, depending on type of model and the studied period. There is not one-way impact on speed of convergence, i.e. they have both positive and negative impacts. However, the estimation results show that the technology spillover significantly raise the speed of convergence among firms in all three sectors of the economy. The evidence is that the speed of convergence of the conditional convergence model (with technology spillover variables) is faster than unconditional convergence one (without technology spillover variables).

The explanation of the role of technology spillover in the convergence process is very meaningful for policy-makers. To induce the development and progress, not only the technological innovation but also technology spillover are very important sources of productivity growth. Along with policies to foster technological innovation, however, we also should emphasize the importance of technological spillover, thanks to which firms need not create new technologies themselves. The combination of technological innovation and spillover would allow us to more efficiently employ our resources in the process of developing all sectors of the whole economy.

V.

1

		Dependent variable dlnpm				Dependent variable: dlnpi		
Model	10.1T	10.1K	10.1C	10.1D	10.2 T	10.2 K	10.2 C	10.2.D
Constant	0,0807***	0,1008***	0.0565***	.0902***	0,0722***	0,1007***	0.0523***	0.0796***
	(0,0025)	(0,0101)	(0.0045)	(0.0031)	(0,0021)	(0,0100)	(0.0038)	(0.0025)
?	- 0,047***	-0,057***	-.0367***	-0,0521***	-0,051***	-0,057***	-0,0406***	-0,0559***
	(0,0012)	(0,0047)	(0,0019)	(0,0015)	(0,0011)	(0,0047)	(0.0523)	(0.0015)
R 2	0,1299	0,2400	0,2113	0,1368	0,1560	0,2113	0,1208	0,1634
	0,1298	0,2370	0,2099	0,1367	0,1559	0,2099	0,1205	0,1632
No. obs.	10767	3185	547	7035	10767	3185	547	7035
F-statistics	1606,76	348,32	146,03	1114,38	1989,96	437,40	146,03	1373,21
	(0,0000)	(0,0000)	(0,0000)	(0,0000)	(0,0000)	(0,0000)	(0,0000)	(0,0000)
Speed of convergence (%)	6,7	8,96	4,7	7,73	7,55	8,96	5,38	8,67
Half-life time	14,27	11,81	18,54	12,95	13,16	11,81	16,72	12,05

Figure 1: Table 1 :

2

	(11.1T)	(11.1K)	(11.1C)	(11.1D)
Dlnpm	Coef.	Coef.	Coef.	Coef.
Lnpm	-0.0512***	-0.0608***	-0.0428***	-0.0572***
	(0.0012)	(0.0047)	(0.0020)	(0.0016)
LH2001	-0.0126	-0.1110*		
	(0.0107)	(0.0618)		
LHh2001	0.0204			
	(0.0150)			
Lhb2001	-0.1691	6.7889***	-.3657*	-.3256*
	(0.1344)	(1.9386)	(.1991)	(.1766)
LH2002	0.0385**		.0286	.0696**
	(0.0187)		(.0270)	(.0279)
LHh2002	0.0336**	-.1156**	.0411	.0803***
	(0.0159)	(.0530)	(.0329)	(.0208)
LHb2002		-1.238**	-.3145***	.2071**
		(.5623)	(.1139)	(.1051)
LHf2002	-1.581***	4.9953***	-.6765	-2.5973***
	(0.3037)	(1.8458)	(.5016)	(.4700)
LH2003	0.0471***		.0521***	
	(0.0146)		(.0163)	
LHh2003	-0.0058*			
	(0.0034)			
Lhb2003	-0.0276**			
	(0.0123)			
Lhf2003	-0.0339***			-.0737***
	(0.0079)			(.0101)
LH2004	-0.0018	-.0909	.0375*	-.0021*
	(0.0012)	(.0789)	(.0219)	(.0012)
LHh2004			.0667**	
			(.0302)	
Lhb2004	-0.0474	-1.0480**	.24996***	
	(0.0456	(.4159)	(.0731)	
Lhf2004	0.0533	-2.2548***	.0553	-.4658**
	(0.0387)	(.6674)	(.0445)	(.1864)
LHh2005	-0.00001	.23671***	-.00008**	
	(6.28e-06)	(.0843)	(.00004)	
Lhb2005	0.0331***	-.1974***	.0396***	
	(0.0103)	(.0661)	(.0102)	
LH2006	0.0356**	.13625	.0308	.0443*

Figure 2: Table 2 :

3

Model	Unconditional convergence model				Conditional convergence model under t impact of technology spillover			
	10.1 T	10.1 K	10.1C	10.1 D	12.1 T	12.1 K	12.1C	12.1 D
?	-0.047***	-0.057***	-.0367***	-0.052***	-0.051***	-0.061***	-0.043***	-0.057***
Speed of convergence	6.7	8.96	4.7	7.73	7.53	10.04	5.78	9.02
A half-life time	14.27	11.81	18.54	12.95	13.18	11.05	15.84	11.7

Figure 3: Table 3 :

3

e) A comparison of estimation of convergence under the impact of technology spillover between model (11.1) and (11.2)

This section compares the estimation results from two models: the versions (11.1) and (11.2) of conditional convergence model. The estimation results of model (11.1) are given in table 2 while the ones of model (11.2) are given in table 4 below.

Figure 4: table 3 .

	conditional convergence model)			
Independent variable\Model	(11.2T) Coefficient	(11.2K) Coefficient	(11.2C) Coefficient	(11.2D) Coefficient
Lnpi	-.0548*** (.0012)	-.0628*** (.0044)	-.0466*** (.0020)	-.0605*** (.0015)
LH2001	-.0115 (.0099)	-.0958* (.0569)		
LHh2001	.0182 (.0139)			
Lhb2001	-.1659 (.1242)	6.3036*** (1.7804)	-.3708** (.1824)	-.3496** (.1639)
LH2002	.0405** (.0173)		.0297 (.0247)	.0700*** (.0259)
LHh2002	.0275* (.0147)	-.1033** (.0487)	.03443 (.0302)	.0712*** (.0193)
Lhb2002		-1.0190** (.5163)	-.2900*** (.1044)	.2447** (.0975)
Lhf2002	-1.776*** (.2807)	4.9552*** (1.6954)	-.6599 (.4598)	-2.3787*** (.4364)
LH2003	.0442*** (.0135)		.0488*** (.01496)	
LHh2003	-.0047 (.0031)			
Lhb2003	-.0234** (.0114)			
Lhf2003	-.0278*** (.0074)			-.0645*** (.0097)
LH2004	-.0015 (.0011)	-.0895 (.0725)	.0356* (.0201)	-.0017 (.0012)
LHh2004			.0616** (.0278)	-.3601** (.1730)
Lhb2004	-.0323 (.0422)	-1.0229*** (.3819)	.2344*** (.0670)	
Lhf2004	.0594* (.0358)	-2.0947*** (.6129)	.0544 (.0407)	
LHh2005	-.00001* (5.81e-06)	.2268*** (.0774)	-.00007* (.00004)	
Lhb2005	.0278*** (.0095)	-.1797*** (.0606)	.0355*** (.0094)	
LH2006	.0332** (.0141)	.11887 (.0946)	.0295 (.0189)	.0410* (.0235)
LHh2006				.0017* (.0010)
Lhb2006	-.0625 (.0570)		-.1381 (.0961)	-.1672** (.0674)
Lhf2006	-.21081*** (.0702)		.1138 (.1036)	-.8021*** (.1190)
LHh2007			.0059*** (.0018)	
Lhb2007			.0322** (.0155)	
LH2008	.03473*** (.01298)	-.0734 (.0522)		
LHh2008	-.0073 (.0057)			.0750*** (.0185)

5

technology spillover.

Model	Convergence model under the impact of technology spillover (11.1)				Convergence model under	
	11.1 T	11.1 K	11.1 C	11.1 D	11.2 T	11.2 K
Coefficient ?	-0.051***	-0.061***	-0.043***	-0.057***	-0.055***	-0.063
Speed convergence of	7.53	10.04	5.78	9.02	8.39	10.67
Half-life time	13.18	11.05	15.84	11.76	12.3	10.69

Figure 6: Table 5 :

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