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Competition and Innovation: An inverted-U relationship using Japanese industry data

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Abstract

This study replicates a model of Aghion et al. ("Competition and Innovation: An inverted-u relationship," *Quarterly Journal of Economics* 2005; 120(2):701-728), which suggests that an inverted-U relationship exists between competition and innovation. We apply patent data and a competition measure based on Japanese firm-level and industry-average data from 1964 to 2006. In a constant slope model using a full dataset, we find the same inverted-U relationship as did Aghion-Bloom-Blundell-Griffith-Howitt (ABBGH). In decade and industry fixed-effects slope models, we find the inverted-U relationship to be fragile.

Keywords: Competition; Innovation; Patent; Inverted-U relationship; Endogeneity;
JEL classification: O31, L00, O25

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1. Introduction

Understanding the relationship between competition and innovation has long been a major focus of industrial organization both theoretically and empirically (Cohen, 2010). Schumpeter (1934) argued that more monopolistic firms can more readily perform R&D activities because of reduced market uncertainty and more stable funding. Since then, many studies have examined the so-called Schumpeterian hypotheses that innovation activity is promoted by large firms and by imperfect competition (Kamien and Schwartz, 1975; Acs and Audretsch, 1987).

The former Schumpeterian hypothesis that innovation activity is promoted by large firms is mainly supported in the literature. Many previous studies mainly found a positive relationship although it is unclear whether the positive relationship is more or less proportional to the firm size (Acs and Audretsch, 1988a,1988b; Cohen and Klepper, 1996). In particular, many studies in the literature have shown that the amount of R&D conducted by performers are closely related to the size of the firm, while R&D productivity declines with firm size (Cohen and Klepper, 1996).

On the other hand, the latter Schumpeterian hypothesis that innovation activity is promoted by imperfect competitionhas been inconclusive. Many empirical studies, in which a market concentration measure is often used as a competition measure, show a positive relationship between competition and innovation (i.e., more competition is associated with more innovation) (Acs and Audretsch, 1988a, 1988b; Blundell *et al*., 1995).

Aghion *et al*. (2005), hereafter ABBGH, build a stylized model to support an inverted-U pattern between product market competition and innovation. ABBGH also empirically support this pattern using UK industry data (seventeen industries over the period 1973 to 1994) using price-cost margin (PCM) measure as a competition measure.

However, prior empirical studies to test for the inverted-U relationship have been inconclusive. Tingvall and Poldahl (2006) test the inverted-U relationship using Swedish manufacturing firms data from 1990 to 2000. They use firm-level R&D data as an innovation measure and the Herfindahl-Hirschman Index (HHI) and PCM as competition measures. Their results show that the inverted-U relationship is supported by the HHI but not by the PCM.

Technology gap spread hypothesis in ABBGH which suggests technology gap increases with competition is supported both by HHI and by PCM. In addition, according a complementarity between the degree of neck-and-neckness and competition ABBGH suggest, the effect of interaction between HHI and technology neck-and-neckness makes the inverted-U relationship sharpened. When using the PCM, however, they do not find any support for complementarities between the degree of neck-and-neckness and competition on R&D.

Correa (2012) analyzes how the establishment of the United States Court of Appeals for the Federal Circuit in 1982 has affected the relationship between innovation and competition in ABBGH. He finds a structural break in the early 1980s, using the same dataset as ABBGH. He argues, taking this break into consideration, the inverted-U empirical relationship found by ABBGH does not hold.

The purpose of our study is to replicate ABBGH and analyze the robustness of ABBGH using larger dataset and applying most comprehensive set of variables.[1] In this study, we use Japanese firm-level and industry-average data with sixty industries over the period 1964 to 2006.

In a constant slope model using full dataset, we find the same inverted-U relationship as ABBGH do. In decade and industry fixed-effects slope models, we find the inverted-U relationship is easy to be fragile. Then, we also check technology gap spread prediction of ABBGH, and this prediction holds in this study. Finally, controlling for endogeneity between competition and innovation using source weighted real exchange rates as instrument variables (IVs), we find also the inverted-U seems fragile.

The rest of the paper is structured as follows. Section 2 discusses the model of ABBGH and our empirical strategy for the robustness of ABBGH. Section 3 shows the data used in our estimation. Section 4 presents our estimation results. Section 5 concludes.

2. Model and empirical strategy for checking the robustness of ABBGH

[1] Studies related to innovation study in Japan include Ijichi et al. (2004, 2010), Inui et al. (2012) and Motohashi (2012). Ijichi et al. (2004, 2010) carry out a questionnaire survey about innovation activities towards Japanese firms in industry sectors. Inui et al. (2012) examine the test of inverted-U relationship between total factor productivity and 1−*Lerner index*, using Japanese firm data. Motohashi (2012) examines the relationship between firms' enter and exit and innovation activity.

In this study we test three major hypotheses: the inverted-U hypothesis, technological spread predictions, and a possible endogeneity of competition. First, we analyze the inverted-U hypothesis using ordinary least squares (OLS) and within estimator. The reason why we do not use count data model is because patent variables in this study are not count data. We also estimate decade and industry fixed-effects slopes using interaction terms in order to check the robustness whether the inverted-U relationship is detected in each slope.

2.1 Model in this study

Following ABBGH and Correa (2012), the conditional citation weighted patents p_{jt} follow a Poisson regression:

$$p_{jt} = \exp\left\{\beta_0 + \beta_1 c_{jt} + \beta_2 c_{jt}^2 + \phi\hat{\upsilon}_{jt} + \sum_{j=1}^{17}\alpha_j D_j + \sum_{t=1973}^{1994}\gamma_t D_t + u_{jt}\right\} \tag{1}$$

where c_{jt} is 1 minus the Lerner Index (competition index) in industry j at time t, $\hat{\upsilon}$ denotes the vector of residuals from OLS regression of competition index on policy and foreign-industry instruments, and the sums represent industry and time fixed effects.

In this study we also estimate citation weighted patents p_{it} at firm level, following Tingval and Poldahl (2006). This is because industry classification is often inappropriate to classify certain firms. This is also because, although competition is easily thought of as an industry property, firms in same industry often try to create their own segment to profile their product and escape competition.

In this study we regress competition variable on patent variable at firm and industry level, using OLS and within estimator (i.e., a fixed-effects model) as follows:

$$\ln p_{it} = \beta_0 + \beta_1 c_{it} + \beta_2 c_{it}^2 + \sum_{t=1965}^{2006}\gamma_t D_t + \alpha_i + u_{it} \tag{2}$$

where i denotes firm or industry. In order to test inverted-U curve is robust in each decade and each industry, we also estimate a fixed-effects slope model as follows:

$$\ln p_{it} = \beta_0 + \beta_1 c_{it} + \beta_k D_k c_{it} + \gamma_1 c_{it}^2 + \gamma_k D_k c_{it}^2 + \sum_{t=1965}^{2006}\lambda_t D_t + \alpha_i + u_{it}, k = 2...J \tag{3}$$

where k denotes each decade or each industry except for base decade or base industry to avoid multi-collinearity.

We combine main effect (base) and each fixed-effects coefficient, and refer to it as combined coefficient (e.g., in equation (3), combined coefficient of c_{it} where k = 2 is (β_1+β_2)c_{it}). We also make standard error of the combine coefficient using a square root of the sum of variances and covariances in each coefficient. We test whether each slope makes inverted-U shape using an inverted-U test as described below.

2.2 Inverted-U test

The inverted-U hypothesis in this study is tested by the inverted-U test following Lind and Mehlum (2010). A general formulation of linear regression model, which includes a quadratic or an inverse term, is as follows

$$y_i = \alpha + \beta x_i + \gamma f\left(x_i\right) + \xi z_i + \varepsilon_i,\ \ i = 1,...,n \tag{4}$$

where x is the explanatory variable of main interest whereas y is the variable to be explained, ε is an error term, and z is a vector of control variables. Given equation (2) and the assumption of only one extremum point, the requirement for an inverted-U shape is that a slope of the curve is positive at the start and negative at the end of a reasonably chosen interval of x-values [xl, xh]. Then an inverted-U shape is implied by the conditions as follows:

$$\beta + \gamma f'\left(x_h\right) < 0 < \beta + \gamma f'\left(x_l\right) \tag{5}$$

Then, a test of conditions in equation (5) at the α-level of confidence is equivalent to the null hypotheses H_0^L and H_0^H of the two standard one-sided tests,

$$H_0^L : \beta + \gamma f'\left(x_l\right) \le 0 \text{ vs. } H_1^L : \beta + \gamma f'\left(x_l\right) > 0 \tag{6}$$

$$H_0^H : \beta + \gamma f'\left(x_h\right) \ge 0 \text{ vs. } H_1^H : \beta + \gamma f'\left(x_h\right) < 0\,. \tag{7}$$

A (1−2α) confidence interval for a extremum point (i.e., $-\hat{\beta}/\hat{\gamma}) - \hat{\beta}/\hat{\gamma}$ is given by $\left[\hat{\theta}_l, \hat{\theta}_h\right]$ as defined in equations (6) and (7) as follows:

$$f'(x_l) < \hat{\theta}_l \equiv \frac{s_{12}t_\alpha^2 - \hat{\beta}\hat{\gamma} - t_\alpha\sqrt{(s_{12}^2 - s_{22}s_{11})t_\alpha^2 + \hat{\gamma}^2 s_{11} + \hat{\beta}^2 s_{22} - 2s_{12}\hat{\beta}\hat{\gamma}}}{\hat{\gamma}^2 - s_{22}t_\alpha^2}, \tag{8}$$

$$f'(x_h) > \hat{\theta}_h \equiv \frac{s_{12}t_\alpha^2 - \hat{\beta}\hat{\gamma} + t_\alpha\sqrt{(s_{12}^2 - s_{22}s_{11})t_\alpha^2 + \hat{\gamma}^2 s_{11} + \hat{\beta}^2 s_{22} - 2s_{12}\hat{\beta}\hat{\gamma}}}{\hat{\gamma}^2 - s_{22}t_\alpha^2}, \tag{9}$$

where $\hat{\theta}_l$ and $\hat{\theta}_h$ are the roots of the same quadratic equation.

2.3 Technological gap spread hypothesis and instrument variables estimation

We test technological gap spread prediction in ABBGH (i.e., proposition 4). This states "in equilibrium, the average technology gap between leaders and followers should be an increasing function of the overall level of industry wide competition (ABBGH, p.718)." This is tested by regressing the firm-level and industry-average technology gap on the Lerner index with year dummies using OLS and within estimator.

Using interaction terms of competition and technology gap as well as ABBGH, we also try to replicate the proposition 5 in ABBGH. That is, "the peak of the inverted U is larger, and occurs at a higher degree of competition, in more neck-and-neck industries (ABBGH, p.717)." ABBGH support two empirical findings about the proposition 5 (ABBGH, p.719); (1) more neck-and-neck industries show a higher level of innovation activity for any level of product market competition, and (2) the inverted-U curve is steeper for the more neck-and-neck industries.

To test the proposition 5 in ABBGH, a model in this study and ABBGH is as follows:

$$\ln p_{it} = \beta_0 + \beta_1 c_{it} + \beta_2 c_{it}^2 + \gamma_1 c_{it} m_{it} + \gamma_2 c_{it}^2 m_{it} + \sum_{t=1965}^{2006} \lambda_t D_t + \alpha_i + u_{it} \tag{10}$$

where *m* denote technology gap as described in following section, and *m* takes a positive value. In this study, we regard a slope of c_{it} and c_{it}^2 as a baseline, and first test whether the baseline is inverted-U curve. We next check whether γ_2 is significantly negative in order to check whether the inverted-U curve is steeper in more neck-and-neck industries than baseline. When γ_2 is negative, the inverted-U curve get steeper in neck-and-neck firms or industries because *m* takes a positive value.

In addition, we study the robustness of the inverted-U curve by considering the endogeneity between competition and innovation, using two-stage least squares (2SLS) and within 2SLS. Along with a full set of year dummies, we use source-weighted real exchange rate (see Bertrand (2004)) as instrument variables (IVs). We make two kinds of the source-weighted real exchange rates, which are in advanced economies defined by IMF and in the other countries.

It is noted that there are missing values of technology gap and the instrument variables due to limitations of available data. Therefore, when testing the second and third instruments above, the subsample size decreases from the entire sample size.

3. Data

The data for this study consists of Japanese firm and industry-average data, patent data, and the source-weighted real exchange rate (Appendix Table A1 presents descriptive statistics of data in this study). The firm and industry-average data come from the Nikkei NEEDS database by Nikkei Inc. The patent data are obtained from the Institute of Intellectual Property (IIP) (see Goto and Motohashi (2007) for detail). In regard to the source-weighted real exchange rate, local currency and consumer price index (CPI) are obtained from the World Bank Database (http://data.worldbank.org) and Eurostat (http://ec.europa.eu/eurostat), and industry import data is obtained from the Japan Industrial Productivity Database (JIP) 2011 (see Fukao *et al*., 2007).

3-1. Firm and Industry data

Japanese firm and industry-average data are based on non-consolidated financial statements. The entire sample has 95,544 firm-level observations from 1964 to 2006, and 2,580 industry-average observations. We grouped the industry-level data into 60 industries in accordance with the JIP Sector Classification (Appendix Table A2).

3-2. Patents

For this study, we construct three types of patent data from 1964 to 2006 from the IIP database. First, we match the firm data with a patent assignee list from the IIP database. Then, we cover changes in business names and head office addresses for all of the samples from investor relations and financial reports, among others. Consequently, we match the business names with the assignee name found in a database. Some characters in the list are occasionally wrong, probably due to the degree of accuracy of optical character recognition; hence, we re-check the matched list for errors.

We organize two types of patent data. One of the patent variables is the number of patent applications, which is simply counted by applicant year. We divide the patent applications by joint applications, and by patent application index standardized in 1971 to control joint application effect and application inflation effect as follows:

$$Pat_{i,t} = \sum_n \left(\frac{\text{Patent application}_{n,i,t}}{\text{Joint application}_{n,i,t}} \right) \cdot \frac{\text{Total patent application}_t}{\text{Total patent application}_{1971}} \qquad (11)$$

where n, i, and t denote respectively each application, each firm, and application year.

Another patent variable is citation weighted patent application. Because there is a truncation problem when raw citation count data is used, we use quasi-structural approach in Hall et al. (2001) to control citing and cited year effects, and obsolescence and diffusion effect. First, we estimate these above effects using full patent dataset of IIP database in the follow model:

$$\log\left[C_{kst} / P_{ks}\right] = \alpha_0 + \alpha_s + \alpha_t + \alpha_k + \exp\left(-\beta_{1k} L\right) / \left(1 - \exp\left(-\beta_{2k}\right)\right) \qquad (12)$$

where C and P denote respectively the total number of raw citation count and raw patent applications, and s, t, and L denote respectively applicant year of citing patent, applicant year of cited patent, and lagged year between applicant year of citing patent and cited patent. $\exp(\exp(-\beta_1 L)\cdot(1-\beta_2))$ denotes probability density function of the citation-lag distribution in each L, and we impose the constraint over L (L=0...46) is unity. Second, we divide raw citation count data by these parameters following Hall et al. (2001) as follows:

$$Cite_{i,s} = \sum_t \sum_k \left(\frac{\sum_n \left(RawCite_{i,s,t,k,n} \big/ \text{Joint application of cited patent}_{i,n,s} \cdot \frac{\text{Total patent application}_s}{\text{Total patent application}_{1971}} \right)}{\exp\left(\alpha_s \cdot \alpha_t \cdot \alpha_k\right) \cdot \exp\left(\exp\left(-\beta_{1k}(t-s)\right) \big/ \left(1 - \exp\left(-\beta_{2k}\right)\right)\right)} \right) \qquad (13)$$

where i denotes each firm. Appendix A3.1 and A3.2 shows the estimated result in equation (12).

When Pat and Cite take 0, we substitute 0.0001.

3-3. Market competition measures

We use the PCM measure as a market competition measure for this study.[2,3] ABBGH suggest a PCM (denoted by *li*) and *1− industry average Lerner Index* (denoted by *1−L*) as follows:

$$li_{it} = \frac{\text{operating profit}_{it} - \text{financial cost}_{it}}{\text{sales}_{it}}, \tag{14}$$

$$1 - L_{jt} = 1 - \frac{1}{N_{jt}} \sum_{i \in j} li_{it} \tag{15}$$

where i, j, and t index firms, industry, and time, and N_{jt} is the number of firms in industry j in year t. We use non-operating expenditure as the financial cost.

In a firm-level regression, we use *1−li* as well as Tingvall and Poldahl (2006). At firm level we assume each firm would have each market and face each market competition even if within the same industry. In addition, we use 0.5-99.5th percentile of *1−li* because *1−li* usually takes a value from 0 to 1, but takes a value from 0.01 to 679 in this study. The 0.5-99.5th percentile of *1−li* takes a value from 0.641 to 1.394, and median of the 0.5-99.5th percentile is 0.973. *1−L* (at industry average) takes a value from 0.841 to 1.135. Figure 1 shows scatter plots of *Pat, Cited* and the number of firms (histogram) towards *1−li*.

3-4. TFP and the technology gap

Following ABBGH, the technology gap at firm level for this study is:

$$m_{it} = \left(TFP_{Ft} - TFP_{it}\right) / TFP_{Ft} \tag{16}$$

where F denotes the frontier firm, which has the highest total factor productivity (TFP) for each industry, and i denotes each firm. At industly level we use industry average value of m_{it}.

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[2] Generally, Lerner index is defined as $(P-MC)/P$ where P and MC denote respectively price and marginal cost. However, the marginal cost is hardly observed as empirical data.

[3] HHI is another market competition measure. Because we have only sample data of Japanese firms, however, we could not identify all or typical (e.g. top 10) firm's share in each industry and could not make HHI.

We measure TFP from 1970 to 2006 using a first order approximation of Cobb-Douglas, not assuming linear homogeneous production function. We measure capital, labor, and intermediate goods shares for each industry by a log-log regression model controlling firm and year fixed effects. Using the estimated capital, labor, and intermediate goods shares, we estimate TFP and m_{it} of each firm.

For our output variable, we use sales divided by industry output deflator which is calculated from dataset of JIP2011. For a labor variables, we use the number of regular employees. For a capital variables, we use capital stock estimated by perpetual inventory method. An initial value of capital stock for a base year is estimated by a nominal value of fixed physical capital divided by industry investment deflator from dataset of JIP2011. The base year is 1970, or is the next old year when there is missing value in 1970. Capital investment variable are a decrease or increase in nominal depreciable fixed physical capital and a nominal depreciation cost, which are divided by industry investment deflator. We use a depreciation rate as 8.67%, which is the average depreciation rate of each depreciable fixed physical capital in Hayashi and Inoue (1991).

For an intermediate good variable, we use sales cost plus sales administrative expense, excluding total wage and depreciation cost. The intermediate good variable is divided by the industry intermediate good deflator from JIP2011.

3-5. Instrument variables

As IVs, we use the source-weighted real exchange rate between 1980 and 2006 from JIP2011, World Bank database, and Eurostat. Following Bertrand (2004), we use the source-weighted real exchange rate (*XRI*) movements to generate exogenous variation in the level of import penetration by industry, and *XRI* in this study is as follows:

$$XR_{j,t} = \sum_i \left(LCU_{i,t} \cdot \frac{CPIJ_t}{CPI_{i,t}} \cdot \frac{IMP_{j,i,t}}{\sum_i IMP_{j,i,t}} \right), \quad (17)$$

$$XRI_{j,t} = \frac{XR_{j,t}}{XR_{j,2005}} \quad (18)$$

where *i*, *j*, and *t* denote each country, each industry, and year, respectively. *LCU* denotes local currency unit in JPY. *CPI* and *CPIJ* denote consumer price index of each country and Japan, respectively. *IMP* denotes volume of imports from each country toward each industry in Japan.

Compared to nominal local currency, this real exchange rate removes three kinds of effects. First, consumer price inflation is adjusted by multiplying each local currency per yen by consumer price index (CPI) in Japan divided by CPI in each country. Second, the CPI-adjusted exchange rate is weighted by import share from each country in each industry (where import share data is from JIP2011). Third, the source-weighted exchange rate is divided by the rate in 2005 to be standardized. An increase of this exchange rate in certain industry means the substantive rise in the value of the yen in the industry. We make two kinds of this exchange rate, which are in advanced economies defined by IMF in 2013, and in the other countries. Appendix A4 shows the country list used in making the source-weighted real exchange rate in this study.

4. Results

4.1 Inverted-U test

We test the inverted-U relationship between $1-li$ and $1-L$, and patent in constant slope and fixed-effects slope models using OLS and within estimator at firm level (Table 1.1) and at industry level (Table 1.2). At firm level the inverted-U tests are all statistically significant. On the other hand, We find the same inverted-U curve, but the inverted-U curve is not observed at industry level when considering industry fixed effects. At industry level, the inverted-U curve is observed only in entire sample without considering industry fixed effects (columns 1 and 2 in Table 1.2). The extremum point of the inverted-U curve is about 1.00, and the 90% confidence interval are about from 0.95 to 1.05.

We next examine whether the inverted-U relationship is robust at firm level in a model in which inverted-U slope varies in each decade (Table 2.1 and 2.2) or each industry (Table 3). In a decade fixed-effects slope model (Table 2.1 and 2.2), without considering the fixed-effects intercept of each firm (columns 1 and 2), inverted-U curves are significant both in entire sample and manufacturing industries in all of each decade except for 1960s. On the other hand, when controlling the fixed-effects intercept of each firm (columns 3 and 4), inverted-U curves are significant only in 1970s, 1980s and 1990s.

Tables 3 shows result of inverted-U tests in a industry fixed-effects slopes model in entire sample (Appendix Table A5 shows the detailed result of Table 3). Without considering the fixed-effects intercept of each firm (columns 1 and 2), inverted-U curves are statistically significant in 15 of 41 manufacturing industries and in 4 of 19 non-manufacturing industries. On the other hand, when controlling the fixed-effects intercept of each firm (columns 3 and 4), the inverted-U curves are not statistically significant except one of the service industries (i.e., #07:mining industry). We find the inverted-U curve seems robust when considering a constant slope using panel data of multiple industries with some decade, but is easy to be fragile when considering fixed-effects slopes of each decade or each industry.

In addition, we regress Pat and Cite on *1−li* in order to check *1−Lerner index* semi-elasticities (Table 4) using a following model:

$$\ln p_{it} = \beta_0 + \beta_1 c_{it} + \beta_k D_k c_{it} + \sum_{t=1965}^{2006} \lambda_t D_t + \alpha_i + u_{it}, k = 2...I \quad (19)$$

We refer to combined coefficient of c_{it} as *1−Lerner index* semi-elasticity. Without considering the fixed-effects intercept of each firm (columns 1 and 2 in Table 4), median of Lerner index semi-elasticity of Pat and Cite is 0.274 and −0.270, respectively. It means that an increase in *1−Lerner index* by 0.01 (1%) is correlated with 0.00274% and −0.0027% increases of Pat and Cite, respectively. On the other hand, when controlling firm fixed effects (columns 3 and 4 in Table 4), median of Lerner index semi-elasticity of Pat and Cite is 0.375 and 0.027, respectively. Medians of Lerner index semi-elasticity of Pat and Cite are 0.902 and 0.759, respectively, in manufacturing industries, and −1.514 and −1.346, respectively in non-manufacturing industries.

4.2 Test of technology gap spread hypothesis

In ABBGH, there are two kinds of innovation intensities for neck-and-neck firms (i.e., technology levels are neck-and-neck in industries) and for unleveled firms (i.e., follower firms), and the composition effect of the two intensities makes the inverted-U curve at industry level (proposition 1, 2, and 3). We check the propositions, dividing the entire sample into neck-and-neck firms (i.e., firms with above median technological gap) and unleveled firms (i.e., firms with above median technological gap). Without considering the fixed-effects intercept of each firm (columns 1, 2, 5, and 6 in Table 5), the inverted-U curves are all statistically significant. On the other hand, when controlling the fixed-effects intercept of each firm (columns 3, 4, 7, and 8), the inverted-U curve is statistically significant only in neck-and-neck firms.

Columns 1 and 2 of Table 6 shows TFP gap elasticities of Pat and Cite using within estimator. TFP gap elasticities of Pat and Cite are −0.333 and −0.507, respectively. It means an 0.01 increase in TFP gap of each firm within each industries is related to 0.00333% and 0.00507% decreases in Pat and Cite, respectively.

Table 6 also shows the test of the technology gap spread prediction (i.e., the proposition 4 in ABBGH). It reports the results from regressing firm-level or industry-average technology gap on the Lerner index with a full set of year dummies (Columns 3 and 5) and a full set of year and firm or industry dummies (Columns 4 and 6). At the firm level there is a significantly positive coefficient (Columns 3 and 4). On the other hand, at the industry level there is a significantly negative coefficient in Column 5, but is a positive significant relationship in Column 6. In our sample, when controlling fixed effects, the proposition 4 in ABBGH holds both at the firm level and industry-average level.

Tables 7.1 and 7.2 show the replicative result of proposition 5 in ABBGH, using interaction terms between 1−Lerner Index and TFP gap. At firm level, the baseline curve is inverted-U in a statistically significant way using OLS (columns 1 and 2 in Table 7.1), but not inverted-U using within estimator (columns 3 and 4). Then, because coefficient of $(1-li)^2 \cdot m_{it}$ is positively significant, the inverted-U curve is not steeper in the neck-and-neck firms than baseline (columns 1 and 2 in Table 7.1).

On the other hand, at industry level, the baseline curve is inverted-U in a statistically significant way only using ln*Cite* as a dependent variable (columns 2 and 4 in Table 7.2). Then, because coefficient of $(1-li)^2 \cdot m_{it}$ is positively significant in column 3 (OLS), and negatively significant in column 4 (within estimator), the inverted-U curve is not steeper in column 3 and steeper in column 4 in neck-and-neck industries than baseline.

In addition, we find the effect of interaction term between TFP gap and competition on Pat and Cite often turns over within the range of competition in an unstable way. For example, in industry-level regressions using lnCite as a dependent variable, the interaction terms between TFP gap and competition have a negative effect on Cite in [0.683, 1.101] and [0.954, 1.176], and a positive effect on Cite in [1.101, 1.176] and [0.683, 0.954] in columns 3 and 4 in Table 6.2, respectively.

4.3 Instrument variables estimation

We check whether the inverted-U will be detected when control endogeneity between competition and Lerner index using 2SLS and within 2SLS. Because we could make the real exchange rate only between 1980 to 2006 in certain industries, sub-sample size decreases to 37,958.

Table 7.1 and 7.2 show results of regressions and second stage of (within) 2SLS at firm level (Table 7.3 show result of first stage of 2SLS). First, using OLS without considering firm fixed-effects (in columns 1 and 3 of Table 7.1), we find the same inverted-U relationship using OLS in sub-sample. On the other hand, in second stage of 2SLS (in columns 2 and 4 of Table 7.1), the inverted-U curve is not statistically significant, and there is a negative relationship between 1−L and Pat and Cite. Second, using within estimator in this sub-sample (in columns 1 and 3 of Table 7.2), the inverted-U curve is not statistically significant. Using the sub-sample in second stage of within 2SLS (in columns 2 and 4 of Table 7.2), the inverted-U curve is not also statistically significant, and there is a negative relationship between *1−Lerner index* and Pat (and Cite).

5. Conclusions

In this study we examine the robustness of ABBGH, which suggest an inverted-U relationship exists between competition and innovation. In a constant slope model using full dataset, we find the same inverted-U relationship as ABBGH do. On the other hand, in a fixed-effects slope model of each decade or each industry, inverted-U relationship could not be observed. When considering the endogeneity using the source-weighted real exchange rates as IVs, inverted-U is not observed. In addition, the technology gap spread hypothesis that expected technology gap increases with competition holds in this study. However, the interaction terms between competition and technology gap does not make the inverted-U relationship sharpened in this study. The effect of the interaction terms is often changed from positive to negative, or from negative to positive in the range of competition variable.

Our study and ABBGH show that when using several tens of industry data in several decades, the relationship between profit rate and innovation propensity seems inverted-U. It seems to suggest that firms or industries with low profit rate promote innovative activity because the extremum point of the inverted-U curve is near 1 in the *1−Lerner index*. The inverted-U relationship is often fragile, however, when considering the slope of inverted-U curve varies in each decade or especially in each industry.

In manufacturing industries, when considering the fixed-effects slope of each industry and intercepts of each firm, the competition does often not affect innovation activity in a statistically significant way. The fixed-effects intercept is interpreted as technological opportunities in the literature (see Cohen (2010)). On the other hand, in non-manufacturing industries, when considering the fixed-effects slope of each industry and intercepts of each firm, firms with high profit rate often promote innovative activities (i.e., the median of *1−Lernear Index* semi-elasticity of patent variables is about −1.5 in this study).

When it comes to competition policy, neck-and-neck industry (i.e., the technical gap is narrow in each firm) seems to promote innovative activity. A 1% decrease in TFP gap is correlated with a 0.3% increase in patent applications in this study (Table 5). However, competition policy which makes inefficient firms to withdrawal from market should be carefully considered before it is implemented, following the literature. In the literature firm size is often positively correlated with R&D propensity, but negatively correlated with R&D productivity (Cohen and Klepper, 1996). Therefore, even if existing firms would get large in the market, innovation activities might be promoted by an increase in the number of firms rather than an increase in the size of each firm. This comparison is one of the remaining issues in the future study, and another remaining issue is that how follower firms act in each industry when a frontier firm develops its own technological capability.

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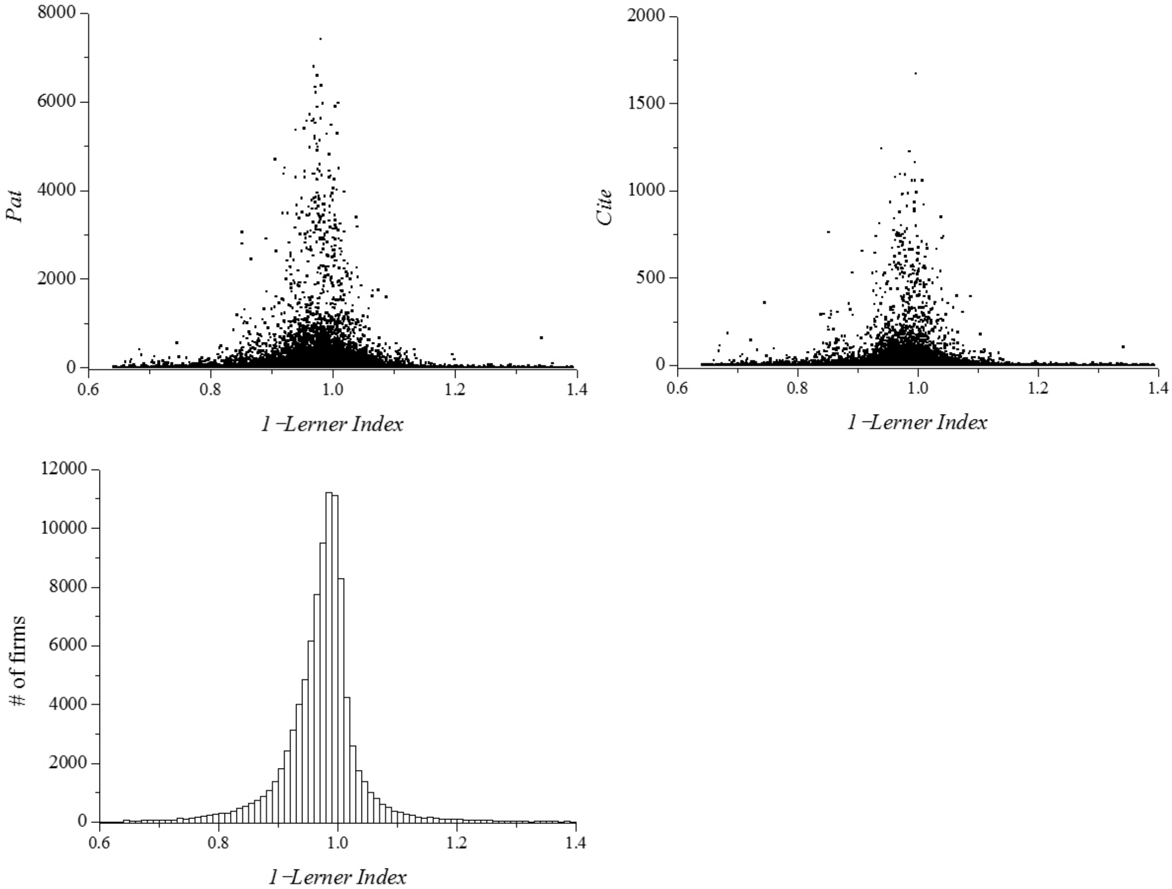

Figure 1. Scatter plots of the number of patent application and cited weighted patents, and histogram of the number of firms (0.01 interval) towards 1−*Lerner index*

Table 1.1 Inverted-U test in entire sample and manufacturing industries at firm level

Entire sample	1	2	3	4
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	OLS	OLS	within	Within
	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)
1−li	50.735***	48.150***	6.192***	7.498***
	(2.308)	(2.412)	(1.590)	(1.775)
$(1-li)^2$	−25.927***	−24.766***	−3.095***	−3.754***
	(1.183)	(1.236)	(0.792)	(0.884)
Constant	−28.693***	−30.649***	−8.43***	−12.226***
	(1.139)	(1.190)	(0.803)	(0.896)
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	94510	94510	94510	94510
Group			3459	3459
Year	64−06	64−06	64−06	64−06
Adj−R2	0.020	0.039		
Within R2			0.161	0.205
Inverted U test	−21.003***	19.317***	3.777***	−4.085***
	Inverted-U	Inverted-U	Inverted-U	Inverted-U
Extremum point	0.978	0.972	1.000	0.999
90% confidence interval	[0.970, 0.987]	[0.962, 0.981]	[0.943, 1.058]	[0.947, 1.050]

Manufacturing Industries	5	6	7	8
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	OLS	OLS	within	within
	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)
1−li	55.255***	56.265***	14.493***	16.233***
	(3.225)	(3.567)	(2.359)	(2.702)
$(1-li)^2$	−29.925***	−30.623***	−6.938***	−7.880***
	(1.628)	(1.801)	(1.166)	(1.335)
constant	−28.277***	−32.280***	−10.715***	−15.293***
	(1.609)	(1.779)	(1.195)	(1.368)
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	55062	55062	55062	55062
Group			1691	1691
Year	64−06	64−06	64−06	64−06
Adj−R2	0.073	0.109		
Within R2			0.1992	0.270
Inverted U test	14.546***	13.240***	−5.233***	−5.404***
	Inverted-U	Inverted-U	Inverted-U	Inverted-U
Extremum point	0.923	0.919	1.044	1.030
90% confidence interval	[0.911, 0.934]	[0.905, 0.931]	[1.014, 1.084]	[1.000, 1.067]

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Table 1.2 Inverted-U test in entire sample and manufacturing industries at industry level

Entire sample	1	2	3	4
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	OLS	OLS	within	Within
	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)
$I-L$	114.460**	261.885***	−126.091***	33.344
	(65.830)	(60.989)	(33.559)	(26.354)
$(I-L)^2$	−72.615**	−134.641***	62.880***	−20.098
	(−2.15)	(31.336)	(17.093)	(13.423)
Constant	−72.115**	−130.536***	62.643***	−16.783
	(−2.25)	(29.679)	(16.475)	(12.938)
Year dummy	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	Yes	Yes
Obs	2580	2580	2580	2580
Group			60	60
Year	64−06	64−06	64−06	64−06
Adj−R2	0.0187	0.1681		
Within R2			0.1669	0.6073
Inverted U test	−1.888*	−4.24***	−	0.730
	Inverted-U	Inverted-U		
Extremum point	0.995	0.973		
90% confidence interval	[0.962, 1.249]	[0.955, 0.990]		

Manufacturing Industries	5	6	7	8
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	OLS	OLS	within	Within
	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)
$I-L$	−111.582**	−73.433	−31.089	−14.454
	(53.656)	(57.493)	(23.887)	(26.430)
$(I-L)^2$	55.256**	36.121	15.233	6.662
	(27.451)	(29.414)	(12.108)	(13.397)
constant	58.856**	38.139	18.510	8.700
	(26.207)	(28.081)	(11.773)	(13.026)
Year dummy	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	Yes	Yes
Obs	1517	1517	1517	1517
Group			41	41
Year	64−06	64−06	64−06	64−06
Adj−R2	−0.0052	0.1852		
Within R2			0.1101	0.6717
Inverted U test	−	−	−	−

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Table 2.1 Inverted–U test of Fixed–effects Slopes of each decade at firm level in entire sample

	Entire sample	1	2	3	4
	Dep.	lnPat	lnCite	lnPat	lnCite
	Procedure	OLS	OLS	within	within
Period		Combined	Combined	Combined	Combined
		Coef.	Coef.	Coef.	Coef.
1960s	$1-li$	28.199***	20.590**	−16.486***	−17.857***
		(9.157)	(9.570)	(5.058)	(5.643)
	$(1-li)^2$	−17.372***	−12.858***	10.754***	12.327***
		(4.668)	(4.879)	(2.586)	(2.885)
1970s	$1-li$	43.573***	41.219***	12.779***	15.103***
		(5.599)	(5.851)	(3.112)	(3.472)
	$(1-li)^2$	−22.958***	−21.708**	−5.165***	−6.023**
		(2.779)	(8.438)	(1.539)	(2.947)
1980s	$1-li$	62.097***	61.424***	23.701***	26.935***
		(5.920)	(6.186)	(3.372)	(3.762)
	$(1-li)^2$	−33.085***	−33.277***	−11.683***	−13.553***
		(3.059)	(10.218)	(1.727)	(3.710)
1990s	$1-li$	56.243***	56.969***	12.163***	14.318***
		(4.714)	(4.927)	(2.810)	(3.135)
	$(1-li)^2$	−27.242***	−27.941***	−6.519***	−7.998***
		(2.416)	(6.375)	(1.415)	(2.494)
2000s	$1-li$	45.782***	42.098***	0.684	0.167
		(3.933)	(4.111)	(2.472)	(2.758)
	$(1-li)^2$	−22.581***	−20.823***	−1.786	−1.574
		(2.055)	(4.614)	(1.268)	(2.001)
common	constant	−22.961***	−25.210***	−14.516***	−18.692***
		(2.827)	(2.955)	(1.654)	(1.845)
	Year dummy	Yes	Yes	Yes	Yes
	Firm fixed effects	No	No	Yes	Yes
	Obs	94510	94510	94510	94510
	Group			3459	3459
	Year	70–06	70–06	70–06	70–06
	Adj–R2	0.0217	0.0396		
	Within R2			0.1640	0.2088
1960s	Inverted–U test	1.828*	1.211	–	–
	(Result)	Inverted–U			
	Exremum point	0.812			
	90% confidence interval	[0.616, 0.880]			
1970s	Inverted–U test	6.812***	6.172***	−1.322	−1.234
	(Result)	Inverted–U	Inverted–U		
	Exremum point	0.949	0.949		
	90% confidence interval	[0.920,0.972]	[0.916, 0.975]		
1980s	Inverted–U test	9.635***	8.788***	−5.966***	−6.541***
	(Result)	Inverted–U	Inverted–U	Inverted–U	Inverted–U
	Exremum point	0.938	0.923	1.014	0.994
	90% confidence interval	[0.921, 0.954]	[0.903, 0.939]	[0.989, 1.048]	[0.969, 1.022]
1990s	Inverted–U test	−9.425***	−9.578***	3.733***	3.573***
	(Result)	Inverted–U	Inverted–U	Inverted–U	Inverted–U
	Exremum point	1.032	1.019	0.933	0.895
	90% confidence interval	[1.015, 1.054]	[1.002, 1.040]	[0.867, 0.974]	[0.820, 0.937]
2000s	Inverted–U test	−9.190***	−8.170***	–	–
	(Result)	Inverted–U	Inverted–U		
	Exremum point	1.014	1.011		
	90% confidence interval	[0.994, 1.038]	[0.989, 1.038]		

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Table 2.2 Inverted−U test of Fixed−effects Slopes of each decade at firm level in manufacturing industries

		1	2	3	4
	Dep.	lnPat	lnCite	lnPat	lnCite
	Procedure	OLS	OLS	within	within
Period		Combined	Combined	Combined	Combined
		Coef.	Coef.	Coef.	Coef.
1960s	*1−li*	45.613***	38.271***	−4.515	−11.254
		(11.338)	(12.540)	(6.862)	(7.853)
	$(1-li)^2$	−26.504***	−21.966***	5.027	9.451**
		(5.799)	(6.414)	(3.505)	(4.011)
1970s	*1−li*	63.410***	66.145***	22.609***	28.049***
		(6.474)	(7.160)	(4.052)	(4.637)
	$(1-li)^2$	−33.701***	−34.756***	−9.579**	−11.834**
		(10.227)	(12.512)	(3.971)	(5.201)
1980s	*1−li*	74.935***	79.445***	33.792***	39.384***
		(7.721)	(8.540)	(4.936)	(5.648)
	$(1-li)^2$	−40.792***	−43.729**	−16.595***	−19.733**
		(15.430)	(18.878)	(6.221)	(8.147)
1990s	*1−li*	57.541***	63.359***	10.070**	12.333**
		(6.714)	(7.426)	(4.441)	(5.083)
	$(1-li)^2$	−29.852***	−33.289**	−5.542	−7.320
		(11.444)	(14.001)	(4.879)	(6.390)
2000s	*1−li*	39.786***	37.740***	9.408**	6.851
		(6.569)	(7.265)	(4.271)	(4.888)
	$(1-li)^2$	−22.219*	−21.582	−6.647	−5.802
		(11.352)	(13.888)	(4.727)	(6.190)
common	constant	−22.122***	−22.992***	−2.617	−5.538**
		(−3.98)	(6.15)	(2.107)	(2.412)
	Year dummy	Yes	Yes	Yes	Yes
	Firm fixed effects	No	No	Yes	Yes
	Obs	55009	55009	55009	55009
	Group			1691	1691
	Year	64−06	64−06	64−06	64−06
	Adj−R2	0.0738	0.1096		
	Within R2			0.2034	0.2749
1960s	Inverted−U test	2.925***	2.298**	−	−
	(Result)	Inverted−U	Inverted−U		
	Exremum point	0.860	0.871		
	90% confidence interval	[0.764, 0.906]	[0.717, 0.925]		
1970s	Inverted−U test	8.359***	8.075***	−2.621***	−2.762***
	(Result)	Inverted−U	Inverted−U	Inverted−U	Inverted−U
	Exremum point	0.941	0.952	1.180	1.185
	90% confidence interval	[0.917, 0.960]	[0.928, 0.971]	[1.122, 1.305]	[1.129, 1.298]
1980s	Inverted−U test	8.287***	7.738***	−6.009***	−6.581***
	(Result)	Inverted−U	Inverted−U	Inverted−U	Inverted−U
	Exremum point	0.919	0.908	1.018	0.998
	90% confidence interval	[0.897, 0.936]	[0.884, 0.927]	[0.994, 1.048]	[0.975, 1.023]
1990s	Inverted−U test	7.956***	7.719***	1.808*	1.570
	(Result)	Inverted−U	Inverted−U	Inverted−U	
	Exremum point	0.964	0.952	0.909	
	90% confidence interval	[0.942, 0.983]	[0.929, 0.971]	[0.546, 0.980]	
2000s	Inverted−U test	4.896***	3.944***	0.580	−
	(Result)	Inverted−U	Inverted−U		
	Exremum point	0.895	0.874		
	90% confidence interval	[0.850, 0.926]	[0.812, 0.912]		

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Table 3 Inverted−U test of Fixed−effects Slope of each industry at firm level

	1	2	3	4
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	OLS	OLS	within	within
Industry	Inv-U test	Inv-U test	Inv-U test	Inv-U test
Manufacturing industries				
#08 Livestock products	−0.41	−0.36	−0.54	−0.29
#10 Flour and grain mill products	0.42	0.31	−0.02	−
#11 Miscellaneous foods and related products	2.74***	2.31**	−	−
#12 Prepared animal foods and organic fertilizers	−	−	−	−
#13 Beverages	−0.11	−0.06	−	−
#15 Textile products	3.08***	2.62***	−	−
#16 Lumber and wood products	1.50	1.29	−	−
#18 Pulp, paper, and coated and glazed paper	1.86*	1.52	−	−
#20 Printing, plate making for printing and bookbinding	1.35	1.03	0.16	−
#22 Rubber products	1.72*	1.51	0.08	−0.18
#23 Chemical fertilizers	−0.77	−0.87	−0.52	−0.25
#24 Basic inorganic chemicals	−	−	−	−0.14
#25 Basic organic chemicals	−	−	−	−
#26 Organic chemicals	2.48**	1.99**	−	0.03
#28 Miscellaneous chemical products	−1.53	−1.40	−	−0.03
#29 Pharmaceutical products	3.36***	2.77***	−	−0.13
#30 Petroleum products	−0.67	1.03	−0.25	−0.24
#32 Glass and its products	1.57	1.20	0.16	0.16
#33 Cement and its products	−1.72*	1.68*	−1.35	−0.82
#34 Pottery	0.72	0.45	−0.27	−0.48
#35 Miscellaneous ceramic, stone and clay products	−	−	−0.07	−0.03
#36 Pig iron and crude steel	−1.25	−1.23	−0.34	−0.36
#37 Miscellaneous iron and steel	−0.88	−0.65	−	−0.29
#38 Smelting and refining of non−ferrous metals	−0.02	−	−0.15	−
#39 Non−ferrous metal products	−1.32	−0.69	−0.48	−0.27
#40 Fabricated constructional and architectural metal products	−0.15	−	−	−0.03
#41 Miscellaneous fabricated metal products	2.28**	1.86*	−0.60	−0.41
#42 General industry machinery	2.77***	2.34**	−0.31	−0.20
#43 Special industry machinery	−3.06***	−3.09***	−0.23	−0.34
#44 Miscellaneous machinery	−3.08***	2.99***	−	0.10
#45 Office and service industry machines	1.64	1.22	−	−0.68
#46 Electrical generating, transmission, distribution and industrial apparatus	−1.41	−1.27	−0.69	−0.72
#47 Household electric appliances	3.40***	−2.63***	−	−0.26
#49 Communication equipment	−0.53	−0.07	−0.36	−0.21
#52 Electronic parts	−3.25***	2.94***	−	−0.01
#53 Miscellaneous electrical machinery equipment	−3.56***	3.05***	−0.18	−0.41
#54 Motor vehicles	0.85	0.80	−	0.04
#55 Motor vehicle parts and accessories	−	−	−0.64	−0.37
#56 Other transportation equipment	1.97**	1.72*	0.05	−0.03
#57 Precision machinery & equipment	3.07***	2.70***	−	−
#59 Miscellaneous manufacturing industries	2.46**	2.26**	−	−0.36
Non-manufacturing industries				
#07 Mining	−5.77***	−5.33***	−3.33***	−2.99***
#09 Seafood products	−	−	0.45	0.26
#60 Construction	1.82*	1.59	−0.29	−0.37
#61 Civil engineering	−0.60	−0.91	−0.55	0.05
#62 Electricity	−	−0.11	−0.09	−0.76
#63 Gas, heat supply	−1.17	1.00	−0.22	−0.01
#67 Wholesale	−1.06	−0.78	−	−
#68 Retail	1.94*	1.80*	−	0.04
#69 Finance	2.23**	1.99**	−	−
#71 Real estate	−1.43	−1.47	0.23	0.16
#73 Railway	1.49	1.37	−	−
#74 Road transportation	0.81	0.77	−	−

#75 Water transportation	1.94*	1.56	−	−
#76 Air transportation	−0.43	0.70	−0.14	−
#77 Other transportation and packing	1.36	1.10	−	−
#78 Telegraph and telephone	1.31	1.18	−	−
#89 Entertainment	−1.94*	−1.64	−	−
#95 Accommodation	−1.35	−1.26	−	−
#110 Other services	2.91***	2.45**	−	−
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	94510	94510	94510	94510
Group			3459	3459
Year	64−06	64−06	64−06	64−06
Adj−R2	0.3662	0.3696		
Within R2			0.1669	0.2113
# of significant Inverted-U slopes				
Entire sample (60 industries)	24	19	1	1
Manufacturing industries (41 industries)	17	15	0	0
Non-manufacturing industries (19 industries)	7	4	1	1

Note: In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. Detailed result of these regression is shown in Appendix Table A5

Table 4. 1−Lerner Index semi-elasticity of Pat and Cite in each industry

		1		2		3		4	
Dep.		lnPat		lnCite		lnPat		lnCite	
procedure		OLS		OLS		Within		Within	
Industry		Combined		Combined		Combined		Combined	
		Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Manufacturing									
#08	$1-li$	0.440*	0.238	−0.244	0.257	13.692***	3.351	8.898**	0.257
#10	$1-li$	−1.065***	0.270	−1.111***	0.321	0.789	4.054	−1.773	0.321
#11	$1-li$	−1.464***	0.195	−1.879***	0.230	−1.903*	1.059	−1.661	0.230
#12	$1-li$	−1.229***	0.286	−2.353***	0.251	44.434***	8.440	54.131***	0.251
#13	$1-li$	0.247	0.259	−0.474	0.313	−3.092	2.608	−1.866	0.313
#15	$1-li$	−0.665***	0.190	−1.150***	0.208	−2.515***	0.700	−2.141	0.208
#16	$1-li$	−0.604**	0.238	−1.048***	0.183	−5.294***	1.918	−6.872***	0.183
#18	$1-li$	−0.628***	0.203	−1.089***	0.198	−1.493	1.338	−2.908	0.198
#20	$1-li$	−0.750***	0.241	−1.072***	0.202	−5.411*	3.121	−6.200	0.202
#22	$1-li$	1.937***	0.219	1.679***	0.213	−3.709*	2.093	−0.561	0.213
#23	$1-li$	0.685**	0.290	0.067	0.279	−1.807	3.768	0.384	0.279
#24	$1-li$	2.886***	0.231	2.749***	0.292	4.205	2.909	9.569*	0.292
#25	$1-li$	4.987***	0.334	5.029***	0.340	5.994	4.148	−0.936	0.340
#26	$1-li$	2.784***	0.207	2.656***	0.322	1.092	1.632	−1.009	0.322
#28	$1-li$	2.564***	0.193	2.320***	0.128	3.279***	0.834	3.860*	0.128
#29	$1-li$	2.834***	0.217	2.001***	0.144	3.706***	0.848	2.605**	0.144
#30	$1-li$	0.821***	0.239	0.212	0.197	9.801***	3.796	3.446	0.197
#32	$1-li$	2.553***	0.260	2.224***	0.264	−1.557	2.379	−3.473	0.264
#33	$1-li$	0.301	0.219	0.235	0.241	3.451**	1.685	0.759	0.241
#34	$1-li$	0.626**	0.247	0.470**	0.226	0.902	1.950	1.203	0.226
#35	$1-li$	0.198	0.220	−0.297	0.224	8.755***	1.538	11.258***	0.224
#36	$1-li$	0.356*	0.214	0.061	0.181	−0.205	1.009	−1.758	0.181
#37	$1-li$	−0.057	0.202	−0.638***	0.158	5.375***	1.208	6.597***	0.158
#38	$1-li$	1.933***	0.238	1.944***	0.196	5.704***	1.751	4.587*	0.196
#39	$1-li$	1.794***	0.207	1.430***	0.202	1.492	1.855	4.458	0.202
#40	$1-li$	−2.998***	0.239	−3.530***	0.202	6.199**	2.445	9.928***	0.202
#41	$1-li$	−0.107	0.200	−0.725***	0.190	1.435	1.122	−0.104	0.190
#42	$1-li$	0.752***	0.203	0.456***	0.132	1.457	1.014	1.069	0.132
#43	$1-li$	1.455***	0.191	0.909***	0.122	0.683	0.507	0.410	0.122
#44	$1-li$	1.302***	0.198	0.941***	0.110	0.254	0.773	−0.589	0.110
#45	$1-li$	1.956***	0.306	1.064***	0.277	−2.518	2.842	−0.899	0.277
#46	$1-li$	3.204***	0.208	3.014***	0.283	3.188**	1.275	5.141	0.283
#47	$1-li$	3.918***	0.203	3.962***	0.143	−2.994***	1.085	2.685	0.143
#49	$1-li$	3.117***	0.206	3.122***	0.147	2.750**	1.152	4.853***	0.147
#52	$1-li$	2.022***	0.204	1.949***	0.144	4.260***	0.923	4.278***	0.144
#53	$1-li$	2.512***	0.202	2.407***	0.135	0.551	0.845	0.347	0.135
#54	$1-li$	5.205***	0.237	5.546***	0.188	−5.727	3.776	−2.305	0.188
#55	$1-li$	1.899***	0.200	1.680***	0.190	13.662***	1.839	17.292***	0.190
#56	$1-li$	0.415**	0.209	0.043	0.142	−0.668	1.511	0.923	0.142
#57	$1-li$	3.118***	0.204	3.057***	0.156	−2.804***	0.967	−0.332	0.156
#59	$1-li$	0.717***	0.206	0.377***	0.144	−0.292	1.299	3.744**	0.144
Non44anufacturing									
#07	$1-li$	−2.225***	0.249	−2.506***	0.269	1.574	1.381	2.391	1.541
#09	$1-li$	0.238	0.285	−0.847***	0.290	−0.744	4.086	0.392	0.290
#60	$1-li$	−1.196***	0.194	−1.297***	0.123	−1.592	1.419	0.158	0.123
#61	$1-li$	−1.552***	0.193	−2.109***	0.104	0.495	1.352	−3.571	0.104
#62	$1-li$	0.718***	0.262	0.463**	0.216	14.242***	3.430	6.242	0.216
#63	$1-li$	−1.508***	0.255	−1.960***	0.276	1.365	2.382	2.594	0.276
#67	$1-li$	−3.829***	0.186	−4.096***	0.194	−2.650***	0.824	−3.679	0.194
#68	$1-li$	−5.239***	0.192	−5.172***	0.084	−4.402***	1.199	−5.855***	0.084
#69	$1-li$	−5.308***	0.221	−5.292***	0.151	−1.770**	0.826	−0.921	0.151
#71	$1-li$	−4.871***	0.210	−4.796***	0.166	−0.304	0.754	−0.802	0.166
#73	$1-li$	−4.308***	0.211	−4.185***	0.152	1.090	1.461	2.649	0.152
#74	$1-li$	−4.307***	0.214	−4.483***	0.172	−10.187***	3.460	−5.071	0.172
#75	$1-li$	−4.396***	0.209	−4.418***	0.164	−3.922***	1.124	−8.001**	0.164

#76	*1−li*	−1.743***	0.300	−2.140***	0.286	6.868*	3.801	−2.611	0.286
#77	*1−li*	−5.220***	0.211	−5.008***	0.285	−7.127***	1.478	−9.711**	0.285
#78	*1−li*	−1.606***	0.247	−1.929***	0.211	−1.780	1.724	−1.255	0.211
#89	*1−li*	−5.102***	0.220	−4.912***	0.218	−1.514*	0.867	−2.084	0.218
#95	*1−li*	−5.035***	0.251	−4.771***	0.227	−4.647***	1.527	−5.774***	0.227
#110	*1−li*	−4.253***	0.196	−4.439***	0.207	−1.128***	0.433	−1.346	0.207
	constant	−3.899	0.204	−6.994***	0.221	−5.507***	0.203	−8.649***	0.226
Year dummy		Yes		Yes		Yes		Yes	
Firm fixed effects		No		No		Yes		Yes	
Obs		94510		94510		94510		94510	
Group						3459		3459	
Year		64−06		64−06		64−06		64−06	
Adj−R2		0.3918		0.3605					
Within R2						0.1669		0.2089	
Entire sample									
Median		0.274		−0.270		0.375		0.027	
[min, max]		[−5.308, 5.205]		[−5.292, 5.546]		[−10.187, 44.434]		[−9.711, 54.131]	
Manufacturing Industries									
Median		0.821		0.470		0.902		0.759	
[min, max]		[−2.998, 5.205]		[−3.530, 5.546]		[−5.727, 44.434]		[−6.872, 54.131]	
Non-Manufacturing Industries									
Median		−4.253		−4.185		−1.514		−1.346	
[min, max]		[−5.308, 0.718]		[−5.292, 0.463]		[−10.187, 14.242]		[−9.711, 6.242]	

Note: ***, **, and * denote significances at the 1, 5, and 10% level, respectively.

Table 5 Inverted-U test of neck-and-neck firms and unleveled firms in entire sample

Neck-and-neck firms (i.e. firm's TFP is above the median)	1	2	3	4
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	OLS	OLS	within	within
	Coef.	Coef.	Coef.	Coef.
	(S.E.)	(S.E.)	(S.E.)	(S.E.)
$1-li$	62.068***	60.763***	13.401***	14.818***
	(4.925)	(5.392)	(3.565)	(4.152)
$(1-li)^2$	−32.285***	−31.700***	−6.519***	−7.232***
	(2.568)	(2.812)	(1.805)	(2.102)
Constant	−29.889***	−32.842***	−7.299***	−11.802***
	(2.374)	(2.599)	(1.767)	(2.058)
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	39286	39286	39286	39286
Group			2240	2240
Year	64−06	64−06	64−06	64−06
Adj−R2	0.0375	0.0579		
Within R2			0.1186	0.1740
Inverted U test	−12.228***	−11.038***	−3.157***	−3.036***
	Inverted-U	Inverted-U	Inverted-U	Inverted-U
Extremum point	0.961	0.958	1.028	1.024
90% confidence interval	[0.949, 0.974]	[0.945, 0.972]	[0.981, 1.111]	[0.976, 1.112]

Unleveled firms (i.e. firm's TFP is below the median)	5	6	7	8
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	OLS	OLS	within	within
	Coef.	Coef.	Coef.	Coef.
	(S.E.)	(S.E.)	(S.E.)	(S.E.)
$1-li$	35.135***	32.392***	2.553	3.114
	(2.549)	(2.581)	(1.765)	(1.937)
$(1-li)^2$	−17.242***	−16.072***	−1.283	−1.584*
	(1.298)	(1.314)	(0.871)	(0.956)
constant	−21.774***	−23.321***	−5.323***	−8.894***
	(1.273)	(1.288)	(0.903)	(0.991)
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	55224	55224	55224	55224
Group			3302	3302
Year	64−06	64−06	64−06	64−06
Adj−R2	0.011	0.0262		
Within R2			0.1471	0.1803
Inverted U test	−11.611***	−11.009***	1.367	1.485
	Inverted-U	Inverted-U		
Extremum point	1.019	1.008		
90% confidence interval	[1.003, 1.036]	[0.991, 1.026]		

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Table 6 TFP gap semi-elasticity of innovation and Test of TFP gap spread hypothesis

	1	2	3	4	5	6
	Firm level	Firm level	Firm level	Firm level	Industry Average	Industry Average
Dep.	lnPat	lnCite	TFP gap	TFP gap	TFP gap	TFP gap
procedure	Within	Within	OLS	Within	OLS	Within
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)	(S.E.)
m_{it} (TFP gap)	−0.333***	−0.507***				
	(0.064)	(0.074)				
$1-li$			0.356***	0.489***	−0.242**	0.408***
			(0.012)	(0.010)	(0.112)	(0.075)
Constant	−4.506***	−7.717***	−0.009***	−0.194***	0.456***	−0.173**
	(0.056)	(0.066)	(0.013)	(0.010)	(0.111)	(−2.36)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	No	Yes		
Industry fixed effects					No	Yes
Obs	78932	78932	78471	78471	2082	2082
Group	2887	2887		2882		59
Year	70−06	70−06	70−06	70−06	70−06	70−06
Adj−R2			0.1300		0.0145	
Within R2	0.0931	0.1379		0.2392		0.1069

Note: ***, **, and * denote significances at the 1, 5, and 10% level, respectively.

Table 7.1 Replications of TFP gap interaction terms in ABBGH at firm level

	1	2	3	4
	Firm level	Firm level	Firm level	Firm level
Dep.	lnPat	lnCite	lnPat	lnCite
procedure	OLS	OLS	Within	Within
	Coef.	Coef.	Coef.	Coef.
	(S.E.)	(S.E.)	(S.E.)	(S.E.)
$1-li$	44.702***	43.534***	4.491***	4.177*
	2.849	3.086	1.947	2.282
$(1-li)^2$	−21.644***	−21.305***	−1.054	−0.755
	1.552	1.680	1.031	1.208
$(1-li)\times$TFP gap	−9.523***	−9.601***	4.240***	4.655***
	1.157	1.253	0.711	0.833
$(1-li)^2\times$TFP gap	3.622***	3.709***	−4.758***	−5.370***
	1.181	1.279	0.724	0.848
Constant	−25.397***	−27.819***	−7.816***	−11.007***
	1.344	1.456	0.940	1.101
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	78471	78471	78471	78471
Group			2882	2882
Year	70−06	70−06	70−06	70−06
Adj−R2	0.0842	0.0883		
Within R2			0.0948	0.1394
Inverted-U test for baseline curve	−9.855***	−9.230***	−	−
(i.e., $1-li$, $1-li$_squared)	(Inverted-U)	(Inverted-U)		
(Extremum point)	1.033	1.022		
[confidence interval]	[1.007, 1.063]	[0.995, 1.054]		
Is curve in neck-and-neck industries steeper than baseline?	No	No	−	−
Effect of TFP gap on Innovation				
Range of positive effect	[0.641, 1.394]	−	[0.891, 1.394]	[0.867, 1.394]
Range of negative effect	−	[0.641, 1.394]	[0.641, 0.891]	[0.641, 0.867]

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Table 7.2 Replications of TFP gap interaction terms in ABBGH at industry level

	1	2	3	4
Dep. procedure	Industry Average lnPat OLS Coef. (S.E.)	Industry Average lnCite OLS Coef. (S.E.)	Industry Average lnPat Within Coef. (S.E.)	Industry Average lnCite Within Coef. (S.E.)
$1-li$	62.964	161.903**	−32.731	58.986**
	73.687	74.554	27.920	27.401
$(1-li)^2$	−36.537	−88.304**	19.175	−30.248**
	37.206	37.644	14.008	13.748
$(1-li)$×TFP gap	−39.334***	−40.604***	22.853***	10.712**
	13.532	13.691	5.085	4.990
$(1-li)^2$×TFP gap	35.074**	36.870***	−23.984***	−11.222**
	13.897	14.061	5.216	5.119
Constant	−144.874***	−74.898**	15.390	−29.674**
	17.272	36.992	13.927	13.668
Year dummy	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	Yes	Yes
Obs	2082	2082	2082	2082
Group			59	59
Year	70−06	70−06	70−06	70−06
Adj−R2	0.0929	0.1260		
Within R2			0.1027	0.5011
Inverted-U test for baseline curve	0.564	1.764*	−	2.027**
(i.e., $1-li$, $1-li$_squared)		(Inverted-U)		(Inverted-U)
(Extremum point)		0.917		0.975
[confidence interval]		[0.532, 0.967]		[0.758, 1.038]
Is curve in neck-and-neck industries steeper than baseline?	−	No	−	Yes
Effect of TFP gap on Innovation				
Range of positive effect	−	[1.101, 1.176]	[0.683, 0.953]	[0.683, 0.954]
Range of negative effect	[0.683, 1.176]	[0.683, 1.101]	[0.953, 1.176]	[0.954, 1.176]

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Table 8.1 Result of 2SLS (IV) estimates (1st stage of 2SLS) at firm and industry level

Firm−level	1.1	1.2	2.1	2.2
	Firm−level	Firm−level	Firm−level	Firm−level
Dep.	*1−L*	$(1-L)^2$	*1−L*	$(1-L)^2$
Procedure	OLS	OLS	Within	Within
	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)
ln*XRI*_Adv.Eco.	0.0000787	0.000326	0.00139***	0.00233**
	(0.000383)	(0.000752)	(0.000496)	(0.000999)
ln *XRI*_Dev.Con.	0.00164***	0.00281***	−0.000175	−0.000163
	(0.000451)	(0.000885)	(0.000430)	(0.000865)
ln *XRI*_Adv.Eco._squared	0.000812***	0.00161***	0.000597***	0.00113***
	(0.000199)	(0.000390)	(0.000200)	(0.000403)
ln *XRI*_Dev.Con._squared	0.000126**	0.000223**	−0.000208***	−0.000386***
	(0.0000555)	(0.000109)	(0.0000493)	(0.0000993)
Constant	0.970***	0.943***		
	(0.00212)	(0.00416)		
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	37958	37958	37958	37958
Group			1640	1640
Year	80−06	80−06	80−06	80−06
Adj−R2	0.0253	0.0252		
Centered R2			0.0539	0.0518
Weak instrument test				
F value	33.9***	33.72***	68.89***	66.12***

Industry Average	3.1	3.2	4.1	4.2
	Industry Average	Industry Average	Industry Average	Industry Average
Dep.	*1−L*	$(1-L)^2$	*1−L*	$(1-L)^2$
Procedure	OLS	OLS	Within	Within
	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)
ln*XRI*_Adv.Eco.	−0.000772	−0.00148	−0.000509	−0.00101
	(0.000707)	(0.00137)	(0.000845)	(0.00165)
ln *XRI*_Dev.Con.	0.000156	0.000262	0.000236	0.000445
	(0.000559)	(0.00108)	(0.000517)	(0.00101)
ln *XRI*_Adv.Eco._squared	0.00115***	0.00224***	0.000120	0.000208
	(0.000359)	(0.000696)	(0.000349)	(0.000680)
ln *XRI*_Dev.Con._squared	−0.0000425	−0.0000859	0.0000243	0.0000456
	(0.0000724)	(0.000140)	(0.0000618)	(0.000121)
Constant	0.968***	0.937		
	(0.00436)	(0.00845)		
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	1154	1154	1154	1154
Group			43	43
Year	80−06	80−06	80−06	80−06
Adj−R2	0.1113	0.1124		
Centered R2			0.2316	0.2311
Weak instrument test				
F value	5.81***	5.87***	10.86***	10.83***

Note: ***, **, and * denote significances at the 1, 5, and 10% level, respectively.

Table 8.2 Result of 2SLS in entire sample at firm and industry level

Firm-level	1	2	3	4
	Firm level	Firm level	Firm level	Firm level
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	2nd stage of 2SLS	2nd stage of 2SLS	2nd stage of Within 2SLS	2nd stage of Within 2SLS
	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)
$1-li$	−2093.372***	−2419.987***	6.762	41.414
	(426.568)	(495.991)	(126.900)	(160.039)
$(1-li)^2$	1081.286***	1251,418***	13.678	-2.294
	(230.673)	(268.214)	(66.477)	(83.837)
Constant	1008.246***	1159.625***		
	(197.628)	(229.791)		
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	37958	37958	37948	37948
Group			1650	1650
Year	80−06	80−06	80−06	80−06
Adj-R2	–	–		
Centered R2			−0.5974	−0.3106
Overidentification test				
Sargan Statistics	0.298	0.417		
Sargan-Hansen statistic			9.167***	13.152***
Inverted U test	–	–	0.677	–

Industry Average	5	6	7	8
	Industry Average	Industry Average	Industry Average	Industry Average
Dep.	lnPat	lnCite	lnPat	lnCite
Procedure	2nd stage of 2SLS	2nd stage of 2SLS	2nd stage of Within 2SLS	2nd stage of Within 2SLS
	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)	Coef.(S.E.)
$1-L$	−9528.170*	−9836.756*	−826.507	−1106.411
	5527.865	5773.393	1375.436	1251.777
$(1-L)^2$	4908.37*	5063.5*	444.427	576.242
	2837.431	2963.459	718.781	654.159
Constant	4624.276*	4775.493*		
	2691.221	2810.755		
Year dummy	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Obs	1154	1154	1154	1154
Group			43	43
Year	80−06	80−06	80−06	80−06
Adj-R2	–	–		
Centered R2			−4.7957	-0.6529
Overidentification test				
Sargan Statistics	2.827	3.013		
Sargan-Hansen statistic			4.439	5.691*
Inverted U test	–	–	–	–

Notes: (1) In regression model, ***, **, and * denote significances at the 1, 5, and 10% level, respectively. (2) In inverted-U tests, ***, **, and * denote significances at the 0.5, 2.5, and 5% level, respectively.

Appendix

Table A1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Firm level					
Entire sample					
Sales	95518	122130.6	617703.5	1	21400000
Sales cost	93751	102610.5	589645.1	1	21200000
Operating profit	95496	5106.5	23556.2	−197000	948000
Non−operating cost	94969	3060.3	15067.4	1	588000
# of regular employee	95408	2023.8	5755.4	1	304000
R&D	50479	2644.6	16519.7	1	705000
Capital stock	80634	46908.2	268656.9	−124000	13000000
TFP	78932	2.954	3.293	0.009	261.5
# of raw patent application	95550	72.557	526.384	0	18988
# of raw cited counts	95550	30.181	220.434	0	7910
Pat	95544	27.737	199.407	0.0001	9200.7
Cite	95544	4.021	31.411	0.0001	1670.6
Technology gap (m_{it})	78932	0.360	0.222	0	0.996
1−li (*1−Lerner Index*)	95470	0.996	2.399	0.01	679
1−li (0.5−99.5th percentile)	94516	0.973	0.066	0.641	1.394
Manufacturing Industries					
Sales	55315	91109.6	316287.9	20	10200000
Sales cost	55227	72569.3	261777	5	8270000
Operating profit	55299	4315.4	17403.1	−197000	861000
Non−operating cost	55242	2423.4	8693.3	1	227000
# of regular employee	55294	2198.1	5506.1	1	92279
R&D	38299	3098.2	18356.5	1	705000
Capital stock	49518	36148.5	126942.9	−20925	2970000
TFP	49421	2.238	2.176	0.4601	261.5
# of raw patent application	55317	120.062	684.956	0	18988
# of raw cited counts	55317	49.716	286.369	0	7910
Pat	55317	46.236	259.789	0.0001	9200.7
Cite	55317	6.643	40.850	0.0001	1670.6
Technology gap (m_{it})	49421	0.308	0.193	0	0.975
1−li (*1−Lerner Index*)	55298	0.977	0.084	0.01	5.863
1−li (0.5−99.5th percentile)	55062	0.976	0.064	0.641	1.394
Industry level (firm average)					
Sales (Real value)	2082	166467.3	246527.2	1244.9	2080000
R&D (Real value)	2082	2729.6	9301.6	1.1	167000
TFP	2082	2.977	2.895	0.553	41.3
Pat	2580	30.476	70.766	0.0001	646.6
Cite	2580	4.357	11.934	0.0001	154.1
Average Technology gap (m_{it})	2082	0.254	0.169	0	0.948
1−L	2580	0.974	0.032	0.841	1.135
*XRI*_AdvancedEconomies	1161	1.534	3.543	0.012	40.807
*XRI*_DevelopingCountries	1161	9.612	121.116	0	2292.87

Table A2. JIP2006 Sector Classification

#	JIP2006 Sector Classification	Sector (Nikkei NEEDS Sector Code)
Manufacturing industries		
8	Livestock products	ham products (101007), milk products (101009)
10	Flour and grain mill products	flour and grain mill products (101003)
11	Miscellaneous foods and related products	sugar (101002), food oil (101004), confectionery products (101006), flavoring materials (101008), other foods (101010)
12	Prepared animal foods and organic fertilizers	feeding stuff (101001)
13	Beverages	alcoholic beverage (101005)
15	Textile products	chemical synthetic fiber (103021), cotton spinners (103022), silk spinners (103023), wool spinners (103024), secondary processing products (103025), other products (103026)
16	Lumber and wood products	building products (133323)
18	Pulp, paper, and coated and glazed paper	major paper producers (105041), other products (105042)
20	Printing, plate making for printing and bookbinding	printing (133321)
22	Rubber products	tire manufacturing (113121), other products (113122)
23	Chemical fertilizers	plant food (107062)
24	Basic inorganic chemicals	chlorine and soda (107063), oxygen (107066)
25	Basic organic chemicals	petroleum chemistry (107064)
26	Organic chemicals	synthetic resin (107065)
28	Miscellaneous chemical products	major chemical manufacturers (107061), fats and washing powders (107067), cosmetics and dental powders (107068), coating materials (107069), pesticide chemicals (107070), other materials (107071)
29	Pharmaceutical products	major Medicine Manufacturers (109081), medicinal products for professional use (109082), medicinal products for the public sector (109083)
30	Petroleum products	petroleum refining and sales (111101), petroleum and coal products (111102)
32	Glass and its products	glass products (115141)
33	Cement and its products	primary raw materials of cement (115142), secondary processing of cement (115143)
34	Pottery	brownware (115144)
35	Miscellaneous ceramic, stone and clay products	brick refractories (115145) carbon (115146)
36	Pig iron and crude steel	integrated steel manufactures (117161), open−arc furnace (117162)
37	Miscellaneous iron and steel	special steel products (117163), alloy iron products (117164), cast and forged steel products (117165), stainless products (117166), other products (117167)
38	Smelting and refining of non−ferrous metals	major milling manufacturers (119181), other milling products (119182)
39	Non−ferrous metal products	aluminum processing products (119183), electrical cables (119184)
40	Fabricated constructional and architectural metal products	iron frame, iron tower and bridge (119185)
41	Miscellaneous fabricated metal products	other metallic products (119186)
42	General industry machinery	press machines (121202), machines for transportation, construction and internal combustion (121204)
43	Special industry machinery	machine tools (121201), textile machines (121203), agricultural machines (121205), chemical engineering machines (121206), sewing machines (121207)
44	Miscellaneous machinery	bearing machines (121208), other machines (121210)
45	Office and service industry machines	office machines (121209)
46	Electrical generating, transmission, distribution and industrial apparatus	heavy electrical machines (123222), control instruments (123226)
47	Household electric appliances	general electrical manufacturers (123221), electronic equipments (123223)
49	Communication equipment	communicators (123224)
52	Electronic parts	electronic components (123225)
53	Miscellaneous electrical machinery equipment	batteries (123227), automobile−related equipments (123228), other products (123229)
54	Motor vehicles	automobile products (127261)
55	Motor vehicle parts and accessories	automobile components (127262), automobile bodies (127263)
56	Other transportation equipment	shipbuilding (125241), wheeled vehicles (129281) bicycles (129282), other products (129283)
57	Precision machinery & equipment	horologes (131301), cameras (131302), measuring gauges (131303)
59	Miscellaneous manufacturing industries	musical instruments (133322), office supplies (133324), other products (133325)
Non-manufacturing industries		
7	Mining	coal (237361), other materials (237362)

9	Seafood products	seafood products (235341)
60	Construction	major construction companies (241401), midsize construction companies (241402), residential houses (241405)
61	Civil engineering	civil engineering, road building and dredging (241403), electrical facilities engeneering (241404), other products (241406)
62	Electricity	electrical power services (267661)
63	Gas, heat supply	gas power services (269681)
67	Wholesale	general merchants and traders (243421), automobile selling (243422), food selling (243423), textile selling (243424), machinery and metal goods selling (243425), chemical products selling (243426), building materials selling (243427), electrical machineries selling (243428), other products selling (243429)
68	Retail	department stores (245441), grocery supermarkets (245442), installment selling (245443) other retailing (245444)
69	Finance	other financial services (252511)
71	Real estate	rental services (253521), real estate brokers (253522)
73	Railway	major private railroad companies (255541), midsize private railroad companies (255542)
74	Road transportation	bus and other companies (255543), land transportation companies (257561)
75	Water transportation	major marine transportation companies (259581), coastwise services (259582), overseas shipping services (259583)
76	Air transportation	air transport services (261601)
77	Other transportation and packing	warehousing (263621), transportation−related services (263622)
78	Telegraph and telephone	telecommunication services (265641)
89	Entertainment	film distributors (271701), amusement facilities (271702)
95	Accommodation	hotel services (271703)
110	Other services	other services (271704)

Table A3.1 Estimation of Citation Probabilities from IIP patent data

	Full model	
	Coef.	S.E.
Constant	−3.915	0.771
Citing Year Effects (base = 1971)		
1964	−4.737	0.861
1965	−4.729	0.755
1966	−4.595	0.695
1967	−3.256	0.673
1968	−3.367	0.682
1969	−3.124	0.687
1970	−2.697	0.682
1972	0.311	0.643
1973	0.377	0.615
1974	0.476	0.646
1975	1.027	0.638
1976	0.846	0.627
1977	0.818	0.589
1978	1.070	0.605
1979	1.168	0.590
1980	1.225	0.619
1981	1.071	0.616
1982	1.278	0.605
1983	1.286	0.612
1984	1.777	0.588
1985	1.793	0.605
1986	1.890	0.597
1987	2.118	0.595
1988	2.149	0.572
1989	2.280	0.609
1990	2.435	0.607
1991	2.456	0.602
1992	2.882	0.584
1993	3.219	0.581
1994	3.253	0.598
1995	3.500	0.575
1996	3.625	0.574
1997	3.685	0.571
1998	3.722	0.594
1999	4.036	0.560
2000	4.164	0.585
2001	4.396	0.586
2002	4.599	0.588
2003	4.874	0.587
2004	5.028	0.580
2005	5.224	0.589
2006	5.185	0.583
2007	4.915	0.579
2008	4.572	0.578
2009	4.241	0.584
2010	4.864	0.605
Cited Year Effects		
1965-69	1.945	0.134
1970-74	1.557	0.145
1975-79	0.819	0.179
1980-84	0.026	0.213
1985-89	−0.772	0.242
1999-94	−1.274	0.298
1995-99	−1.649	0.370
2000-04	−2.548	0.429
2005-09	−4.291	0.423
2010	−7.130	0.582

Beta1: Obsolescence	−0.042	0.005
Beta2: Diffusion	−1.149	0.174
Obs	1645	
R-squared	0.3967	

Table A3.2 Potential Deflators for Citing Patent Totals

Application Year	(1) Total Patents	(2) Index of Patent Total (1971=1)	(3) Citing Year Coefficient (from Table 3)	(4) Pure Propensity to Cite Effect [(3)/(2)]	(5) Simulated Cumulative Lag Distributions
1964	38384	0.372	0.009	42.405	1.000
1965	42463	0.411	0.009	46.538	1.000
1966	46476	0.450	0.010	44.581	1.000
1967	48037	0.465	0.039	12.067	1.000
1968	55835	0.541	0.035	15.673	1.000
1969	61551	0.596	0.044	13.558	1.000
1970	77053	0.746	0.067	11.073	1.000
1971	103238	1.000	1.000	1.000	1.000
1972	127434	1.234	1.364	0.905	1.000
1973	141482	1.370	1.458	0.940	1.000
1974	146242	1.417	1.610	0.880	1.000
1975	156657	1.517	2.793	0.543	1.000
1976	157919	1.530	2.331	0.656	1.000
1977	157999	1.530	2.265	0.676	1.000
1978	162982	1.579	2.914	0.542	0.999
1979	172569	1.672	3.216	0.520	0.999
1980	188125	1.822	3.403	0.535	0.999
1981	215451	2.087	2.918	0.715	0.998
1982	234062	2.267	3.588	0.632	0.998
1983	251376	2.435	3.620	0.673	0.997
1984	281199	2.724	5.912	0.461	0.995
1985	296936	2.876	6.010	0.479	0.994
1986	311280	3.015	6.617	0.456	0.992
1987	329264	3.189	8.317	0.383	0.989
1988	328058	3.178	8.576	0.371	0.986
1989	337067	3.265	9.781	0.334	0.981
1990	353767	3.427	11.419	0.300	0.976
1991	354566	3.434	11.658	0.295	0.969
1992	350295	3.393	17.850	0.190	0.961
1993	347392	3.365	25.004	0.135	0.950
1994	335192	3.247	25.874	0.125	0.938
1995	349496	3.385	33.105	0.102	0.923
1996	356750	3.456	37.539	0.092	0.906
1997	369729	3.581	39.828	0.090	0.885
1998	379620	3.677	41.331	0.089	0.861
1999	357517	3.463	56.578	0.061	0.833
2000	431019	4.175	64.321	0.065	0.800
2001	410458	3.976	81.087	0.049	0.763
2002	390164	3.779	99.346	0.038	0.719
2003	379853	3.679	130.808	0.028	0.670
2004	377792	3.659	152.609	0.024	0.615
2005	357352	3.461	185.592	0.019	0.552
2006	375100	3.633	178.601	0.020	0.482
2007	363117	3.517	136.259	0.026	0.404
2008	346722	3.358	96.696	0.035	0.318
2009	232028	2.248	69.499	0.032	0.222
2010	53233	0.516	129.565	0.004	0.116

Table A4 Country list in creating real exchange rates

Advanced economies (24 countries)	The other countries (79 countries)
Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Greece, Hong Kong SAR (China), Iceland, Ireland, Italy, Korea Rep., Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Swaziland, Sweden, United States	Algeria, Bahamas, Bahrain, Barbados, Belize, Bhutan, Botswana, Brunei Darussalam, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Colombia, Congo, Rep., Costa Rica, Cote d'Ivoire, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Equatorial Guinea, Ethiopia, Fiji, Gabon, Gambia, The, Grenada, Guatemala, Haiti, Honduras, Hungary, India, Indonesia, Iran, Islamic Rep., Jamaica, Jordan, Kenya, Kuwait, Lesotho, Libya, Malawi, Malaysia, Malta, Mauritius, Morocco, Myanmar, Nepal, Niger, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Philippines, Qatar, Rwanda, Samoa, Saudi Arabia, Senegal, Seychelles, Solomon Islands, South Africa, Sri Lanka, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Switzerland, Syrian Arab Republic, Tanzania, Thailand, Togo, Tonga, Trinidad and Tobago, Uganda, Vanuatu, Zambia

Notes: We use country data which do not have missing values of more than 5 years. When there are missing values, we substitute average values of adjacent data into the missing values. When CPI is 0, we substitute 0.1.

Table A5 Detailed result of Table 3 (at firm level)

		1	2	3	4
	Dep.	lnPat	lnCite	lnPat	lnCite
	Procedure	OLS	OLS	within	within
		Combined coef.	Combined coef.	Combined coef.	Combined coef.
		(S.E.)	(S.E.)	(S.E.)	(S.E.)
Manufacturing industries					
#08	$1-li$	32.945***	30.286***	235.931***	141.725**
		(5.102)	(5.525)	(69.731)	(77.808)
	$(1-li)^2$	−14.554***	−13.440***	−113.907***	−68.062*
		(4.865)	(5.269)	(35.711)	(39.848)
#10	$1-li$	51.533***	52.211***	5.392	−11.206
		(7.039)	(7.622)	(49.452)	(55.180)
	$(1-li)^2$	−34.974***	−36.603***	−2.566	5.137
		(6.907)	(7.479)	(27.037)	(30.168)
#11	$1-li$	35.322***	32.956***	−35.599***	−44.900***
		(2.305)	(2.496)	(11.336)	(12.650)
	$(1-li)^2$	−18.875***	−17.787***	16.665***	21.387***
		(1.550)	(1.679)	(5.582)	(6.229)
#12	$1-li$	−23.578**	−25.997*	−908.828**	−629.141
		(11.553)	(12.510)	(450.725)	(502.933)
	$(1-li)^2$	40.863***	41.288***	485.849**	348.264
		(11.543)	(12.499)	(229.669)	(256.271)
#13	$1-li$	29.375***	26.648***	−10.431	−58.290*
		(3.669)	(3.973)	(21.017)	(23.451)
	$(1-li)^2$	−11.018***	−9.873**	3.796	29.233*
		(3.284)	(3.556)	(10.805)	(12.057)
#15	$1-li$	39.652***	36.605***	−10.709	−1.187
		(2.099)	(2.272)	(7.831)	(8.738)
	$(1-li)^2$	−22.295***	−20.611***	3.941	−0.454
		(1.246)	(1.349)	(3.751)	(4.185)
#16	$1-li$	47.196***	43.391***	−10.941	−8.868
		(2.973)	(3.219)	(27.222)	(30.375)
	$(1-li)^2$	−29.771***	−27.290***	2.708	0.959
		(2.439)	(2.641)	(13.048)	(14.560)
#18	$1-li$	47.183***	44.783***	−11.186	−67.730**
		(2.509)	(2.717)	(23.175)	(25.859)
	$(1-li)^2$	−29.847***	−28.775***	4.662	31.186**
		(1.859)	(2.013)	(11.129)	(12.418)
#20	$1-li$	41.293***	41.752***	40.087	−19.756
		(3.555)	(3.850)	(44.347)	(49.484)
	$(1-li)^2$	−24.333***	−26.077***	−23.258	6.939
		(3.184)	(3.448)	(22.620)	(25.240)
#22	$1-li$	51.257***	48.225***	16.790	31.023
		(3.110)	(3.368)	(29.589)	(33.016)
	$(1-li)^2$	−31.569***	−29.649***	−10.264	−15.813
		(2.605)	(2.820)	(14.781)	(16.493)
#23	$1-li$	37.460***	36.957***	255.659***	138.841*
		(5.394)	(5.840)	(89.252)	(99.590)
	$(1-li)^2$	−18.867***	−19.851***	−126.339***	−67.947*
		(5.119)	(5.544)	(43.749)	(48.817)
#24	$1-li$	26.542***	18.567***	−25.654	100.254
		(4.456)	(4.825)	(89.308)	(99.653)
	$(1-li)^2$	−5.490	1.612	15.317	−46.427
		(4.182)	(4.529)	(45.724)	(51.021)
#25	$1-li$	15.223***	14.823**	−147.379	−83.290
		(5.580)	(6.043)	(96.541)	(107.724)
	$(1-li)^2$	8.086	7.642	77.770	41.753
		(5.368)	(5.813)	(48.918)	(54.584)
#26	$1-li$	44.941***	46.513***	−0.291	5.362
		(2.821)	(3.055)	(22.181)	(24.750)
	$(1-li)^2$	−24.350***	−26.978***	0.682	−3.177

		(2.262)	(2.450)	(11.026)	(12.303)
#28	$1-li$	36.987***	35.185***	9.783	15.516
		(2.246)	(2.432)	(10.801)	(12.052)
	$(1-li)^2$	−16.454***	−15.767***	−3.300	−5.914
		(1.431)	(1.549)	(5.469)	(6.103)
#29	$1-li$	47.040***	44.290***	8.125	16.431**
		(2.308)	(2.500)	(7.590)	(8.470)
	$(1-li)^2$	−26.716***	−25.664***	−2.366	−7.411*
		(1.501)	(1.625)	(4.046)	(4.515)
#30	$1-li$	35.260***	39.282***	173.740*	160.465
		(4.550)	(4.927)	(105.397)	(117.605)
	$(1-li)^2$	−16.527***	−22.065***	−82.458	−78.965
		(4.226)	(4.576)	(52.985)	(59.122)
#32	$1-li$	46.824***	48.993***	35.039	40.814
		(3.869)	(4.190)	(45.686)	(50.977)
	$(1-li)^2$	−26.458***	−29.884***	−18.686	−22.611
		(3.497)	(3.787)	(23.303)	(26.002)
#33	$1-li$	38.066***	38.402***	284.624***	186.836***
		(3.090)	(3.346)	(36.034)	(40.208)
	$(1-li)^2$	−19.848***	−21.123***	−140.030***	−92.664***
		(2.574)	(2.787)	(17.927)	(20.004)
#34	$1-li$	65.269***	65.652***	44.621	86.677**
		(3.138)	(3.398)	(27.325)	(30.490)
	$(1-li)^2$	−47.321***	−48.780***	−21.950	−42.922**
		(2.663)	(2.884)	(13.691)	(15.277)
#35	$1-li$	27.096***	19.961***	39.362*	43.424
		(2.845)	(3.081)	(23.803)	(26.561)
	$(1-li)^2$	−8.827***	−2.982	−15.490	−16.274
		(2.280)	(2.468)	(12.031)	(13.425)
#36	$1-li$	33.435***	31.934***	30.451**	30.450**
		(2.418)	(2.618)	(13.197)	(14.726)
	$(1-li)^2$	−15.084***	−14.749***	−15.300**	−16.071**
		(1.708)	(1.849)	(6.569)	(7.330)
#37	$1-li$	31.559***	28.542***	15.706	60.266***
		(2.523)	(2.732)	(16.644)	(18.572)
	$(1-li)^2$	−13.697***	−12.130***	−5.065	−26.336**
		(1.868)	(2.023)	(8.149)	(9.093)
#38	$1-li$	31.058***	29.296***	40.782*	−17.513
		(3.204)	(3.469)	(23.673)	(26.415)
	$(1-li)^2$	−11.208***	−10.303***	−17.557	11.069
		(2.692)	(2.915)	(11.818)	(13.186)
#39	$1-li$	37.915***	32.904***	93.396***	71.944**
		(3.020)	(3.270)	(30.480)	(34.010)
	$(1-li)^2$	−18.215***	−14.427***	−44.965***	−33.009**
		(2.497)	(2.704)	(14.885)	(16.609)
#40	$1-li$	24.610***	20.855***	−7.606	45.457
		(3.855)	(4.174)	(54.863)	(61.218)
	$(1-li)^2$	−9.537***	−7.154*	6.944	−17.897
		(3.499)	(3.789)	(27.603)	(30.800)
#41	$1-li$	45.428***	42.805***	57.569***	40.494**
		(2.391)	(2.590)	(13.371)	(14.920)
	$(1-li)^2$	−27.831***	−26.688***	−28.440***	−20.564**
		(1.667)	(1.805)	(6.753)	(7.535)
#42	$1-li$	45.097***	43.261***	39.782***	28.491**
		(2.229)	(2.413)	(13.238)	(14.771)
	$(1-li)^2$	−26.361***	−25.690***	−18.135***	−12.971**
		(1.481)	(1.603)	(6.249)	(6.973)
#43	$1-li$	38.977***	37.569***	19.589***	29.667***
		(2.045)	(2.214)	(6.070)	(6.774)
	$(1-li)^2$	−19.513***	−19.521***	−9.161***	−14.179***
		(1.141)	(1.236)	(2.933)	(3.273)
#44	$1-li$	39.539***	39.743***	−0.170	7.068
		(2.202)	(2.384)	(8.067)	(9.001)

	$(1-li)^2$	−20.309***	−21.804***	0.217	−3.819
		(1.356)	(1.468)	(4.014)	(4.479)
#45	$1-li$	46.114***	45.959***	4.712	102.247***
		(3.536)	(3.829)	(25.551)	(28.510)
	$(1-li)^2$	−26.506***	−28.234***	−3.691	−52.766***
		(3.169)	(3.432)	(12.992)	(14.497)
#46	$1-li$	38.856***	37.051***	72.820***	88.725***
		(2.616)	(2.833)	(15.496)	(17.291)
	$(1-li)^2$	−17.682***	−16.940***	−36.228***	−43.485***
		(1.930)	(2.090)	(8.039)	(8.970)
#47	$1-li$	48.199***	43.220***	−10.218	41.249**
		(2.324)	(2.517)	(14.353)	(16.015)
	$(1-li)^2$	−26.388***	−19.480***	3.543	−18.756**
		(1.597)	(1.469)	(6.969)	(7.776)
#49	$1-li$	35.064***	31.994***	46.968***	42.427***
		(2.447)	(2.650)	(15.143	(16.897)
	$(1-li)^2$	−13.905***	−11.670***	−21.819***	−18.535**
		(1.752)	(1.897)	(7.454)	(8.317)
#52	$1-li$	42.378***	40.676***	8.689	15.376*
		(2.315)	(2.507)	(9.242)	(10.312)
	$(1-li)^2$	−22.485***	−21.729***	−2.243	−5.626
		(1.548)	(1.676)	(4.669)	(5.210)
#53	$1-li$	43.544***	42.881***	15.245*	35.518***
		(2.247)	(2.433)	(8.884)	(9.913)
	$(1-li)^2$	−23.178***	−23.519***	−7.370*	−17.652***
		(1.447)	(1.567)	(4.441)	(4.956)
#54	$1-li$	69.528***	66.560***	−45.007	26.465
		(5.174)	(5.602)	(117.446)	(131.050)
	$(1-li)^2$	−46.638***	−44.182***	19.640	−14.369
		(4.911)	(5.318)	(58.678)	(65.475)
#55	$1-li$	31.082***	28.880***	163.757***	135.616***
		(3.063)	(3.317)	(34.055)	(37.999)
	$(1-li)^2$	−11.125***	−10.002***	−75.989***	−59.891***
		(2.575)	(2.788)	(17.221)	(19.216)
#56	$1-li$	46.932***	43.274***	5.467	8.523
		(2.673)	(2.894)	(22.917)	(25.571)
	$(1-li)^2$	−28.527***	−26.116***	−2.901	−3.595
		(2.078)	(2.250)	(10.854)	(12.111)
#57	$1-li$	49.916***	47.950***	−0.671	−3.168
		(2.311)	(2.502)	(10.888)	(12.150)
	$(1-li)^2$	−29.032***	−27.993***	−1.053	1.424
		(1.567)	(1.697)	(5.400)	(6.026)
#59	$1-li$	44.477***	39.499***	−2.864	52.097***
		(2.478)	(2.683)	(15.014)	(16.753)
	$(1-li)^2$	−26.050***	−22.193***	1.301	−24.332***
		(1.794)	(1.943)	(7.529)	(8.401)
Non-manufacturing industries					
#07	$1-li$	29.484***	25.128***	47.743***	30.163**
		(2.366)	(2.562)	(11.826)	(13.196)
	$(1-li)^2$	−13.6247***	−10.479***	−22.066***	−13.279*
		(1.601)	(1.734)	(5.610)	(6.260)
#09	$1-li$	26.060***	18.747***	154.600**	98.109
		(4.352)	(4.713)	(68.224)	(76.127)
	$(1-li)^2$	−7.692*	−2.250	−84.209**	−52.970
		(4.013)	(4.346)	(36.917)	(41.193)
#60	$1-li$	43.589***	40.842***	30.943*	53.389**
		(2.559)	(2.771)	(18.226)	(20.337)
	$(1-li)^2$	−26.993***	−25.202***	−15.660*	−25.626**
		(1.945)	(2.106)	(8.753)	(9.767)
#61	$1-li$	28.319***	27.713***	72.854***	12.112
		(2.617)	(2.834)	(22.910)	(25.564)
	$(1-li)^2$	−11.838***	−12.693***	−36.677***	−7.930
		(1.987)	(2.152)	(11.599)	(12.942)

#62	$1-li$	24.041***	29.264***	85.120	392.520***
		(5.267)	(5.703)	(94.310)	(105.235)
	$(1-li)^2$	−4.559	−11.366*	−37.320	−203.409***
		(5.256)	(5.691)	(49.633)	(55.382)
#63	$1-li$	34.851***	35.235***	42.319	9.331
		(3.976)	(4.305)	(35.375)	(39.473)
	$(1-li)^2$	−18.430***	−20.248***	−21.436	−3.521
		(3.701)	(4.007)	(18.474)	(20.614)
#67	$1-li$	25.307***	22.888***	−6.037	−10.774
		(2.153)	(2.332)	(9.114)	(10.169)
	$(1-li)^2$	−11.165***	−9.875***	1.661	3.478
		(1.310)	(1.419)	(4.443)	(4.958)
#68	$1-li$	29.179***	25.696***	0.815	14.847
		(2.393)	(2.591)	(15.161)	(16.917)
	$(1-li)^2$	−16.476***	−13.752***	−2.644	−10.527
		(1.639)	(1.775)	(7.695)	(8.586)
#69	$1-li$	29.423***	26.650***	−7.626	−5.512
		(2.373)	(2.570)	(6.542)	(7.300)
	$(1-li)^2$	−16.449***	−14.482***	3.130	2.453
		(1.526)	(1.652)	(3.469)	(3.871)
#71	$1-li$	25.641***	24.806***	14.025**	12.064
		(2.312)	(2.503)	(6.644)	(7.414)
	$(1-li)^2$	−12.078***	−12.092***	−7.592**	−6.815
		(1.453)	(1.573)	(3.497)	(3.903)
#73	$1-li$	34.199***	31.025***	−22.010	−29.220
		(2.707)	(2.931)	(19.344)	(21.584)
	$(1-li)^2$	−20.581***	−18.149***	11.504	15.882
		(2.105)	(2.279)	(9.616)	(10.729)
#74	$1-li$	36.634***	31.464***	−87.117	−236.812**
		(3.989)	(4.320)	(85.181)	(95.048)
	$(1-li)^2$	−23.163***	−18.960***	39.708	119.613**
		(3.658)	(3.961)	(43.928)	(49.017)
#75	$1-li$	29.415***	29.622***	−19.039	−52.160***
		(2.463)	(2.668)	(16.339)	(18.231)
	$(1-li)^2$	−15.888***	−16.947***	7.275	21.219**
		(1.784)	(1.932)	(7.823)	(8.729)
#76	$1-li$	29.988***	35.665***	78.983	−13.321
		(5.383)	(5.829)	(72.094)	(80.444)
	$(1-li)^2$	−13.802***	−20.775***	−35.927	5.380
		(5.121)	(5.545)	(35.898)	(40.056)
#77	$1-li$	31.304***	31.399***	−24.472	−24.617
		(2.865)	(3.103)	(19.905)	(22.211)
	$(1-li)^2$	−18.606***	−19.417***	9.378	8.067
		(2.293)	(2.483)	(10.704)	(11.943)
#78	$1-li$	44.823***	40.685***	−52.845***	−59.025***
		(2.928)	(3.171)	(16.834)	(18.784)
	$(1-li)^2$	−28.997***	−25.939***	26.593***	30.085***
		(2.436)	(2.638)	(8.718)	(9.728)
#89	$1-li$	26.874***	25.276***	−12.789*	−25.791***
		(2.280)	(2.468)	(7.515)	(8.385)
	$(1-li)^2$	−13.762***	−12.849***	5.776	12.144**
		(1.466)	(1.588)	(3.823)	(4.266)
#95	$1-li$	26.204***	25.318***	−27.484	−34.898
		(2.591)	(2.805)	(18.054)	(20.145)
	$(1-li)^2$	−13.251***	−12.967***	10.818	13.794
		(1.964)	(2.126)	(8.513)	(9.499)
#110	$1-li$	29.820***	27.912***	−12.193***	−11.777***
		(2.092)	(2.266)	(3.933)	(4.388)
	$(1-li)^2$	−15.927***	−15.082***	5.581***	5.262**
		(1.149)	(1.244)	(1.971)	(2.200)
	constant	−21.779***	−24.015***	−13.111***	−15.873***
		(0.997)	(1.080)	(1.605)	(1.791)
	Year dummy	Yes	Yes	Yes	Yes

Firm fixed effects	No	No	Yes	Yes
Obs	94510	94510	94510	94510
Group			3459	3459
Year	70−06	70−06	70−06	70−06
Adj−R2	0.3662	0.3696		
Within R2			0.1669	0.2113

Note: ***, **, and * denote significances at the 1, 5, and 10% level, respectively.