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Do Competitive Markets Stimulate Innovation?:
An Empirical Analysis Based on Japanese Manufacturing Industry Data

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Do Competitive Markets Stimulate Innovation?

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Abstract

Going all the way back to Schumpeter (1934), economists have long discussed whether market competition stimulates innovation. To reconcile conflicting earlier empirical evidence, Aghion and Griffith (2005) developed a model showing that competition can have both a positive and a negative effect on innovation, depending on the degree of competition in the market.

Following Aghion and Griffith's work, this paper empirically examines the effect of market competition – measured either by the Herfindahl Index or the Lerner Index – on productivity growth and R&D intensity using micro data for Japan's manufacturing sector. We found evidence of an inverted U-shaped relationship between competition and innovation when we use the Herfindahl Index as a measure of competition in the market. Especially for the period since 2000, the data lend strong support for the hypothesis of an inverted U-shaped curve.

In addition, we examined the effect of new entrants on the innovative activity of incumbents. The results of our estimation using a regulation index as our measure of entry barriers suggest that the effect on incumbents' TFP growth depends on their technology level. When incumbents' technology level is close to the technology frontier in their industry, competition from new entrants induces these firms to make efforts to increase their productivity in order to escape from competition. On the other hand, such competition discourages innovation in firms far from the industrial technology frontier.

Keywords: Market competition, TFP, Inverted U-shaped curve, Technology frontier

JEL classification numbers: L11, L25, L50, O31

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1. Introduction

Studies on market competition and firms' innovative activities have a long history. Seventy years ago, Schumpeter (1934) argued that more monopolistic firms can more readily perform R&D activities because they face less market uncertainty and have larger and more stable funds. On the other hand, Arrow (1962) showed that innovative firms benefit more from an innovation if there is greater competition in the market. In the late 1970s and 1980s, using game-theoretic approaches, Louly (1979) and Dasgupta and Stiglitz (1980) examined the effects of market competition on innovative activity. They showed that firms in competitive markets are likely to overinvest in R&D. Gilbert and Newbery (1982) showed that firms which dominate a product market have the incentive to innovate in order to maintain their monopolistic position.[1] And in the 1990s, Grossman and Helpman (1991) and Aghion and Howitt (1998) constructed growth models where competition in innovative activity is endogenized. These growth models support the Schumpeterian hypothesis that more monopolistic firms are likely to be more innovative. The above theoretical developments with regard to R&D activities stimulated a wave of empirical studies in the 1990s.[2] Geroski (1990), for example, examined the effect of the market concentration ratio on innovation using panel data for 73 industries in the U.K. covering the period of 1970 and 1979. Using count data of innovation at the industry level as the index of innovation, he showed that an increase in the concentration ratio decreased innovative activities. Since the mid-1990s, a number of studies examining the effect of the competitive environment on innovative activities

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1 A summary of game-theoretic approaches to R&D activities is provided in chapter 10 of Tirole (1988).

2 A summary of several empirical studies before the 1990s examining the Schumpeterian hypothesis is provided by Scherer (1984).

using firm-level data have been published. Among these, Nickell (1996) studied the effect of market structure on TFP by using U.K. firm-level data from 1972 to 1986. By estimating a production function that includes independent variables representing market structure, he showed that market competition promoted the productivity growth of firms. Nickell, Nicolitsas, and Dryden (1997), in addition to the impact of market competition, also examined the effects of corporate governance such as the pressure from financial intermediaries and effects of shareholders on managers' efforts to innovate. Their results showed that not only market competition but also financial pressure has a positive impact on the productivity growth of firms. Meanwhile, Blundell, Griffith, and Van Reenen (1999) used count data on innovation and patent data instead of TFP growth as the dependent variable. Their estimation results showed that market share has a positive impact on firms' innovative activities, although the concentration ratio has a negative impact. In addition, their results suggest that cash flow does not affect innovative activities.

These empirical results obtained in the 1990s supported the idea that market competition stimulates innovative activity and hence contradicted the theoretical prediction of the Schumpeterian growth model proposed by Aghion and Howitt (1998). Aghion et al. (2002) and Aghion and Griffith (2005) therefore developed a new model which explains both the Schumpeterian hypothesis and the positive effect of market competition on innovative activity. They assumed that firms in the intermediate goods market can produce different types of intermediate goods. These firms are categorized into two types. One type of firm belongs to a sector in which firms compete neck-and-neck and the technological gap between competing firms is small. In this sector, firms have an incentive to conduct innovation to escape from competition. On the other hand, other firms that are far from the technology frontier have little incentive to innovate, because the rents such firms derive from innovation are small. In this case, the Schumpeterian effect works. Overall, Aghion et al. (2002) and Aghion and Griffith (2005) showed that the relationship between competition and innovative activity can be described by an inverted U-shaped curve.[3] In their empirical examination of the model, employing firm-level data for the U.K. and using count data on patents weighted by citations as the dependent variable and the Lerner index and the price cost margin as indices of market competition, Aghion and Griffith (2005) showed that there exists an inverted U-curve relationship between competition and innovation. Similarly, Tingvall and Poldahl (2007) tested for the presence of an inverted U-curve relationship using Swedish manufacturing firm data and found evidence that such a relationship holds between the Herfindahl index and R&D activities. The empirical studies referred to above focused on the innovative activities of incumbents. However, deregulation promotes the entry of firms and affects market structure. Against this background, Geroski (1989), for example, examined the effects of new entrants on productivity in the U.K. in the 1970s. He concluded that new entrants had a positive impact on productivity in the long run, although the estimated effects of new entrants were ambiguous in the short run. Focusing on the effect of trade liberalization in India, Aghion et al. (2003) showed that industries which were close to the technology frontier attained higher growth rates after liberalization. They found that firms which were close to the technology frontier became more aggressive in terms of their innovative activity. Aghion et al. (2006) examined the effect of new foreign firm entrants on innovation by domestic incumbents. The authors showed that the entry of technologically advanced

3 That the relationship between competition and innovative activity is non-linear had already been suggested in empirical studies by Scherer (1965) and Levin, Cohen, and Mowery (1985).

foreign firms has a positive effect on innovation in sectors close to the frontier, but not on innovation in sectors initially further behind the frontier.

The effect of labor market regulations on innovation was analyzed by Bassanini and Ernst (2002) and Aghion and Griffith (2005). They showed that pro-employer deregulation increased the incentive to innovate. Moreover, Nicolleti and Scarapetta (2003) showed for OECD countries that the lower entry barriers and state controls are, the faster is the process of catch-up to best practice technologies in manufacturing industries.

In Japan, economists and policy makers during the 1990s called for deregulation and a reform of competition policies to help revitalize the Japanese economy. However, few empirical studies have examined the effects of deregulation and the reform of competition policies in Japan. One of the few exceptions is the study by Okada (2005), who, following Nickell (1996), estimated a production function including competition measures and R&D intensity using Japanese firm-level data. His estimation results suggest that greater competition enhances firms' productivity growth significantly. Another rare exception is the study by Nakanishi and Inui (2007), which examined the effect of deregulation on TFP growth at the industry level in Japan using the regulation index included in the Japan Industry Productivity (JIP) 2006 database. Their estimation results also showed that deregulation enhances TFP growth at the industrial level.

The aim of this paper is to improve on the previous empirical studies on Japan by considering several new measures of competition and regulation. First, based on Aghion and Griffith (2005), we examine the inverted U-shaped relationship between competition and innovative activity, an aspect that Okada (2005) did not examined in his paper. Second, we consider the effect of new entrants on the performance of incumbents. Measuring the gap from the technology frontier and using the FDI ratio, we are able to examine the effect of the threat of new entrants on incumbents' innovative activity, similar to the way Aghion et al. (2006) did in their study. Third, we examine the effect of regulation on firm performance at the firm-level by using a similar type of regulation measure as that employed by Nakanishi and Inui (2007) as an explanatory variable in our estimation.

The remainder of this paper is organized as follows. In the next section, we provide an overview of the revised Schumpeterian model developed by Aghion and Griffith (2005) and explain the implications of the model. Section 3 introduces the data used in our estimation and provides the empirical hypotheses, while Section 4 presents and discusses our estimation results on the effects of competition and deregulation on firm performance. Section 5, finally, summarizes our results and discusses possible extensions of this study.

2. The inverted U-curve and the effects of new entry : theoretical interpretations

In this section, we discuss the theoretical interpretations of the inverted U-curve and the effects of new entry, following Aghion and Griffith (2005). A basic Schumpeterian model was developed by Aghion and Howitt (1992, 1998), who, in an endogenous growth framework, showed that firms which earn monopoly rents have greater incentive to innovate. As indicated in the introduction, this model was not supported by the empirical studies conducted in the 1990s. Therefore, Aghion and Griffith (2005) revised the basic Schumpeterian model in a way that conforms with the empirical evidence produced in the 1990s.

In their model, the production function of final goods (y) is expressed as follows:

$$(1) \qquad y_t = \int_0^1 A_{it}^{1-\alpha} x_{it}^{\alpha} di$$

A_{it} : productivity of intermediate input in sector i at time t

x_{it} : a continuum of intermediate input i, indexed by $i \in [0,1]$

In each sector i, only one firm produces intermediate input i at the constant marginal cost of the final good (y).[4] Since the firm faces a competitive fringe of imitators that can produce the same input at a constant marginal cost, it sets the limit price of intermediate input i at the constant marginal cost (m):

$$(2) \qquad p_{it} = m \quad \text{(we assume } 1 < m < \frac{1}{\alpha}\text{)}$$

where p_{it} is the price of intermediate input i in terms of the final goods price. The more competition there is in the intermediate goods market, the lower the value of m becomes. Hence, the parameter m is an inverse measure of the degree of competition.

We assume the final-goods-producing sector is competitive. Using the maximizing condition of a final goods producer, we find that p_{it} is equal to marginal productivity:

$$(3) \qquad p_{it} = \frac{\partial y_t}{\partial x_{it}} = \alpha(\frac{x_{it}}{A_{it}})^{\alpha-1}$$

4 We assume labor input is equal to 1. In our model, we focus on the competition in intermediate goods. Therefore, the competition is horizontal.

From (2) and (3), we get:

(4) $$x_{it} = (\frac{m}{\alpha})^{1/\alpha - 1} A_{it}$$

We assume that the world technology frontier grows at a constant rate (g), as shown in the following equation:

(5) $$\overline{A}_t = g\overline{A}_{t-1}$$

where g>1

Firms are able to improve productivity by carrying out R&D investment. When a firm spends $(1/2)gA_{t-1}q^2$ on an R&D project, it achieves an improvement in productivity with probability *q*. On the other hand, when the firm fails to achieve productivity-improving innovation, the probability of which is *1-q*, it remains at the previous technological level.

Aghion and Griffith (2005) assume that there are two different types of firm (type-0 and type-1) in the intermediate goods market, while the basic Schumpeterian model assumed only one type. The productivity of the type-0 firm is at the technology frontier in period *t-1*, that is $A^0_{t-1} = \overline{A}_{t-1}$. On the other hand, the productivity of the type-1 firm is one step behind the technology frontier in period *t-1*, that is, $A^1_{t-1} = \overline{A}_{t-2}$

First, we consider the behavior of the type-1 firm. From (3) and (4), the profits of the type-1 firm (π^1_{it}) are expressed as follows:

(6) $$\pi_{it}^{1} = (p_{it} - 1)x_{it}^{1} = h(m)A_{it}^{1}$$

where $h(m) = (m-1)(\frac{m}{\alpha})^{1/\alpha - 1}$

The type-1 firm optimizes R&D investment (q^1) to maximize expected net rent after the innovation:

(7) $$\max_{q^1} \{(\overline{A}_{t-1} - \overline{A}_{t-2})h(m)q^1 - \frac{1}{2} g\overline{A}_{t-2}(q^1)^2\}$$

The first order condition with respect to q^1 in (7) is:

(8) $$q^1 = (1 - \frac{1}{g})h(m)$$

Equation (8) implies that a less competitive market structure (that is, a small *m*) enhances R&D investment, as the conventional Schumpeterian hypothesis suggests. Aghion and Griffith (2005) called this the "Schumpeterian effect."

Next, we turn to the behavior of the type-0 firm. If the type-0 firm successfully innovates, its productivity remains at the technology frontier,and it will set its price at $(\frac{1}{\alpha})$, because it maintains a monopoly in the market. In this case, the profits of the type-0 firm (π_{it}^{0}) are:

(9) $$\pi_{it}^{0} = h(\frac{1}{\alpha})\overline{A}_{t}$$

However, if the type-0 firm fails to innovate, its productivity remains at the previous level, that is $A_t^0 = \overline{A}_{t-1}$. Therefore, the type-0 firm faces a competitive market and its profits are

$$(10) \qquad \pi_{it}^0 = h(m)\overline{A}_{t-1}$$

The type-0 firm chooses the level of R&D effort that maximizes the following expected net rent:

$$(11) \qquad \max_{q^0} \{[\overline{A}_t h(\frac{1}{\alpha}) - \overline{A}_{t-1} h(m)]q^0 - \frac{1}{2} g\overline{A}_{t-1}(q^0)^2\}$$

The first order condition with respect to q^0 in (11) is:

$$(12) \qquad q^0 = h(\frac{1}{\alpha}) - \frac{1}{g} h(m)$$

In contrast to (8), Equation (12) implies that market competition stimulates R&D effort because the type-0 firm is able to avoid competition if it succeeds in innovation. Aghion and Griffith (2005) called this the "escape competition effect".

R&D investment in the total intermediate sector (Q) is expressed as follows:

$$(13) \qquad Q = s^0 q^0 + s^1 q^1$$

where s^i is the share of type j firms in the total intermediate sector (j=0,1).

Equation (13) indicates that the effect of competition on R&D activities depends on the growth rate of the world technology frontier. When g is sufficiently large, the "Schumpeterian effect" dominates. On the other hand, if g is close to 1, the "escape competition effect" dominates. In the intermediate case, the "escape competition effect" dominates when the market is less competitive (m is close to $\frac{1}{\alpha}$). However, when the market is very competitive (m is close to 1), the "Schumpeterian effect" dominates. In this intermediate case, we are able to find the inverted U-curve relationship between competition and innovative activities.

The above argument focused on the innovative behavior of incumbents. Based on the above model, we consider the effect of new entry or deregulation on innovative activity. In this study, we assume a new entrant, which produces intermediate goods with the most advanced technology at that time. Then the type-1 firm is able to survive only when it succeeds in innovating and the potential competitor fails to enter the market. We assume that the new entrant has to pay fixed costs when it enters the market. Deregulation usually decreases entry costs. Therefore, deregulation stimulates new entry and the type-1 firm loses its incentive to innovate. Aghion et al. (2006) call this the "discouragement effect."

On the other hand, the type-0 firm is able to dominate the market if it succeeds in innovation. Therefore, it invests more aggressively in R&D due to deregulation. Aghion et al. (2006) call this the "escape entry effect." As a result, the effect of new entry or deregulation depends on how far the productivity of the incumbent firm is from the world technology frontier.

3. Empirical hypotheses and data description

Based on the theoretical model presented above, we examine the effect of market competition on innovative activities using firm-level data for Japan. The basic empirical specification is as follows:

$$
\begin{aligned}
(14) \quad IA_{fjt} = {} & \alpha_f + \alpha_j + \alpha_t + \alpha_1 COMP_{jt-1} + \alpha_2 (COMP_{jt-1})^2 + \alpha_3 IMP_{jt-2} + \alpha_4 SIZE_{fjt-1} \\
& + \alpha_5 Age_{fjt-1} + \alpha_6 FO_{fjt},
\end{aligned}
$$

Explanations of the variables used in the estimations are shown in Table 1. We use panel data taken from the *Basic Survey of Business Activities of Enterprises* (BSBAE) conducted by Ministry of Economy, Trade and Industry (METI). The BSBAE database includes all Japanese manufacturing firms with more than fifty employees. Our data cover firms which were established before 1996 and remained in business during the period from 1997 to 2003. After dropping firms that are outliers in terms of relative TFP, we have 59,455 observations for the natural log of relative TFP ($\ln TFP$) and the growth rate of relative TFP ($d\ln TFP$).[5] The distribution of observations by year and industry is shown in Table 2.

Insert Tables 1 and 2

[5] We drop firms for which the absolute value in $\ln TFP$ or $d\ln TFP$ exceeds three standard variations in their industry. In other words, a firm is omitted if $|\delta_{fjt}^{\ln TFP}| > |3 * \delta_{jt}^{\ln TFP}|$ or $|\delta_{fjt}^{d\ln TFP}| > |3 * \delta_{jt}^{d\ln TFP}|$, where $\delta_{fjt}^{\ln TFP}$ and $\delta_{fjt}^{d\ln TFP}$ are the standard deviation of $\ln TFP$ and $d\ln TFP$, respectively.

As for the dependent variable, we use two indicators of firms' innovative activity (IA_{fjt}). The first indicator is a multilateral productivity index for each industry *j* and is obtained by applying the following equation:[6]

$$
\begin{aligned}
\ln TFP_{f,t} &= (\ln Q_{f,t} - \overline{\ln Q_t}) - \sum_{i=1}^{n} \frac{1}{2}(S_{f,i,t} + \overline{S_{i,t}})(\ln X_{f,i,t} - \overline{\ln X_{i,t}}) \\
&\quad + \sum_{s=1}^{t} (\overline{\ln Q_s} - \overline{\ln Q_{s-1}}) - \sum_{s=1}^{t} \sum_{i=1}^{n} \frac{1}{2}(\overline{S_{i,s}} + \overline{S_{i,s-1}})(\overline{\ln X_{i,s}} - \overline{\ln X_{i,s-1}})
\end{aligned} \tag{15}
$$

Here, $\ln TFP_{f,t}$ represents the natural logarithm of the TFP level of firm *f* at time *t*, $\ln Q_{f,t}$ stands for real gross output (real sales in this case) of firm *f* at time *t*, and $\ln X_{f,i.t}$ is the natural logarithm of real input of production factor *i* (since there are three types of production factor – capital, labor, and intermediate input – the *n* for the sigma notation is 3 in this case) of firm *f* at time *t*. $S_{f,i,t}$ represents the cost share of production factor *i* of firm *f* at time *t*. $\overline{\ln Q_t}$ is the geometric average of the output, at time *t*, of all firms in the industry to which firm *f* belongs, while $\overline{\ln X_{i,t}}$ stands for the geometric average of the input of production factor *i*, at time *t*, of all firms in the industry to which firm *f* belongs. Finally, $\overline{S_{i,t}}$ is the arithmetic average of the cost share of the input of production factor *i*, at time *t*, of all firms in the industry to which firm *f* belongs.

The second measure of innovative activity is R&D intensity, which is defined as follows:

[6] See Caves, Christensen, and Diewert (1982) and Good, Nadiri, and Sickles (1997).

(16) $$R\,\&\,D\,intensity_{fjt} = R\,\&\,D_{fjt}\,/\,Y_{fjt}$$

$R\&D_{fjt}$ is the level of R&D investment of firm *f* in industry *j* in year *t* and we use the natural logarithm of R&D intensity as the dependent variable.

We employ two competition measures ($COMP_{jt}$) in the estimation. The first is the Herfindahl Index, which is calculated from the data in the BSBAE database. The other is the Lerner Index, which is calculated using data from the JIP 2006 database. The Herfindahl Index is calculated by the following equation:

(17) $$Herf_{jt} = \sum_{i=1}^{N} sales(\%)^2{}_{fjt}\ ,$$

where $sales_{fjt} = SALES_{fjt} / \sum_{f=1}^{N} SALES_{fjt}$ and $SALES_{fjt}$ stands for the sales of firm *f* in industry *j* at time *t*.

We use the inverse of the Herfindahl Index ($INVHerf_{jt}$) as an explanatory variable, and when the value of $INVHerf_{jt}$ is closer to 1, there is more competition in the industry. Since the Herfindahl Index only measures domestic market competition, we also add the import ratio (Imp_{jt}) as an explanatory variable to control for international competition in the industry. The import ratio is defined by the following equation:

(18) $$Imp_{jt} = \frac{Imports_{jt}}{Y_{jt}},$$

where $Imports_{jt}$ is the amount of import and Y_{jt} the amount of production in industry j at time t. The data for constructing this variable are taken from the JIP 2006 database supplementary tables.

The other competition measure, the Lerner Index, is defined as follows:

(19) $$LERNER_{jt} = \frac{Y_{jt} - r_{jt}K_{jt} - w_{jt}L_{jt} - p_{M_{jt}}M_{jt}}{Y_{jt}}$$

where r_{jt} is the rental cost of capital, w_{jt} is the wage rate, and $p_{M\,jt}$ is the price of intermediate goods in industry j at time t. The data for these variables are taken from the JIP 2006 database. We use $1 - LERNER_{jt}$ as our competition measure and the value becomes closer to 1 when there is more competition in the industry. As a result, $COMP_{jt}$ in Equation (14) is represented by either $INVHerf_{jt}$ or $1 - LERNER_{jt}$.

We expect the coefficients on the competition measures ($INVHerf_{jt}$ or $1 - LERNER_{jt}$) to be positive if market competition stimulates innovative activity. However, Aghion and Griffith (2005) suggest that the relationship between competition and innovative activity is not linear. We therefore include square terms of our competition measures in Equation (14) to examine whether there is an inverted-U relationship between competition and innovative activity.

The control variables included in the estimation are the natural logarithm of the number of employees of firm f at time t ($\ln(Firm\ Size)_{ft}$) to control for firm size

($Size_{fjt}$) and the log of the age of firm f at time t ($\ln(Firm\ Age_{ft})$) to control for the effects of accumulated intangible assets (Age_{fjt}) on firms' productivity. The necessary data for constructing these variables are taken from the BSBAE database.

In addition, to control for the effect of foreign ownership, we include FO_{fjt}, which is a dummy variable with a value of 1 when the firm is 33% or more foreign owned and 0 otherwise. In addition, we include firm dummy variable (α_f), industry dummy variable (α_j), and time dummy (α_t) variable.

In order to examine the effect of new entry and regulation on innovative activity of incumbent firms, we modified Equation (14) to include a regulation index and an indicator of the technology gap among firms in an industry:

$$\begin{aligned} IA_{fjt} &= \alpha_0 + \alpha_j + \alpha_t + \alpha_1 COMP_{jt-1} + \alpha_2 (COMP_{jt-1})^2 + \alpha_3 IMP_{jt-2} + \alpha_4 SIZE_{fjt-1} \\ &+ \alpha_5 Age_{fjt-1} + \alpha_6 FO_{fjt-1} + \alpha_7 reg_{jt-1} + \alpha_8 Tgap_{fjt} + \alpha_9 FDI_{jt-1} \\ &+ \alpha_{10} Tgap_{fjt} * reg_{jt-1} + +\alpha_{11} Tgap_{fjt} * FDI_{jt-1} \end{aligned} \tag{20}$$

The regulation index (reg_{jt}) used in Equation (20) is taken from the Cabinet Office, Government of Japan (2007).[7] The regulation measure takes a value between 0 and 1 and its value decreases the more a market has been deregulated compared with the situation in 1995. If deregulation promotes new entry of firms, incumbent firms may increase their innovative efforts. Therefore, we expect the coefficient on α_7 to take a negative value. $Tgap_{fjt}$ is defined as the gap between the average $\ln TFP_{fjt}$ within the top 25% ($=\ln TFP_{jt}^{Top25}$) of firms in the industry which firm i belongs to and $\ln TFP_{fjt}$:

[7] An explanation of the regulation index is provided in the Appendix.

(21) $$Tgap_{fjt} = \ln TFP_{jt}^{Top25} - \ln TFP_{fjt}$$

The coefficient on $Tgap_{fjt}$ expresses the catch-up effect, meaning that a large technology gap stimulates innovative activity. However, as explained in the previous section, firms which are far from the technology frontier may be discouraged from engaging in innovative activities when deregulation makes it easier for firms with advanced technology to enter the market. To examine this discouragement effect, we use $Tgap_{fjt-1} * FDI_{jt-1}$ and $Tgap_{fjt-1} * reg_{jt-1}$, where FDI_{jt} is an industry-level variable that is defined as the ratio of the number of firms for which the foreign ownership ratio is over 33% of the total number of firms in the industry. This ratio is calculated from data provided in the supplementary tables of the JIP 2006 database. If there is such a discouragement effect operating, the coefficient on $Tgap_{fjt-1} * FDI_{jt-1}$ should be negative while that on $Tgap_{fjt-1} * reg_{jt-1}$ should be positive.

Descriptive statistics of the variables used in the estimation are shown in Table 3. The table is divided into two parts, with one showing the summary statistics for the case when the TFP growth rate ($d \ln TFP_{it}$) is used as the dependent variable is and the other for the case when the natural logarithm of R&D intensity is used as the dependent variable.[8] Since Aghion and Griffith's (2005) model that we use here analyzes the innovative behavior of incumbent firms, we limit our sample to firms that already existed in the initial period in the estimation (1993).

8 The summary statistics for the two cases differ because in the case where the log of R&D intensity is used as the dependent variable, firms that do not invest in R&D ($R\&D_{it} = 0$) are omitted.

Insert Table 3

4. Estimation results

4.1. Competition and innovative activity

First, we examine the linear relationship between competition and innovative activity. We estimate Equation (14) excluding the squared term of the competition measure ($(COMP)^2$). We use the fixed effect method for the period between 1997 and 2003 and the results are shown in Table 4. Four different specifications to examine the relationship between innovation and competition using our two measures each of innovative activity and market competition are estimated: (1) TFP growth and the inverse Herfindahl Index; (2) TFP growth and (1-Lerner Index); (3) R&D intensity and the inverse Herfindahl Index; and (4) R&D intensity and (1-Lerner Index).

Insert Table 4

As shown in Table 4, the coefficients on the competition measure are positive and significant in all specifications. This result implies that market competition stimulates innovative activity. International competition through import has a positive and significant impact on TFP growth, but a negative effect on R&D intensity, suggesting that international competition promotes a wide range of short-term innovations that are reflected in TFP growth rather than specific and long-term innovative activity, which R&D intensity represents. Firm size has a positive effect both on TFP growth and on

R&D intensity. On the other hand, firm age and foreign ownership do not have any significant effects on either.

Next, we examine the hypothesis of an inverted U-shaped relationship between competition and innovative activity using Equation (14). The estimation results are displayed in Table 5 and suggest that the hypothesis of an inverted U-shaped relationship between competition and innovative activity is supported in Equations 5-1 and 5-3 where the inverse Herfindahl index is used as the competition measure. On the other hand, when we use (1-Lerner Index) as the measure of competition, the inverted U-shaped relationship hypothesis holds only in the case where R&D intensity is used as an explanatory variable. When we compare the coefficients on the competition measures (*competition*) in Tables 4 and 5, the coefficients in Table 5, except in Equation 5-2, are larger and more significant than those in Table 4. This suggests that the positive impact of competition on innovative activity is underestimated when we assume a linear relationship between competition and innovative activity. The results for the other variables in Tables 4 and 5 are essentially the same.

Insert Table 5

Our sample includes firms that do not engage in R&D and in order to check the robustness of our results, we re-estimate Equation (14) after dividing our sample into firms that conduct R&D and those that do not, with the results for the former displayed as Equations 6-1 and 6-3 and those for the latter shown as Equations 6-2 and 6-4 in Table 6. Confirming our previous results, we find that the inverted U-shaped relationship holds only when we use the Herfindahl Index as the measure of competition and only in the sample of firms that do conduct R&D. Aghion and Griffith's (2005) model examines the behavior of the incumbent innovator and our estimation results also indicate the relationship holds more strongly in the sample of firms that do conduct R&D.

Insert Table 6

As a further robustness test, we also divide our sample into two sub-periods, 1997-1999 and 2000-2003, and then re-estimate Equation (14). The results, shown in Table 7, indicate that the inverted U-shaped relationship between competition and innovative activity holds only in the estimations for the 2000-2003 period. The results imply that Japanese firms' innovative activity has become more sensitive to market competition in recent years in the context of very weak domestic economic growth.

Insert Table 7

In sum, the results in Tables 5 to 7 indicate that when TFP growth and the Herfindahl Index are used for the measurement of innovative activity and competition respectively, we do find evidence of an inverted U-shaped relationship between the two. TFP is a broader measure of innovative activity than R&D activity and our estimation results imply that this broader measure is affected by the domestic competitive environment. Moreover, it is also positively affected by international competition. Because the Lerner Index is influenced by the business cycle, our estimation results may not accurately capture the relationship between innovation and competition when we use the Lerner Index as a measure of competition. Tingvall and Poldahl (2007) have estimated the relationship between innovation and competition examining Swedish firms and using the same measures of innovation and competition as we do here. They similarly found that the inverted U-shaped relationship only held when they employed the Herfindahl Index as the measure of competition in their estimations.

4.2. Effects of Entry Barriers on Innovative Activity

Next, we examine the effects of new firm entry on the innovative activity of incumbent firms. The estimation results for the fixed effect model of Equation (20) with TFP growth as the dependent variable are shown in Table 8. In this estimation, we focus on the coefficients of the technology gap measure, the two measures for entry barriers (reg_{jt-1} and FDI_{jt-1}), and the cross-terms of the technology gap measure and the two measures for entry barriers. Based on the results presented in the preceding section, we use the TFP growth rate as our measure of innovation and the inverse Herfindahl Index as our measure of competition.[9]

Insert Table 8

The coefficient on the technology gap measure is positive, as expected in all specifications. This implies that there is a catch-up effect to best practice technologies in

[9] We also estimated Equation (20) with R&D intensity as the dependent variable. Doing so, we obtained results that provide strong support for the hypothesis of an inverted U-shaped relationship. However, the technology gap has a negative impact on R&D intensity, which contradicts our expectation. Moreover, we were unable to obtain any significant coefficients on the regulation variable, the foreign participation ratio, and the cross-terms of the technology gap measure and these two explanatory variables.

manufacturing industries. As for the measures of entry barriers, the coefficients on reg_{jt-1} have the expected negative sign and are significant. On the other hand, the coefficients on FDI_{jt-1} are negative and significant. This may imply that the entry of foreign firms with a very high level of technology has a very strong discouragement effect on domestic incumbent firms. The coefficient on $Tgap_{fjt-1} * reg_{jt-1}$ is positive and significant, implying that the discouragement effect hypothesis is supported in these estimations. Although the coefficients on $Tgap_{fjt-1} * FDI_{jt-1}$ are insignificant, the negative signs also support the discouragement effect hypothesis.

Again, to check the robustness of our results, we also estimated Equation (20) dividing our sample into two periods (1997-1999 and 2000-2003) as in the estimation of Equation (14) above. Table 9 shows that we obtain estimation results that are similar but more statistically significant in the period of 2000-2003 than those for the total period. This also suggests that the relationship in Japan between competition and firm entry on the one hand and innovation on the other has become more pronounced in the 2000s. Such a development would reflect the fact that the Japanese government in recent years has introduced various pro-competition reforms and that import competition from low-wage countries has increased substantially. In this new environment, Japanese firms' efforts to innovate have become more sensitive to the competitive situation in the market and the entry of new competitors. On the other hand, FDI penetration in Japan, especially in the manufacturing sector, is still very limited, and this may be one of the reasons why we did not obtain the expected results in our estimation.[10]

10 For more details on FDI penetration in Japan see Paprzycki and Fukao (2008).

Insert Table 9

5. Conclusion

Following Aghion and Griffith (2005), we examined the effect of market competition, as measured by the Herfindahl Index and Lerner Index, on productivity growth and R&D intensity using micro data for the Japanese manufacturing sector. We found an inverted U-shaped relationship between competition and innovation when the Herfindahl Index is used as a measure of competition in the market, although the relationship was not confirmed when we used the Lerner Index. The result implies that the positive impact of competition on innovative activity is underestimated when we assume a linear relationship between competition and innovative activity.

In addition, we studied the effect of new entrants on the innovative activities of incumbents. Our estimation results showed that the effect on the TFP growth of incumbents depended on their technology level. When a firm's technology level is close to the technology frontier in that industry, then new entry encourages these firms to make greater efforts toward increasing productivity in order to escape from competition. However, it discourages innovation in firms far from the technology frontier of that industry.

In order to further examine the robustness of our findings in this paper, we could use different measures of firms' innovative activities. There is a large literature on measuring innovative activity, and while here we used the TFP growth rate and R&D intensity, other studies employ, for example, the number of citation-weighted patents.

Since the BSBAE database does not include such information, we would have to use a different database to obtain the necessary data to conduct this kind of estimation.

There is also a vast literature on measuring TFP growth and here we confined ourselves to measuring it by employing the index method. However, it is also possible to estimate TFP growth by employing the production function method. In this case, we would need to take into account simultaneity problems, and in order to alleviate this problem, we should employ the methods developed by Olley and Pakes (1996) or Levinsohn and Petrin (2003).

Additional possible extension would be to examine the spillover effects of innovation, following Tingvall and Poldahl (2007), or to include the effects of financial pressure and corporate governance in the estimation of R&D intensity, as in Hosono, Tomiyama, and Miyagawa (2004). Furthermore, we could estimate the equations confining our sample to firms from intermediate input industries and firms with high R&D investments, since the Aghion and Griffith (2005) model actually focuses on the behavior of innovative firms which produce intermediate goods. However, probably a more important extension of this paper would be to examine the relationship between competition and innovative activity in the non-manufacturing sector.

Appendix 1: The measurement of relative TFP

Q_{fjt} is real gross output and is defined as :

(A1) $$Q_{fjt} = sales_{fjt} / output\ price\ index_{jt}$$

The output price index is taken from the JIP 2006 database and the nominal value of firms' sales is taken from the BSBAE database.

We consider three inputs: labor, capital, and intermediate input. Labor is expressed in terms of man-hours. The number of workers is taken from the BSBAE database and the working hours in each industry are taken from the Monthly Labour Survey statistics" published by the Ministry of Health, Labour and Welfare. For capital, we take the book value of tangible assets excluding land from the BSBAE database. To construct the real value of capital stock, we convert the book value to market value by multiplying it with the ratio of the market to book value, which we constructed from the Development Bank of Japan (DBJ) database.

Intermediate input is calculated as follows:

(A2) $$M_{fjt} = \frac{(operating\ cost_{fjt} - laborcost_{fjt} - depreciation\ cost_{fjt})}{input\ price\ index_{jt}}$$

The input price index is taken from the JIP 2006 database. Total wage payments from the BSBAE database are used as labor costs taken, and operating costs and depreciation costs are available from the database.

In order to calculate the cost of capital, we use the corporate income tax, government bond rate, long-term prime rate, price of capital goods, consumption of fixed capital (these variables are all taken from the JIP 2006 database), and loan/total asset ratio (λ_{ijt}), which is calculated from BSBAE database. The cost of capital is defined by the following equation:

$$\text{(A3)} \qquad c_{ftk} = \frac{1-z_t}{1-u_t} P_{tk} \left\{ \lambda_{it} * r_t + (1-u_t)(1-\lambda_{ft}) i_t + \delta_K - \frac{\dot{P}_{tK}}{P_{tK}} \right\}$$

where c_{ftk} is firm *f*'s cost of capital in year t, while u is the effective corporate tax rate, r is the bond rate, i is the long-term prime rate and δ is the consumption of fixed capital. Finally, z represents the expected present value of tax saving due to depreciation allowances on one unit of investment, which is obtained using the following formula:

$$\text{(A4)} \qquad z_t = u_t * \delta_K / [\{\lambda_t r_t + (1-\lambda_t)(1-u_t) i_t\} + \delta_i]$$

Appendix 2: Regulation Index

Government regulations may have an important impact on the performance of an industry by affecting the allocation of resources and productive efficiency. In order to assess the impact of regulation on economic performance, we use a regulation index recently created by the Cabinet Office (2006). This regulation index is available for the period 1995 to 2005 and measures the degree of regulation in each industry by using information on the number of regulatory laws and rules pertaining to that industry. For the calculation of the index, laws and regulations are weighted by the extent to which they restrict activity. For example, regulations which completely prohibit particular business activities in an industry receive a weight that is 1,000 times greater than regulations that simply require firms to report to or inform the authorities.

Specifically, the index is calculated as follows:

$$RS_{it} = \sum_{jk} \left\{ \left(WM_j \times WT_k \right) \times N_{jk}^{it} \right\} \quad \text{(A5)}$$

where

RS_{it}= the weighted number of laws and rules in industry i (1-97)[11] in year t (1995-2002);

WM_j= the weight used for each regulation and the method of regulatory enforcement; there are 5 categories in increments of a factor of 10 representing the extent to which regulations restrict activity: WM_1=1, WM_2=10, WM_3=100, WM_4=1,000 and WM_5=10,000;

WT_k= regulations are also classified into 4 categories, each with its own weight: WT_1= regulations based on ministerial announcements; WT_2= regulations based on ministerial ordinance; WT_3= regulations based on government ordinance; and WT_4= regulations based on law; the weight for each type is 1, 2, 3 and 4, respectively;

N^{it}_{jk}= the number of regulations in industry i in year t, enforced by method j and type k

[11] The industrial classification used here is the same as in the JIP 2006 database.

of regulatory law and rules.

Finally,

$RI_{it}= (RS_{it}/RS_{i,1995})$,

where

RI_{it} =the regulation index in industry *i* and year, using 1995 as the base year.

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Table 1. Summary of Variables

Variable	Definition	Unit of observation
dlnTFP	Growth of relative TFP	Firm-year
lnR&D/Y	Lagged R&D intensity; R&D intensity = R&D investment/real output	Firm-year
α_f	Firm dummy	Firm
α_j	Industry dummy	Industry
α_t	Time dummy	Year
invHerf	Inverse of the Herfindahl Index; the more competitive the industry, the greater this value	Industry-year
(1-LERNER)	One minus the Lerner Index; the more competitive the industry, the closer this value is to 1	Industry-year
Tgap	Technology gap; the gap between the average relative TFP within the top 25% firms in the industry which the firm belongs to and the relative TFP of the firm	Firm-year
Reg	Regulation index	Industry-year
FDI	The percentage firms in the industry for which the foreign ownership ratio is over 33%	Industry-year
Imp	Import ratio (= imports/output); used to control for import competition in the industry	Industry-year
ln(SIZE)	Logged number of employees in the firm	Firm-year
ln(AGE)	Logged firm age	Firm-year
FO	Foreign ownership; a dummy variable taking a value of 1 when the foreign investment rate is over 33%, otherwise 0; used to control for the effect of foreign ownership	Firm-year

Table2. Industry Distribution

jipind	1997	1998	1999	2000	2001	2002	2003	Total
Livestock products	166	169	181	168	174	160	158	1,176
Seafood products	136	134	137	138	133	143	136	957
Flour and grain mill products	30	31	32	33	27	30	28	211
Miscellaneous foods and related products	591	594	608	602	611	595	586	4,187
Prepared animal foods and organic fertilizers	33	30	32	34	35	33	34	231
Beverages	131	135	130	123	128	125	117	889
Textile products	593	547	511	457	431	414	367	3,320
Lumber and wood products	111	105	111	107	99	94	90	717
Furniture and fixtures	116	110	115	115	108	112	105	781
Pulp, paper, coated and glazed paper, and Paper products	335	324	332	326	313	287	285	2,202
Printing, plate making for printing and bookbinding	428	434	435	421	421	423	427	2,989
Leather and leather products	27	26	20	23	19	21	18	154
Rubber products	109	110	110	106	109	108	97	749
Basic organic chemicals, Chemical fertilizers	145	140	142	133	128	120	116	924
Chemical fibers, Organic chemicals	14	15	12	13	11	14	7	86
Miscellaneous chemical products	327	314	322	310	294	288	286	2,141
Pharmaceutical products	168	166	162	159	174	171	170	1,170
Petroleum products	27	25	25	24	23	23	20	167
Coal products	17	19	16	19	25	19	19	134
Glass and its products and Pottery	68	63	67	66	66	64	68	462
Cement and its products	177	174	165	167	157	151	138	1,129
Miscellaneous ceramic, stone and clay products	174	173	165	151	139	138	136	1,076
Pig iron and crude steel	141	132	133	140	134	132	123	935
Miscellaneous iron and steel	167	162	145	148	142	143	135	1,042
Smelting and refining of non-ferrous metals	41	39	38	36	43	46	44	287
Non-ferrous metal products	210	215	202	196	185	180	174	1,362
Fabricated constructional and architectural metal products	264	249	246	226	216	211	212	1,624
Miscellaneous fabricated metal products	466	478	479	479	453	437	443	3,235
General industry machinery	179	188	175	161	151	147	146	1,147
Special industry machinery	290	284	288	309	291	300	302	2,064
Miscellaneous machinery	568	546	561	555	576	565	551	3,922
Office and service industry machines	118	122	123	121	131	114	111	840
Electrical generating, transmission, distribution and industrial apparatus	307	297	287	287	293	298	292	2,061
Household electric appliances and Electronic equipment and electric measuring	117	108	99	86	81	80	83	654
Electronic data processing machines, digital and analog computer equipment and accessories	137	136	144	133	130	140	140	960
Communication equipment	212	220	215	203	189	176	161	1,376
Electronic parts	514	537	549	518	473	484	475	3,550
Miscellaneous electrical machinery equipment	157	147	146	164	163	167	158	1,102
Motor vehicles, Part, Accessories and Other transportation equipment	164	173	166	149	145	153	144	1,094
Precision machinery & equipment	249	266	256	246	231	249	238	1,735
Plastic products	482	470	507	484	471	474	468	3,356
Miscellaneous manufacturing industries	185	188	184	186	173	175	166	1,257
Total	8,891	8,795	8,773	8,522	8,296	8,204	7,974	59,455

Table3. Descriptive Statistics

	TFP growth model					R&D intensity model				
	observation	average	std. dev.	minimum	maximum	observation	average	std. dev.	minimum	maximum
dlnTFP $_t$ *(TFP growth)*	59455	0.0053	0.0771	−0.6668	0.8508	29029	0.0067	0.0778	−0.6668	0.8188
ln(R&D/Y) $_t$ *(logged R&D intensity)*	29029	−4.8042	1.5005	−11.0088	0.5017	29029	−4.8042	1.5005	−11.0088	0.5017
† invHerf $_{t-1}$ *(competition)*	287	0.0105	0.0076	0.0004	0.0850	287	0.0099	0.0074	0.0004	0.0850
† (1−LERNER) $_{t-1}$ *(competition)*	287	0.9059	0.1449	0.1113	1.2562	287	0.8957	0.1538	0.1113	1.2562
Technology Gap $_{t-1}$ *(Technology Gap with Frontier firm)*	59157	0.1229	0.0959	−0.3301	1.1300	28925	0.1089	0.0941	−0.3301	1.0858
† reg $_{t-1}$ *(regulation)*	287	0.4230	0.4191	0	1.0860	287	0.4455	0.4153	0	1.0860
† FDI $_{t-1}$ *(Foreign frim perticipation ratio in the industry)*	287	0.4089	0.8668	0	6.6929	287	0.5863	1.1011	0	6.6929
ln(firm size) $_{t-1}$ *(logged employment)*	59455	5.1883	0.8987	3.9120	10.0026	29029	5.5071	0.9744	3.9120	9.9266
ln(firm age) $_{t-1}$ *(logged firm's age)*	59455	3.5624	0.4937	0	4.7005	29029	3.6485	0.4655	0	4.7005
† Import Ratio $_{t-2}$ *(import penetration)*	287	0.0953	0.1076	0.0017	1.0467	287	0.0951	0.1088	0.0017	1.0467
FO $_t$ *(Foreign ownership dummy)*	59455	0.0150	0.1214	0	1	29029	0.0217	0.1458	0	1

i) Observations of † variables are number of industries multiplyied by number of estimation periods.

Table 4. Linear Estimation

	Dependent variable: TFP growth		Dependent variable: lnR&D/Y	
Variable	Estimation 4-1 Fixed effect	Estimation 4-2 Fixed effect	Estimation 4-3 Fixed effect	Estimation 4-4 Fixed effect
invHerf $_{t-1}$	0.3602 *		4.2889 *	
(Competition)	1.67		1.79	
(1-LERNER) $_{t-1}$		0.0547 ***		0.3699 ***
(Competition)		8.46		6.50
IMP $_{t-2}$	0.0350 ***	0.0373 ***	-0.2965 **	-0.2674 **
(International trade)	2.73	3.09	-2.07	-2.09
ln(SIZE) $_{t-1}$	0.0350 ***	0.0346 ***	0.1810 ***	0.1813 ***
(Lagged employment)	10.97	10.99	4.23	4.44
ln(AGE) $_{t-1}$	-0.0075 **	-0.0052	0.0010	0.0061
(Lagged firm age)	-2.07	-1.46	0.02	0.13
FO $_{t}$	-0.0084	-0.0106	0.0944	0.0824
(Foreign ownership dummy)	-0.86	-1.21	1.14	1.16
Constant $_{t}$	-0.1431 ***	-0.1962 ***	-6.0309 ***	-6.3063 ***
	-4.71	-6.45	-16.81	-17.91
Industry dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
Number of observations	59,455	60,163	29,029	29,834
Number of groups	12,599	12,654	7,101	7,194
F value	43.7114	46.9374	4.3560	5.1956
R^2 overall	0.0735	0.0717	0.0073	0.0129
R^2 within	0.0764	0.0805	0.0129	0.0160
R^2 between	0.1415	0.1336	0.0054	0.0090

i) ***, **, * indicate significance at the 1%, 5%, and 10% level respectively.

Table 5. Competition and Innovation

Variable	Dependent variable: TFP growth				Dependent variable: lnR&D/Y			
	Estimation 5-1 Fixed effect		Estimation 5-2 Fixed effect		Estimation 5-3 Fixed effect		Estimation 5-4 Fixed effect	
invHerf $_{t-1}$ (*Competition*)	1.2486	***			7.3946	**		
	3.93				2.15			
invHerf^2 $_{t-1}$ (*Competition*)	-40.8148	***			-97.3002	*		
	-9.11				-1.88			
(1-LERNER) $_{t-1}$ (*Competition*)			0.0049				0.7380	***
			0.33				5.64	
(1-LERNER)^2 $_{t-1}$ (*Competition*)			0.0446	***			-0.3305	***
			4.24				-3.41	
IMP $_{t-2}$ (*International competition*)	0.0302	**	0.0349	***	-0.2818	**	-0.2362	*
	2.36		2.92		-1.98		-1.85	
ln(SIZE) $_{t-1}$ (*Lagged employment*)	0.0347	***	0.0349	***	0.1803	***	0.1780	***
	10.86		11.11		4.23		4.37	
ln(AGE) $_{t-1}$ (*Lagged firm age*)	-0.0081	**	-0.0051		0.0029		0.0061	
	-2.20		-1.42		0.06		0.13	
FO $_t$ (*Foreign ownership dummy*)	-0.0082		-0.0106		0.0954		0.0833	
	-0.85		-1.21		1.15		1.17	
Constant $_t$	-0.1414	***	-0.1914	***	-6.0318	***	-6.3514	***
	-4.63		-6.27		-16.90		-18.04	
Industry dummy	Yes		Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes		Yes	
Number of observations	59,455		60,163		29,029		29,834	
Number of groups	12,599		12,654		7,101		7,194	
F value	46.1754		46.5511		4.3732		5.1644	
R^2 overall	0.0791		0.0715		0.0067		0.0145	
R^2 within	0.0828		0.0811		0.0134		0.0166	
R^2 between	0.1562		0.1318		0.0048		0.0103	

i) ***, **, * indicate significance at the 1%, 5%, and 10% level respectively.

Table 6. Estimation for Subsamples of Firms with and without R&D Investment

Variable	Dependent variable: TFP growth							
	Estimation 6−1		Estimation 6−2		Estimation 6−3		Estimation 6−4	
	Fixed effect		Fixed effect		Fixed effect		Fixed effect	
invHerf $_{t-1}$ *(Competition)*	1.2210	***	0.6877					
	2.96		0.96					
invHerf^2 $_{t-1}$ *(Competition)*	−44.0940	***	−33.6190	***				
	−7.28		−2.90					
(1−LERNER) $_{t-1}$ *(Competition)*					0.0131		−0.0864	
					0.77		−1.14	
(1−LERNER)^2 $_{t-1}$ *(Competition)*					0.0523	***	0.0150	
					4.36		0.33	
IMP $_{t-2}$ *(International competition)*	0.0381	**	0.0692	*	0.0426	***	0.0623	*
	2.37		1.85		2.85		1.65	
ln(SIZE) $_{t-1}$ *(Lagged employment)*	0.0369	***	0.0773	***	0.0371	***	0.0780	***
	9.03		7.83		9.24		7.88	
ln(AGE) $_{t-1}$ *(Lagged firm age)*	−0.0074		−0.0093		−0.0040		−0.0101	
	−1.34		−1.46		−0.73		−1.57	
FO $_t$ *(Foreign ownership dummy)*	−0.0061		−0.0072		−0.0090		−0.0062	
	−0.55		−0.29		−0.91		−0.25	
Constant $_t$	−0.1516	***	−0.3363	***	−0.2158	***	−0.2708	***
	−3.86		−4.47		−5.49		−3.35	
R&D investment	YES		No		YES		No	
Industry dummy	Yes		Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes		Yes	
Number of observations	45,045		14,410		45,806		14,357	
Number of groups	11,384		6,305		11,459		6,257	
F value	36.0563		8.7908		37.8020		8.4478	
R^2 overall	0.0763		0.0520		0.0698		0.0467	
R^2 within	0.0927		0.0705		0.0942		0.0659	
R^2 between	0.1284		0.0788		0.1091		0.0677	

i) ***, **, * indicate significance at the 1%, 5%, and 10% level respectively.

Table 7. Competition Effect After 2000

Variable	Dependent variable: TFP growth				Dependent Variable: lnR&D/Y			
	Estimation 7-1	Estimation 7-2	Estimation 7-3	Estimation 7-4	Estimation 7-5	Estimation 7-6	Estimation 7-7	Estimation 7-8
	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect
invHerf $_{t-1}$	-0.6529	2.1483 ***			7.1530	4.4392		
(Competition)	-1.37	3.53			1.19	0.87		
invHerf^2 $_{t-1}$	-13.8918 **	-61.5716 ***			-19.0669	-70.2434		
(Competition)	-2.01	-6.85			-0.19	-0.94		
(1-LERNER) $_{t-1}$			-1.5450	0.0810 ***			0.7929	0.6969 ***
(Competition)			-9.35	3.59			0.55	4.78
(1-LERNER)^2 $_{t-1}$			0.8538 ***	0.0394 ***			-0.4301	-0.4031 ***
(Competition)			9.28	2.60			-0.53	-3.80
IMP $_{t-2}$	0.0455 *	0.0806 ***	0.0563 ***	0.0847 **	-0.0980	-0.5462 **	-0.0301	-0.4083 **
(International competition)	1.83	3.35	2.26	3.82	-0.43	-2.57	-0.14	-2.26
ln(SIZE) $_{t-1}$	0.0785 ***	0.0581 ***	0.0762 ***	0.0574 ***	0.1834 *	0.1546 **	0.2042 **	0.1413 **
(Lagged employment)	9.62	9.37	9.39	9.47	1.91	2.39	2.21	2.31
ln(AGE) $_{t-1}$	-0.0049	-0.0322 *	-0.0040	-0.0180	-0.0284	-0.0285	-0.0397	0.0202
(Lagged firm age)	-1.05	-1.73	-0.88	-0.90	-0.53	-0.21	-0.75	0.13
FO $_t$	-0.0003	-0.0174	-0.0014	-0.0149	-0.1429	0.1323	-0.1357	0.0992
(Foreign ownership dummy)	-0.02	-0.86	-0.12	-0.83	-1.23	1.46	-1.34	1.24
Constant $_t$	-0.3401 ***	-0.1984 **	0.3355 ***	-0.3386 ***	-4.8459 ***	-5.6192 ***	-5.4615 ***	-5.9582 ***
	-5.86	-2.50	3.60	-4.03	-5.82	-8.74	-5.62	-8.65
Year	year<2000	year>=2000	year<2000	year>=2000	year<2000	year>=2000	year<2000	year>=2000
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	26,459	32,996	26,758	33,405	12,907	16,122	13,259	16,575
Number of groups	10,434	10,633	10,475	10,714	5,545	5,710	5,633	5,814
F value	14.3218	32.7480	16.4352	37.4449	10.3128	3.8339	50.0425	4.2980
R^2 overall	0.0284	0.0838	0.2490	0.0813	0.0061	0.0178	0.0000	0.0249
R^2 within	0.0545	0.1230	0.0583	0.1328	0.0114	0.0138	0.0102	0.0166
R^2 between	0.0527	0.1410	0.0454	0.1238	0.0064	0.0190	0.0000	0.0247

i) ***, **, * indicate significance at the 1%, 5%, and 10% level respectively.

Table 8. The Technology Gap and Entry Effects

Variable	Estimation 8-1 Fixed effect	Estimation 8-2 Fixed effect	Estimation 8-3 Fixed effect	Estimation 8-4 Fixed effect
	Dependent variable: TFP growth			
invHerf $_{t-1}$ *(Competition)*	1.2429 ***	1.2294 ***	1.2062 ***	1.1985 ***
	3.93	3.89	3.81	3.79
invHerf^2 $_{t-1}$ *(Competition)*	-40.9376 ***	-40.7811 ***	-40.4556 ***	-40.3566 ***
	-9.15	-9.13	-9.04	-9.03
Tgap $_{t-1}$ *(Technology gap with frontier firm)*	1.96E-01 ***	1.80E-01 ***	2.00E-01 ***	1.86E-01 ***
	19.86	14.67	19.53	14.41
Tgap$_{t-1}$*reg $_{t-1}$ *(Complimentarity with regulation)*		3.53E-02 **		3.09E-02 **
		2.30		1.99
reg $_{t-1}$ *(Regulation)*		-4.48E-03 *		-4.63E-03 *
		-1.72		-1.78
Technology Gap$_{t-1}$*FDI $_{t-1}$ *(Complementarity with foreign direct investment)*			-4.15E-03	-1.86E-03
			-0.59	-0.27
FDI $_{t-1}$ *(Foreign firm participation ratio in the industry)*			-0.0063 ***	-0.0065 ***
			-2.93	-3.02
IMP $_{t-2}$ *(International competition)*	0.0359 ***	0.0358 ***	0.0362 ***	0.0360 ***
	11.33	11.28	11.40	11.36
ln(SIZE) $_{t-1}$ *(Lagged employment)*	-0.0062 *	-0.0062 *	-0.0062 *	-0.0062 *
	-1.71	-1.70	-1.72	-1.71
ln(AGE) $_{t-1}$ *(Lagged firm age)*	0.0227 *	0.0234 *	0.0239 *	0.0242 *
	1.79	1.85	1.90	1.92
FO $_t$ *(Foreign ownership dummy)*	-0.0077	-0.0078	-0.0068	-0.0069
	-0.82	-0.83	-0.71	-0.73
Constant $_t$	-0.1743 ***	-0.1711 ***	-0.1724 ***	-0.1694 ***
	-5.69	-5.57	-5.62	-5.52
Industry dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
Number of observations	59,157	59,157	59,157	59,157
Number of groups	12,549	12,549	12,549	12,549
F value	52.6080	51.0792	50.9070	49.4270
R^2 overall	0.0879	0.0882	0.0899	0.0901
R^2 within	0.1004	0.1006	0.1008	0.1009
R^2 between	0.1690	0.1695	0.1728	0.1730

i) ***, **, * indicate significance at the 1%, 5%, and 10% level respectively.

Table 9. The Technology Gap and Entry Effects

Variable	Dependent variable: TFP growth							
	Estimation 9-1	Estimation 9-2	Estimation 9-3	Estimation 9-4	Estimation 9-5	Estimation 9-6	Estimation 9-7	Estimation 9-8
	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect
invHerf $_{t-1}$	1.8143 ***	4.6335 ***	1.8809 ***	4.5867 ***	0.3913	3.5906 ***	0.4331	3.5156 ***
(Competition)	4.06	7.95	4.21	7.87	0.91	6.12	1.00	6.02
invHerf^2 $_{t-1}$	-94.0949 ***	-140.2075 ***	-94.9160 ***	-139.8568 ***	-71.1866 ***	-120.7221 ***	-71.5838 ***	-120.1100 ***
(Competition)	-14.43	-15.48	-14.56	-15.47	-10.95	-13.44	-11.02	-13.43
Tgap $_{t-1}$	9.78E-01 ***	7.69E-01 ***	9.89E-01 ***	7.36E-01 ***	1.00E+00 ***	7.93E-01 ***	1.02E+00 ***	7.58E-01 ***
(Technology gap with frontier firm)	64.01	44.01	52.90	33.53	61.83	43.36	53.37	33.11
Tgap$_{t-1}$*reg $_{t-1}$			-2.11E-02	1.12E-01 ***			-3.72E-02 *	1.05E-01 ***
(Complementarity with regulation)			-0.93	3.32			-1.66	3.11
reg $_{t-1}$			-1.64E-05	-2.66E-02 ***			-1.26E-04	-2.65E-02 ***
(Regulation)			0.00	-4.24			-0.03	-4.24
Technology Gap$_{t-1}$*FDI $_{t-1}$					-2.54E-02	-1.83E-02 *	-2.78E-02	-1.32E-02
(Complementarity with foreign direct investment)					-1.15	-1.78	-1.26	-1.28
FDI $_{t-1}$					-0.0448 ***	-0.0353 ***	-0.0451 ***	-0.0366 ***
(Foreign firm participation ratio in the industry)					-6.54	-7.81	-6.62	-8.08
IMP $_{t-2}$	0.0380	0.0128 ***	0.0362	0.0142 ***	0.0303	0.0093 ***	0.0270	0.0098 ***
(International competition)	1.71	0.60	1.61	0.66	1.35	0.43	1.20	0.46
ln(SIZE) $_{t-1}$	0.0094	0.0160	0.0098	0.0167	0.0086	0.0165	0.0094	0.0172
(Lagged employment)	1.43	2.77	1.50	2.90	1.32	2.87	1.45	3.00
ln(AGE) $_{t-1}$	0.0022 *	-0.0212	0.0022	-0.0228	0.0014	-0.0245	0.0014	-0.0268
(Lagged firm age)	0.56	-1.20	0.56	-1.28	0.37	-1.36	0.37	-1.47
FO $_t$	-0.0095	-0.0052	-0.0094	-0.0050	-0.0076	-0.0028	-0.0075	-0.0025
(Foreign ownership dummy)	-0.86	-0.32	-0.85	-0.30	-0.67	-0.17	-0.66	-0.15
Constant $_t$	-0.2582 ***	-0.1481 *	-0.2611 ***	-0.1326 *	-0.1632 ***	-0.0861	-0.1664 ***	-0.0684
	-4.42	-1.89	-4.45	-1.68	-3.09	-1.11	-3.13	-0.88
Year	year<2000	year>=2000	year<2000	year>=2000	year<2000	year>=2000	year<2000	year>=2000
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	26,379	32,854	26,344	32,806	26,344	32,806	26,344	32,806
Number of groups	10,404	10,588	10,378	10,565	10,378	10,565	10,378	10,565
F value	98.5352	72.3819	94.8195	73.0810	101.8135	73.6775	98.4009	74.4843
R^2 overall	0.1117	0.1421	0.1120	0.1430	0.1129	0.1452	0.1133	0.1457
R^2 within	0.3485	0.3673	0.3488	0.3688	0.3570	0.3746	0.3573	0.3758
R^2 between	0.1234	0.1482	0.1241	0.1499	0.1194	0.1485	0.1198	0.1486

i) ***, **, * indicate significance at the 1%, 5%, and 10% level respectively.