Determinants of Potential Growth: Productivity Dynamics of Entry, Exit, Innovation and Diffusion in Japanese Industries

Kiyohiko G. Nishimura
Takanobu Nakajima
Kozo Kiyota
Kazunori Minetaki
Yoshihiro Tamai
Futoshi Kurokawa
1) Introduction
2) Data and Measurement of Productivity
3) Productivity Dynamics of Japanese Industries in the 1990s
   a) Industries in general
   b) Information Industries in particular
4) Productivity Convergence at the Firm Level
5) Innovation versus Diffusion
6) Concluding Remarks
1. Introduction

Why is the analysis of firm-level productivity important?

- "Comparisons of productivity performance across countries are central to many of the questions concerning long-run economic growth" (Bernard and Jones, 1996, p. 1216).

- There has been a large literature that investigate convergence and determinants of cross-country productivity performance. … However, results are not conclusive, and there remain many questions.

- Limitation of macro-based research
1. Introduction

Why is the analysis of firm-level productivity important?

- The growth of a *country* results from the growth of *industries*, which comes from the growth of *firms*.

   ➔ The productivity growth of a country is, ultimately, attributed to the productivity growth of firms.
1. Introduction

Can we apply the framework of country-level studies directly to firm-level studies?

- Can we apply the framework of country-level studies directly to firm-level studies?

⇒ No! …… Entry and Exit Behavior

- 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.
1. Introduction
Can we apply the framework of country-level studies directly to firm-level studies?

- 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.
  ➔ The firm is likely to be closed down and/or bankrupt so that it drops out of the data set we consider.
  ➔ Entry/Exit behavior is central to firm-level analysis
1. Introduction

Questions examined in this report

Question 1
What is the relationship between entry/exit patterns and industry productivity?
1. Japanese industries in general
2. IT software industries in particular

Question 2
Is there convergence in productivity among firms, after properly accounting for entry/exit?

Question 3
What are the determinants of firm-level productivity growth?
1. Introduction
   Another contribution

- Previous establishment- and firm-level studies on productivity growth mainly focused on manufacturing.

- It is difficult for such studies to discuss the macroeconomic effects of firm-level productivity growth.

- Our studies cover not only manufacturing firms but also non-manufacturing firms.
2. Data and Measurement of Productivity

Data on industries in general (skipped)

Main Source:

Firm-level confidential micro data from *Results of the Basic Survey of Japanese Business Structure and Activities* by METI.

All firms w/ 50+ employees and w/ 30million yen paid capital, engaging at least partly in mining, manufacturing, trade, and/or restaurant activities

<table>
<thead>
<tr>
<th>Periods:</th>
<th>Coverage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-2000</td>
<td>25% of (GDE - Govt Cons.)</td>
</tr>
</tbody>
</table>

Number of observations:

The number of “active firms” exceeds 22,000 in each year after the clean-up of the data.
2. Data and Measurement of Productivity

Data on IT software industries (skipped)

Source on IT Software Industries:

Activity-level establishment/firm data from 
*Survey of Selected Service Industries, Information Service* by METI.

All firms at least partially involved in software and information service 
activities. It covers more firms than “Census”.

**Periods:**

1997-2002

**Number of observations:**

The number of “active firms” exceeds 35,000 in 
each year after the clean-up of the data.
2. **Data and Measurement of Productivity**

**Measurement of Productivity** *(skipped)*

**Multilateral Total Factor Productivity (TFP) index**

- Construct the *hypothetical firm* that has the arithmetic mean values of log output, log input, and input cost shares over firms in each year.

- The multilateral index measures the TFP of each firm in year $t$ relative to that of a *hypothetical firm* in year 0 (initial year).
2. Data and Measurement of Productivity

Measurement of Productivity (skipped)

The TFP index for firm \( i \) in year \( t \) relative to that of the hypothetical firm in the initial year is defined as

\[
\ln \theta_{it} \approx \left( \ln Q_{it} - \ln Q_t \right) + \sum_{\tau=2}^{t'} \left( \ln Q_{\tau} - \ln Q_{\tau-1} \right)
- \sum_{j=1}^{J} \frac{1}{2} \left( s_{ijt} + \bar{s}_{jt} \right) \left( \ln X_{it} - \ln X_t \right)
- \sum_{\tau=2}^{t'} \sum_{j=1}^{J} \frac{1}{2} \left( \bar{s}_{j\tau} + \bar{s}_{j\tau-1} \right) \left( \ln X_{\tau} - \ln X_{\tau-1} \right)
\]

where \( \ln Q \), \( \ln X \), and \( S \) are the log output, log input, and the cost share for firm \( i \), respectively. \( \ln Q \), \( \ln X \), and \( \bar{S} \) are the values of the hypothetical firm in year.
2. Data and Measurement of Productivity

Multilateral Total Factor Productivity (TFP) index

Outputs: value-added
Inputs: capital and labor.

As for other additional data and their manipulation, we adopt the methodology described in the Appendix in Nishimura, Nakajima, and Kiyota (Journal of Economic Behavior and Organization, 2005).
3. Productivity Dynamics of Japanese Industries in the 1990s

**Question 1**
What is the relationship between entry/exit patterns and productivity?

- Are Japanese industries “stagnant”? “stagnant”: few entries, few exits
- Does natural selection mechanism (NSM) work? NSM: Productive firms survive, and unproductive firms die.
3. Productivity Dynamics of Japanese Industries in the 1990s

Major findings about industries in general

Japanese industries are not stagnant...

High Entry Rate into “the Set of Active Firms”
High Exit Rate from “the Set of Active Firms”

Table 1.3: Entry and Exit Rates of Japanese Firms

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
<td>20.4</td>
<td>15.5</td>
<td>9.4</td>
<td>10.9</td>
<td>10.4</td>
</tr>
<tr>
<td>Exit</td>
<td>16.7</td>
<td>10.8</td>
<td>9.9</td>
<td>11.0</td>
<td>10.3</td>
</tr>
</tbody>
</table>

Entry rate: new entrants / existing firms
Exit rate: exit firms / existing firms

Entry and exit rates are higher than those in Canada and lower than those in the United States.
3. Productivity Dynamics of Japanese Industries in the 1990s

Major findings about industries in general

Table 1.6: Breakdown of the NSM in A Severe Recession

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survive</td>
<td>2.02</td>
<td>1.85</td>
<td>2.04</td>
<td>2.08</td>
</tr>
<tr>
<td>Exit</td>
<td>1.47</td>
<td>1.52</td>
<td>2.07</td>
<td>1.92</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survive</td>
<td>1.66</td>
<td>1.89</td>
<td>2.24</td>
<td>2.42</td>
</tr>
<tr>
<td>Exit</td>
<td>1.35</td>
<td>1.84</td>
<td>2.41</td>
<td>2.18</td>
</tr>
</tbody>
</table>

Note: The year 1996 is key to the interpretation of the results because the vulnerability of the Japanese financial market started to become obvious in 1996-97.
3. Productivity Dynamics of Japanese Industries in the 1990s (skipped)

Major findings about industries in general

Figure 1.2: TFP for entry, surviving, and exit firms
3. Productivity Dynamics of Japanese Industries in the 1990s

Major findings about industries in general

Why the NSM did not work in a severe recession?

- Banking Crisis (Hokkaido Takushoku 1997 etc.)
- One possible explanation: the “moral hazard” of banks with myopic management vision.
- With the growth of non-performing loans in less productive but conspicuously large firms, some banks that did not want to make their non-performing loans public continued to lend money to these less productive firms.
- In contrast, they curtail their loans from productive firms since these firms can repay their debts, but this triggers their exits.
3. Productivity Dynamics of Japanese Industries in the 1990s
Software and information service industries

Table 2.7: Breakdown of the NSM in Information Service Industries

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Survive</td>
<td>Exit</td>
<td>Survive</td>
<td>Exit</td>
<td>Survive</td>
</tr>
<tr>
<td><strong>All Firms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.189</td>
<td>1.110</td>
<td>1.180</td>
<td>1.474</td>
<td>1.013</td>
<td>0.984</td>
</tr>
<tr>
<td><strong>Non-specialized Firms</strong></td>
<td>1.073</td>
<td>0.943</td>
<td>1.182</td>
<td>2.313</td>
<td>0.954</td>
</tr>
<tr>
<td><strong>Specialized Firms</strong></td>
<td>1.312</td>
<td>1.259</td>
<td>1.178</td>
<td>1.176</td>
<td>1.078</td>
</tr>
</tbody>
</table>
3. Productivity Dynamics of Japanese Industries in the 1990s

Software and information service industries

Break-down of 1998-1999

No specific explanation… probably mirage of data? (since its breakdown is from “non-specialized firms that engage in information services only partially.”)

Break-down of 2000-2001

Found in specialized firms … real not illusionary
Burst of the “IT bubble” and following severe recession in IT-related industries.
Failure of NSM.
4. Productivity Convergence at the Firm level

To examine the determinants of productivity growth, we first examine technological diffusion and resulting convergence.

We use a productivity convergence model proposed by Bernard and Jones (1996, AER)

But this model is designed for country- and industry-level data.

Question 2

Is there productivity convergence among firms? How can we incorporate the effects of the entry/exit into this productivity convergence study?
4. Productivity Convergence at the Firm level

The analysis without considering the effects of exits causes a statistically significant sample selection bias in the speed-of-productivity convergence estimation.

Methodology

We have used sample selection model to correct the bias.
4. Productivity Convergence at the Firm level

**Methodology**

1) **Selection equation**

\[ S_{iT} = \begin{cases} 
1 & \text{if } \gamma_0 + \gamma_1 \ln \theta_{i0} + \gamma_2 \ln AGE_{i0} + \gamma_3 \ln L_{i0} + \gamma_4 D_{i0}^{\text{multi}} + \nu_{iT}; \\
0 & \text{otherwise.} 
\end{cases} \]

2) **Productivity convergence equation**

\[ \Delta \ln \theta_{iT} = \beta_0 + \beta_1 \ln \theta_{i0} + \mu_{iT} \]

The correlation between \( \nu_{iT} \) and \( \mu_{iT} : \rho \).

If \( \rho \neq 0 \), sample selection bias exists.
4. Productivity Convergence at the Firm level

**Methodology**

Speed-of-convergence $\lambda$ is obtained from the relationship between $\lambda$ and $\beta_1$:

$$\beta_1 = -\frac{1 - (1 - \lambda)^T}{T}$$
4. Productivity Convergence at the Firm level

Major findings

Table 3.2: Baseline Model and Sample Selection Bias

<table>
<thead>
<tr>
<th>Selection equation</th>
<th>Model 0</th>
<th>Model 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>-0.071***</td>
<td>-0.080***</td>
</tr>
<tr>
<td>$\rho$</td>
<td>---</td>
<td>-0.75***</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>8.8%</td>
<td>10.3%</td>
</tr>
<tr>
<td>$N$</td>
<td>10237</td>
<td>18886</td>
</tr>
<tr>
<td>LR test for $H_0: \rho=0$</td>
<td>---</td>
<td>313.39***</td>
</tr>
</tbody>
</table>
4. Productivity Convergence at the Firm level

Major findings

To examine the difference in the speed-of-convergence across industries, we modify the baseline specification as follows.

\[ \beta_1 \ln \theta_{i0} + \omega^1 D_i^1 \ln \theta_{i0} + \ldots + \omega^j D_i^j \ln \theta_{i0} \]

where D is a dummy variable that takes the value one if firm i belongs to industry j.

\[ \beta_1 \ln \theta_{i0} + \omega^j D_i^j \ln \theta_{i0} \]

The speed-of-convergence is ...

\[ \frac{1 - (1 - \lambda^j)^T}{T} = \begin{cases} \beta_1 + \omega^j & \text{if } \omega^j \text{ is statistically significant.} \\ \beta_1 & \text{otherwise.} \end{cases} \]
4. Productivity Convergence at the Firm level

Major findings

Table 3.5: Distribution of the Speed-of-convergence (the number of industries)

<table>
<thead>
<tr>
<th>Speed-of-convergence ((\lambda^i)) based on Model 1</th>
<th>&lt; 3%</th>
<th>&lt; 5%</th>
<th>&lt; 10%</th>
<th>&lt; 15%</th>
<th>&lt; 20%</th>
<th>20% ≤</th>
</tr>
</thead>
<tbody>
<tr>
<td>All industry</td>
<td>2</td>
<td>32</td>
<td>1</td>
<td>10</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1</td>
<td>11</td>
<td>0</td>
<td>9</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Non-manufacturing</td>
<td>1</td>
<td>21</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>IT industry</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Non-IT industry</td>
<td>2</td>
<td>31</td>
<td>1</td>
<td>8</td>
<td>15</td>
<td>6</td>
</tr>
</tbody>
</table>
4. Productivity Convergence at the Firm level

Major findings

1) We find productivity convergence among firms widely in Japan, in both manufacturing industries and non-manufacturing ones.

2) The convergence rate is much faster among firms than countries.

3) There are substantial differences among industries in the convergence speed: IT industries that heavily rely on technological progress show faster rates of convergence.
5. Innovation versus Diffusion

Question 3
What are the determinants of firm-level productivity growth?

We focus on the role of innovation and diffusion.
5. Innovation versus Diffusion

Innovation versus Diffusion
Innovation Factors: R&D, patents, FDI, imports

Diffusion Factors:

a) Explicit Emulation ("Active" Diffusion)
   (spillovers through patents, FDI, imports, etc.)

b) Implicit Emulation ("Passive" Diffusion)
   (autonomous productivity convergence through learning-by-doing)
5. **Innovation versus Diffusion**

**Methodology**

We have used the sample selection model, adding innovation and diffusion variables.

\[
\Delta \ln \theta_{iT} = \beta_0 + \psi \text{InnovationFactor}_{i0} + \beta_1 \ln \theta_{i0} \\
+ \xi \ln \theta_{i0} \times \text{DiffusionFactor}_{i0} \\
+ \text{OtherControlVariables} + \mu_{iT}
\]

Innovation variables: R&D, Patents, FDI, Imports

Diffusion variables: Patents, FDI, Imports
<table>
<thead>
<tr>
<th>Diffusion Factors</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFP × Patents</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>TFP × FDI</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>TFP × Imports</td>
<td>-0.078**</td>
<td>-0.072**</td>
<td>-0.073**</td>
<td>-0.068*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Innovation Factors</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D</td>
<td>0.120**</td>
<td>0.128**</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Patents</td>
<td>1.293***</td>
<td>1.270***</td>
<td>1.288***</td>
<td>1.260***</td>
</tr>
<tr>
<td>FDI</td>
<td>0.019***</td>
<td>0.020***</td>
<td>0.022***</td>
<td>0.022***</td>
</tr>
<tr>
<td>Imports</td>
<td>0.152***</td>
<td>0.147***</td>
<td>0.142***</td>
<td>0.137***</td>
</tr>
<tr>
<td>R&amp;D × IT industry dummy</td>
<td></td>
<td>0.243*</td>
<td>0.235*</td>
<td></td>
</tr>
<tr>
<td>Patent × IT industry dummy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FDI × IT industry dummy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports × IT industry dummy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other control variables</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment scale</td>
<td>0.010***</td>
<td>0.009***</td>
<td>0.010***</td>
<td>0.009***</td>
</tr>
<tr>
<td>(Employment growth)$^2$</td>
<td>-0.020***</td>
<td>-0.020***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Capital growth)$^2$</td>
<td>-0.045***</td>
<td>-0.045***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.123**</td>
<td>0.131**</td>
<td>0.125**</td>
<td>0.131**</td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
<td>(0.051)</td>
<td>(0.052)</td>
<td>(0.051)</td>
</tr>
</tbody>
</table>

| Log-likelihood            | -615.9  | -588.8  | -612.7  | -586.0  |
| Akaike Information Criterion | 1823.7 | 1773.6 | 1825.4 | 1775.9 |
| $N$                       | 18886   | 18886   | 18886   | 18886   |
| LR test for $H_0: \rho=0$ | 3.99**  | 4.68**  | 4.01**  | 4.70**  |
5. Innovation versus Diffusion

Major findings

Table 4.2: Distribution of the “Passive” Diffusion (the number of industries)

<table>
<thead>
<tr>
<th>Speed-of-convergence (ϕ^\prime) based on Model 1</th>
<th>&lt; 3%</th>
<th>&lt; 5%</th>
<th>&lt; 10%</th>
<th>&lt; 15%</th>
<th>&lt; 20%</th>
<th>20% ≤</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>2</td>
<td>32</td>
<td>0</td>
<td>11</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Model 2</td>
<td>2</td>
<td>29</td>
<td>2</td>
<td>13</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Model 3</td>
<td>2</td>
<td>33</td>
<td>0</td>
<td>10</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Model 4</td>
<td>2</td>
<td>29</td>
<td>2</td>
<td>13</td>
<td>17</td>
<td>7</td>
</tr>
</tbody>
</table>
5. Innovation versus Diffusion

Major findings

1) Innovation and diffusion are important factors of firm-level productivity growth.

2) Innovative improvements come from not only directly R&D activities, but also indirectly from patent purchases and other factors that are not well-investigated before as sources of innovation.

3) Patent purchases are more effective in this regard than R&D expenditure that is effective only in IT industries.
6. Concluding Remarks

- This report examines the productivity dynamics of entry, exit, innovation, and diffusion in Japanese industries, based on firm-level data.
- The NSM does not always hold in a severe recession.
- There is a strong evidence of productivity convergence among firms.
- Not only innovation but also diffusion is an important source of productivity growth.