Productivity Convergence at the Firm Level: Effects of Exit on Firm-level Productivity Growth in Japan*

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Abstract

This paper investigates firm-level productivity growth with careful consideration on the effects of entry/exit. We found the productivity convergence among firms. Besides, the analysis without considering the effects of exits causes a statistically significant sample selection bias in the speed-of-convergence estimation.

Key Words: firm-level productivity, convergence, technology diffusion, selection bias
JEL Classification Code: D21 (Firm Behavior); D24 (Production; Capital and Total Factor Productivity; Capacity)

1. Introduction

"Comparisons of productivity performance across countries are central to many of the questions concerning long-run economic growth." (Bernard and Jones, 1996) Thus, there has been a large body of literature that investigated cross-country productivity

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convergence both at the country level (e.g., Dollar and Wolff, 1988; Dorwick and Nguyen, 1989; Wolff, 1991) and at the industry level (e.g., Baumol, 1986; Bernard and Jones, 1996; Pascual and Westermann, 2002). While Bernard and Jones (1996) found little evidence of convergence in manufacturing, others supported productivity convergence in countries with lower productivity at the initial period but growing rapidly in the subsequent periods.

However, 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 productivity growth of a country is attributed to the productivity growth of firms. Thus, to examine characteristics of across-country productivity convergence, it is of the utmost importance to examine characteristics of the productivity convergence among firms. In spite of this importance, none but Griffith, Redding, and Simpson (2002) examined the productivity convergence at the firm level.

This paper examines the growth of productivity at the firm level, extending the study by Griffith, Redding, and Simpson (2002). Note that countries hardly enter/exit while firms often do. Our contribution is twofold. First, this paper is, to the best of our knowledge, the first study to analyze firm-level productivity growth with careful consideration on the effects of entry/exit. Second, we use a large-scale database of firms in Japan for the period 1994-2000, which contributes to the literature by adding another national perspective to available evidence.

2. Research Design

2.1. Model

The simple model of productivity convergence proposed by Bernard and Jones (1996) is our initial model. The model has been extensively utilized in the studies of cross-country productivity convergence and recent establishment- and firm-level productivity studies (Griffith, Redding, and Simpson, 2002). Let us denote total factor productivity (TFP) for firm i in year t by θ_{it}. The estimation model is described as follows:

$$\Delta\ln\theta_{iT}=\frac{1}{T}(\ln\theta_{iT}-\ln\theta_{i0})=\beta_0+\beta_1\ln\theta_{i0}+\mu_{iT}, \quad (1)$$

where the speed of catch-up λ is denoted by a negative coefficient of $\beta_1=-\{1-(1-\lambda)^T\}/T$ and μ_{iT} is an error term.

2.2. Econometric issues

The standard procedure of a cross-country productivity convergence is to estimate equation (1) and then to get the estimate of the speed-of-convergence λ from the estimate of β_1. However, this procedure cannot be applied to cross-firm convergence directly, since we have a problem of data truncation in firm data that is not present in country data. In the case of country data, whether or not a particular country is in the data set we consider is not correlated to the country's productivity level. In contrast, whether or not a particular firm is in the data set is quite likely to be correlated to the firm's productivity level. If a particular firm's productivity goes under some threshold level, this usually implies a serious profitability problem for the firm. Then, the firm is likely to be closed down and/or bankrupt so that it drops out of the data set we consider. This correlation between data truncation and productivity may produce a well-known bias of sample selection if we estimate equation (1) by an ordinary least squares (OLS).[1)]

Let us consider firms' entry and exit patterns between year 0 and year T, which are classified into three types as summarized in Table 1. Type-1 firms are survivors that continue to stay in the market between year 0 and year T. Type-2 firms are exit firms that stay in year 0 but exit from the market before year T. Type-3 firms are entrants that start their business after year 0. Whether or not productivity is observed depends on the patterns of entry and exit. The entry and exit variations lead to the missing data for the dependent or independent variables. The problem is that we cannot observe $\Delta\ln\theta_{iT}$ for Type-2 firms because Type-2 firms exit from the market between year 0 and year T, which may cause sample selection bias in estimating productivity convergence equation (1).[2)]

Table 1: Entry, Exit, and Observability of Variables

		Year 0	Year T	Independent variable	Dependent variable
		θ_{i0}	θ_{iT}	$\ln\theta_{i0}$	$\Delta\ln\theta_{iT}$
Type-1	Survivors	observable	observable	observable	Observable
Type-2	Exiters	observable	missing	observable	Missing
Type-3	Entrants	missing	observable	missing	Missing

To overcome this sample selection problem, we thus introduce selection equation. Dunne, Roberts, and Samuelson (1989) find that plant size and age are statistically significant determinants of plant failure. Following the findings of Dunne, Roberts, and Samuelson, we assume that exit depends on two factors: employment scale (L) and firm age (AGE). In addition, we assume that natural selection mechanism works: firms with lower productivity exit from the market. Thus, the selection equation for the exiting

1) For more detail, see Heckman (1976).
2) If firm i exits from the market between year 0 and year T, υ_{iT} is not observable, and the growth rate of TFP, $\Delta\ln\upsilon_{iT}$ cannot be defined. This means that the dependent variable is a missing variable.

firms is represented as follows:

$$s_{iT} = \begin{cases} 1 & \text{if } \gamma_0 + \gamma_1 \ln\theta_{i0} + \gamma_2 \ln L_{i0} + \gamma_3 \ln AGE_{i0} + \upsilon_{i0} \geq 0; \\ 0 & \text{otherwise,} \end{cases} \quad (2)$$

where υ_{i0} is an error term. Let us define ρ be the correlation between μ_{iT} and υ_{i0}: $E(\mu_{iT} \mid \upsilon_{i0}) = \rho\upsilon_{i0}$. Sample selection bias exists if $\rho \neq 0$.

2.3.　Data and Measurement of Productivity

The micro database of *Kigyou Katsudou Kihon Chousa Houkokusho* (*The Results of the Basic Survey of Japanese Business Structure and Activities*) prepared by METI (1996-2004) was used for this study. This survey was first conducted in 1991, again in 1994, and annually thereafter. The main purpose of the survey is to capture statistically the overall picture of Japanese corporate firms in light of their activity diversification, globalization, and strategies on R&D. From this survey, we develop a longitudinal panel data set for the years from 1994 to 2002.

In computing TFP, we employ the multilateral index method developed by Caves, Christensen, and Diewert (1982) and extended by Good, Nadiri, Roller, and Sickles (1983). This multilateral index uses a separate hypothetical firm as a reference point for each cross-section of observations by industry and chain-links the reference points together over time in the same way as the conventional Theil=Törnqvist index of productivity growth. The index relies on a single reference point that is constructed as a hypothetical firm that has the arithmetic mean values of log output, log input, and input cost shares over firms in each year. Each firm's output and inputs are measured relative to this reference point in each year and then the reference points are chain-linked over time. Output is defined as gross output while inputs are capital, labor, and intermediate inputs. For more detailed description, see Nishimura, Nakajima, and Kiyota (2005).

3. Results

Table 2 reports the estimation results of the model with and without selection equations. The results without the selection equation (Model 0) are generated by OLS while the results with the selection equation (Model 1) are generated by Heckit estimation. To obtain the speed-of-convergence, we first estimate β_I, and then compute λ using the relationship between β_I and λ: $\beta_I = -\{1-(1-\lambda)^T\}/T$. Note that the baseline model without the selection equation uses only Type-1 (surviving) firms so that we lose 6,490 observations of Type-2 (exiting) firms.

Two findings stand out from this table. Firstly, in both Models 0 and 1, we observe the strong evidence of productivity convergence. However, the speed-of-convergence is different between the two. The convergence speed is faster in Model 1 than in Model 0. Furthermore, the coefficient of ρ is significantly negative. A log-likelihood ratio (LR) test for H_0: $\rho=0$ is rejected at the 1 percent level. This implies that there exists a statistically significant sample selection bias, causing about a 0.9 percentage point downward bias to λ. Thus, the results clearly suggest the necessity to incorporate the selection equation in the analysis of firm-level speed of productivity convergence.

Table 2: Estimation Results and Sample Selection Bias

		Model 0	Model 1	
		Productivity convergence equation	Selection equation	Productivity convergence equation
β_0	Constant	-0.003***	-1.875***	0.000
		[0.000]	[0.081]	[0.000]
$\beta_1(\gamma_1)$	$\ln\theta_{i0}$	-0.072***	1.085***	-0.076***
		[0.001]	[0.107]	[0.001]
γ_2	$\ln L_{i0}$		0.360***	
			[0.011]	
γ_3	$\ln AGE_{i0}$		0.121***	
			[0.018]	
N		11,280	17,770	11,280
ρ				-0.562***
				[0.023]
λ		10.2%		11.1%
LR test for H_0:$\rho=0$				186.70***

Note: Standard errors are in brackets. *** indicates significance level at 1%.

Secondly, the speed of productivity convergence is significantly faster than the speed reported in the previous country-level studies. While, for example, Dorwick and Nguyen (1989) reported that the speed-of-convergence among countries was 2.5 percent annually, the result of Model 1 shows that the speed of convergence is 11.1 percent. At first glance, this seems a very high rate, but it is not so high if one looks at its order of magnitude. Suppose that the productivity level of firm is 10 while that of the most productive firm is 100. If the speed-of-convergence is 11.1 percent (i.e., $\lambda=0.111$), it still takes about 22 years for firm i to catch up to the most productive firm.[3] Note that whether or not a firm can survive for more than 22 years is an important issue. Nishimura, Nakajima, and Kiyota (2005) confirmed that in Japan about half of new firms exited from the market within five years.[4]

3) It takes more than 27 years to catch up to the most productive firm if the speed-of-convergence is estimated as 8.8 percent (Model 0).

4) This is not a Japan specific fact. For instance, about 70 percent of new firms exited from the market within 10 years in France. See, Bellone, Musso, Nesta, and Quére (2006) for more detail.

4. Conclusion

This paper has examined the growth of productivity at the firm level, especially focusing on the effects of convergence. Our findings are summarized as follows. Firstly, the productivity convergence among firms exists. In addition, the speed-of-convergence is faster than the speed observed in the previous national- or industry-level studies, which indicate an annual average rate of 11.1 percent.

Secondly, analysis without considering the effects of exits causes a statistically significant sample selection bias in the speed-of-convergence estimation. We have used sample selection models to correct the bias and have found a 0.9 percent point downward bias in the speed-of-convergence in the analysis without the selection equation.

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