Preliminary

Open Innovations, Productivity and Export: Evidence from Japanese Firms*

ITO Banri
Senshu University and RIETI

TANAKA Ayumu
RIETI

Abstract

This paper empirically examines the relation between the firm's productivity and joint decision of R&D strategies and exporting, based on Japanese firm-level data and the simple theoretical framework which extends the firm heterogeneity model so that both internal (own R&D) and external (outsourcing or technology purchase) R&D strategies are taken into account. The empirical results from non-parametric and semi-parametric way show that exporting firms engaged in R&D activities are more productive than non-exporters and exporters with no R&D, regardless of the internal and external R&D strategy, and exporters engaged in the both R&D strategies are most productive, as predicted.

JEL: C14, D24, F10, O33
Keywords: R&D, open innovation, productivity, nonparametric tests

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1. Introduction

The recent seminal theoretical studies in international economics have focused on the role of firm heterogeneity in firm's internationalization (Melitz, 2003; Helpman, Melitz and Yeaple, 2004; Antràs and Helpman). They suggest that more productive firms succeed to enter international market. While the less productive firms supply for only domestic market, only the relatively more productive firms export. However, these studies rely on the assumption that the firm heterogeneity, the productivity differential is given from the outside of the model because they assume that firms stochastically draw their productivity level.

There are several studies which attempt to link productivity-enhancing investments such as R&D investments to exporting, and suggest a possible complementarity between the two activities (Yeaple, 2005; Lileeva and Trefler, 2007; Aw et al., 2009, 2011; Bustos, 2011). Although these studies examine the link between the R&D investments and exporting, they exclusively focus on firm's in-house R&D effort, and thus the expanding R&D outsourcing or technology purchase is not considered. The management literature emphasize that, in recent decades, factors such as development of ICT, increased global competition, and technology complexity have forced firms to shift from closed innovation to open innovation (Chesbrough, 2003; Christensen et al., 2005). Hence, productive firms may succeed in innovating by using external resources through buyer–supplier networks, strategic alliances, or research collaborations with unrelated firms. Nevertheless, the role of open innovation as a R&D strategy has not been analyzed in the context of the internationalization of firms.

This paper empirically examines the relation between the firm's productivity and joint decision of R&D strategies and exporting, based on Japanese firm-level data and the simple theoretical framework which extends the firm heterogeneity model so that both internal (own R&D investment) and external (R&D outsourcing or technology purchase) R&D strategies are taken into account. We apply both the non-parametric Kolmogorov–Smirnov (KS) tests and the semi-parametric quantile regressions (QRs) which allow the nature of data distribution rather than a parametric approach. Both results are qualitatively similar in the sense that they are consistent with the theoretical predictions. The results reveal that there is a remarkable heterogeneity among exporters according to their R&D strategy. Although the large fraction of exporters is non-R&D firms, their productivity is the lowest among exporters. Both exporters with purely internal R&D and exporters with purely external R&D are more productive than non-R&D exporters. The most productive ones are exporters engaged in the both internal and external R&D. The QRs additionally reveal an interesting result that internal R&D is more important for the less productive firms while external R&D is more important for the more productive firms. The results suggest that the internal R&D strategy is initially crucial for access to international market while open innovation is essential to further promote innovations for internationalized firms.

The remainder of this paper is organized as follows. In the next section, we present our theoretical framework. Section 3 describes data and descriptive statistics of key variables. In section 4, we present empirical strategy and the results of non-parametric and semi-parametric tests. Section 5 concludes with a summary.

2. Theoretical framework

Our theoretical framework is based on the simple model by Bustos (2011) that demonstrate the decision of exporting and upgrading technology by heterogeneous firms. We consider a monopolistic competitive industry in which firms produce differentiated goods as in literature of heterogenous firms (Melitz, 2003). The firms face the market demand function of a particular goods *j* drawn from a Dixit-Stiglitz type utility function, $x = Yp^{-\varepsilon}$ where *x* is the quantity, *Y* is the market size as demand level in home country, *p* is the price, and $\varepsilon = 1/(1-\alpha)$ is a constant elasticity of demand where α presents a parameter to determine the elasticity of substitution between goods with $0 < \alpha < 1$.

Firms produce the differentiated goods using labor and their productivity is heterogeneous as far as that marginal costs are different across firms even if they use the same technology. Let us index the productivity as θ. Before entering market, firms randomly draw the productivity level θ from Pareto distribution with cumulative distribution function $G(\theta)$, and then they decide to enter or to exit the market. To enter the domestic market, it is required to pay a fixed cost, f_D. The marginal cost for production, c, is expressed by $c = w\theta$, where θ is the productivity parameter to express the labor input coefficient, and w is the wage rate. Since we set symmetry assumption between the two countries, the wages are considered as the numeraire. For simplicity, the marginal cost of production is normalized to unity. Under the above assumptions, the prices of the goods are expressed as $p = c/(\alpha\theta)$. The profit of firms operating in domestic market is expressed as follows:

$$\pi_D = \phi Y - f_D \tag{1}$$

where $\phi = \theta^{\varepsilon-1}(\varepsilon-1)^{\varepsilon-1}\varepsilon^{-\varepsilon}$ is an easily recognized transformation of productivity measurement. To enter export market, firms must pay additional fixed cost and transportation costs. The fixed cost of export is f_E, and transportation costs are expressed by τ as iceberg trade costs ($\tau > 1$). From the symmetry assumption, demand function of foreign country for a particular good is given by $x^{*}=Y^{*}p^{-\varepsilon}$, and then the profit function including decision of export is rewritten as:

$$\pi_E=\phi\left(Y+E\tau^{-\varepsilon}Y^{*}\right)-Ef_E \quad (2)$$

where E=0, 1 indicates the firm's exporting decision. As described in Melitz (2003), the firm enters to export market when ϕ surpasses the cutoff point of $f_E/\left(\tau^{-\varepsilon}Y^{*}\right)$.

Firms have options to upgrade their technology accompanied by paying an additional fixed cost such as R&D investments. There are two choices of R&D strategies. One is internal R&D strategy which means that firms implement own R&D investment, and the other one is external R&D strategy which means that firms rely on R&D outsourcing or technology purchase. Firms engaged in the internal R&D strategy pay an additional fixed cost f_{IR} and can increase their productivity from ϕ to $\delta\phi$ $(\delta>1)$ while those engaged in external R&D strategy pay an additional fixed cost f_{ER} and can increase the productivity from ϕ to $\lambda\phi$ $(\lambda>1)$. The profit of firm with internal R&D strategy and that with external R&D strategy are expressed as follows, respectively:

$$\pi_{E,IR}=\delta\phi\left(Y+E\tau^{-\varepsilon}Y^{*}\right)-Ef_E-f_{IR} \quad (3)$$

$$\pi_{E,ER}=\lambda\phi\left(Y+E\tau^{-\varepsilon}Y^{*}\right)-Ef_E-f_{ER} \quad (4)$$

We also consider firm that adopts the both internal and external R&D strategies. The productivity can be improved from ϕ to $\gamma\phi$ $(\gamma>1)$, and the profit when the firm uses the two R&D strategies is as follows:

$$\pi_{E,IR,ER} = \gamma\phi\left(Y + E\tau^{-\varepsilon}Y^{*}\right) - Ef_{E} - f_{IR} - f_{ER} \tag{5}$$

From these profits according to possible choices, only firms with a productivity level above the following cutoff find it profitable to engage in R&D.

$$\phi_{IR} > \frac{f_{IR}}{(\delta - 1)\left(Y + E\tau^{-\varepsilon}Y^{*}\right)} \tag{6}$$

$$\phi_{ER} > \frac{f_{ER}}{(\lambda - 1)\left(Y + E\tau^{-\varepsilon}Y^{*}\right)} \tag{7}$$

$$\phi_{IR,ER} > \frac{\left(f_{IR} + f_{ER}\right)}{(\delta\lambda - 1)\left(Y + E\tau^{-\varepsilon}Y^{*}\right)} \tag{8}$$

Following Bustos (2011), we focus on the case where the productivity level in engagement of R&D is larger than that in engagement only export. From this restriction, the case of that firms operating in only domestic market with R&D strategy is not considered while there exists exporting firms without R&D strategy.

It is an interesting issue to derive the cutoff among the three modes of R&D strategies undertaken by exporters, (i) internal R&D, (ii) external R&D, and (iii) both internal and external R&D strategies. The decision whether the firm chooses internal R&D or external R&D depends on the parameter to shift the productivity and fixed costs. However, it is difficult to determine the sign condition of these factors between internal R&D and external R&D. The theory of "make-or-buy" decisions has been leaded by the two main approaches; the transaction cost economics approach represented by

Williamson (1975; 1985) and the property rights theory approach represented by Grossman and Hart (1986) and Hart and Moore (1990). Based on the assumption of incomplete contracts and relationship-specific investment, the two approaches propose a way of overcoming the possible hold-up problem due to ex-post opportunistic behavior. The transaction cost economics approach insists that the hold-up problem can be avoided by vertical integration, and firms are likely to be more vertically integrated when the relation specificity is greater. On the other hand, the property right theory approach emphasize that allocating residual rights of control to the firm whose relation-specific investment is more important in making production efficient. This argument is associated with that the outside option is different between vertical integration and non-integration (i.e., outsourcing). If a firm chooses vertical integration, its outside options increase by obtaining the residual rights of control and foregoing the supplier's incentive to invest in the relationship. Hence, vertical integration is not always efficient. In particular, outsourcing strategy is incentive for the supplier to invest in the relationship when the supplier's investment plays an important role. From the transaction cost economics approach, it is predicted that the greater asset specificity is positively correlated with vertical integration regardless of which firm carry on the relation specific investment. The prediction suggested by the property rights theory is that the increase in relation specific investment of buyer has positive effect on the probability of vertical integration while that of supplier should negatively affect it. Assuming that the asset specificity can be attributed by firm-specific factors, the decision for the two modes of R&D strategies is influenced by not only the parameter shifting the productivity and fixed cost but also firm-specific factors. Hence some firms may prefer the internal R&D while the other firms likely to prefer external R&D even if their productivity level is the same.

On the other hand, comparing the profit of the mixed strategy of internal R&D and external R&D with the single strategy, the cutoff for switching from the single strategy to the mixed strategy can be derived as follows:

$$\phi'_{IR,ER} > \frac{f_{ER}}{(\gamma-\delta)(Y + E\tau^{-\varepsilon}Y^{*})} \tag{9}$$

$$\phi''_{IR,ER} > \frac{f_{IR}}{(\gamma-\lambda)(Y + E\tau^{-\varepsilon}Y^{*})} \tag{10}$$

where $\phi'_{IR,ER}$ is the cutoff for switching from the internal R&D strategy to the mixed strategy while $\phi''_{IR,ER}$ denotes that from the external R&D strategy to it. Suppose that these cutoff values are larger than ϕ_{IR} or ϕ_{ER}, both inequalities $\phi'_{IR,ER} > \phi_{IR}$ and $\phi''_{IR,ER} > \phi_{ER}$ must be satisfied. Combining the two inequalities leads the following inequality.

$$\frac{(\gamma-\lambda)}{(\lambda-1)} < \frac{f_{IR}}{f_{ER}} < \frac{(\delta-1)}{(\gamma-\delta)} \tag{11}$$

Under this condition, only firms with a productivity level above the following cutoff find it profitable to engage in both internal and external R&D than single R&D strategy. In our empirical analysis, the following order of productivity level can be tested, $\phi_D < \phi_E < \phi_{E,IR}$ or $\phi_{E,ER} < \phi_{E,IR,ER}$. In other words, exporters engaged in both internal and external R&D are the most productive, and they are followed, in descending order of productivity, by exporters engaged in internal or external R&D, exporters which do not engage in R&D and non-exporters.

3. Data and descriptive statistics

3.1 Data

Our empirical analysis is based on a firm-level data retrieved from the *Basic Survey of Japanese Business Structure and Activities* (*Kigyo Katsudo Kihon Chosa* in Japanese) for the period 1997–2007 conducted by the Japan Ministry of Economy, Trade, and Industry (METI). Completing this annual national survey is mandatory for all firms with 50 or more employees and paid-up capital or investment funds exceeding ¥30 million in the mining, manufacturing, wholesale, retail, and food and beverage industries.[1]

We use Japanese parent firms' TFP as our measure of productivity. The TFP is obtained

[1] The response rate of METI survey is more than 80% of population.

from an estimated two-digit industry-specific production function, using Levinsohn and Petrin (2003) techniques. We use Japanese parent firms' real value added as the output and hours worked (*L*) and fixed tangible assets (*K*) as inputs. Following Arnold and Hussinger (2010) who examine the relationship between productivity and patterns of export and FDI, we use the relative TFP to compare the TFP for various industries. The relative TFP is obtained by dividing the TFP estimates by the average TFP in the respective industry and year. All nominal values are deflated by an industry-level deflator, which is taken from the System of National Account Statistics.

3.2 Descriptive statistics

The data provides us with the information on whether a firm (i) conducts own R&D, (ii) outsources R&D, and (iii) purchases technological knowledge. We define own R&D as internal R&D and outsourcing R&D and technology purchase as external R&D. Based on this definition and exporting status, we classify all firms into eight types: non-exporters without any kinds of R&D, non-exporters with internal R&D, non-exporters with external R&D, non-exporters with both internal and external R&D, exporters without any kinds of R&D, exporters with internal R&D, exporters with external R&D, and exporters with both internal and external R&D.

Table 1 displays the number of firms for the eight types of firms. Non-exporters without any kinds of R&D are majority. Although there are non-exporters with internal and/or external R&D, in our empirical analysis, we will exclude them since our theoretical model does not take them into account. However, we obtain qualitatively similar results, as reported in Tables A1 and A2 of the Appendix, even when we include them in the analysis. Among exporters, there are a large number of exporters without any kinds of R&D expenditure. Many exporters conduct internal R&D only, while relatively small number of exporters conducts external R&D only. Exporters with both type of R&D are many.

Table 1 The number of firms by types

	Non-exporters	Exporters	Total
No R&D	6177	1210	7387
Internal R&D	2297	1865	4162
External R&D	253	170	423
Both R&D	539	1113	1652
Total	9266	4358	13624

Table 2 presents the mean of TFP by the eight firm types. It shows that exporters are on average more productive than non-exporters in line with the previous studies. It, however, reveals that there is substantial heterogeneity within exporters. Exporters without any kinds of R&D are less productive than exporters with R&D and they are even less productive than non-exporters with R&D. Among firms with R&D, firms with both internal and external R&D are more productive than firms with single type of R&D. These results suggest that there is a link between firm productivity and R&D status.

Table 2 Average TFP by firm types

	Non-exporters	Exporters	Total
No R&D	0.394	0.586	0.425
Internal R&D	0.688	1.133	0.887
External R&D	0.887	1.409	1.096
Both R&D	2.989	4.268	3.850
Total	0.630	1.790	1.000

4. Empirical strategy

4.1. KS tests

We employ two empirical methods to examine the relationship between firm productivity and various R&D and export status. First, we employ the non-parametric Kolmogorov–Smirnov (KS) test. We use the KS test because it is a stricter test of productivity differences than just comparing mean levels of productivity in the sense that it considers all moments of the distribution. The KS tests allow us to compare overall productivity distribution of firms by R&D and export status, based on the concept of first order stochastic dominance. First-order stochastic dominance of $G_1(\theta)$ with respect to $G_2(\theta)$ is defined as $G_1(\theta) - G_2(\theta) \leq 0$ uniformly in $\theta \in \Re$, with strict equality for some θ. In order to examine the stochastic dominance, we conduct one-sided and two-sided KS tests.

The two-sided KS test examines the hypothesis that both distribution, $G_1(\theta)$ and $G_2(\theta)$, are identical. The null and alternative hypotheses can be expressed as

$$H_0 : G_1(\theta) - G_2(\theta) = 0 \quad \text{for all} \quad \theta \in \Re$$

$$\text{vs.} \quad H_1 : G_1(\theta) - G_2(\theta) \neq 0 \quad \text{for some} \quad \theta \in \Re .$$

The one-sided test of stochastic dominance can be formulated as:

$$H_0 : G_1(\theta) - G_2(\theta) \leq 0 \quad \text{for all} \quad \theta \in \Re$$

$$\text{vs.} \quad H_1 : G_1(\theta) - G_2(\theta) > 0 \quad \text{for some} \quad \theta \in \Re .$$

If the null hypothesis for the two-sided test is rejected and the null hypothesis for the one-sided test is not rejected, we can conclude that $G_1(\theta)$ stochastically dominates $G_2(\theta)$. Following previous studies such as Delgado et al. (2002), we conduct the KS test separately for each year from 2001 to 2008, since the independence assumption is likely to be violated if we use pooled observations from several years for the KS test.

4.2. Quantile regression

Second, we also use the semi-parametric quantile regression (QR) to examine the relationship between firm productivity and exporting/R&D status. QRs have several attractive features and used by Wagner (2006) and Arnold and Hussinger (2010) in trade literature. One of these attractive features is that the QRs estimates are more robust to outliers than the ordinary least squares (OLS) estimates by relaxing the normality assumption.[2] Another attractive feature is that the QRs allow us to estimate the impacts of covariate on any particular percentile of the distribution, while the OLS allow us to estimate the average relationship only.

Using the QRs, we obtain the qth QR estimator β_q which minimizes over β_q the following objective function:

$$Q(\beta_q) = \sum_{i:y_i \geq x_i'\beta_q}^{N} q \left| \ln TFP_i - x_i'\beta_q \right| + \sum_{i:y_i < x_i'\beta_q}^{N} (1-q) \left| \ln TFP_i - x_i'\beta_q \right| \qquad (12)$$

where $0 < q < 1$, i indexes firm, and x_i is a vector of covariates. We obtain the coefficients by the linear programming method since the objective function is not differentiable. All of the data are being used for each QR. The weights q vary across each QR. QRs can provide parameter estimates at different quantiles. The estimated coefficients can be interpreted as the partial derivative of the conditional quantile of the

[2] In fact, the distribution of TFP is highly skewed. The Shapiro-Wilk test rejects the normality at the significance level of 1%.

dependent variable with respect to a particular covariate. In our case, for example, the estimated coefficient indicates that the marginal change in the log of TFP at the qth conditional quantile due to a marginal change in the capital-labor ratio. QR is semi-parametric in the sense that it avoids assumptions about parametric distribution of regression errors.

5. Results

5.1 The KS tests

Before the KS tests, we graphically examine the cumulative distribution functions (CDF) of TFP by exporting and R&D status. Figure 1 displays the CDF of TFP. The TFP distributions of exporters are located on the right side of that of non-exporters. Among exporters, exporters without R&D are distributed over the lowest-productivity range, while exporters with both in-house and outsourcing R&D are distributed over the highest-productivity range. Exporters with in-house R&D only and exporters with outsourcing R&D only are distributed over the middle range of productivity. These graphical assessments suggest that exporters are more productive than non-exporters, that among exporters, exporter with R&D are more productive than exporters without R&D, and that exporters with both type of R&D are more productive than exporters with single type of R&D.

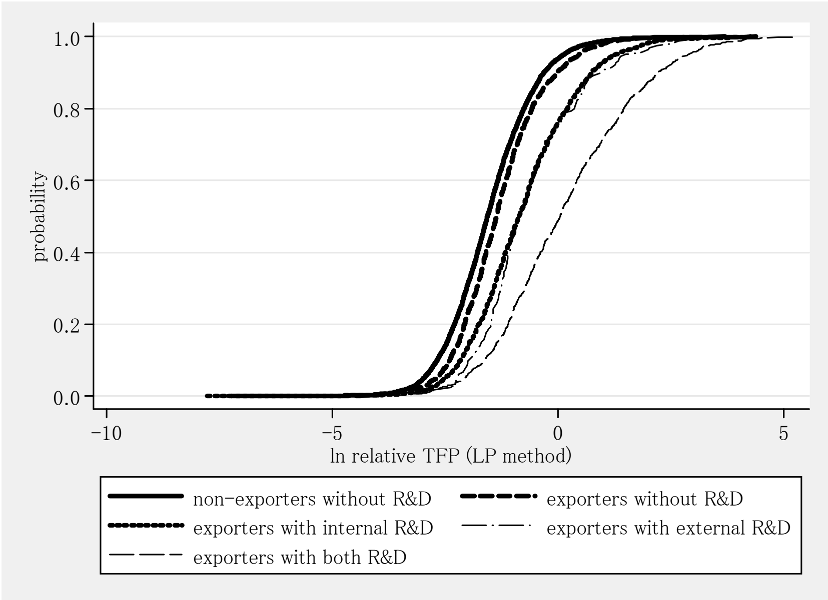

Figure 1: CDF of TFP in the manufacturing sector (2008).

Next, we formally examine the relationship between firm productivity and export/R&D status using the KS tests. Table 2 presents the KS test statistics for type A firms versus type B firms. From the test statistics, we can derive several conclusions for the TFP distribution: (i) the first row indicates that the productivity distribution of exporters with no R&D stochastically dominates the productivity distribution of non-exporters with no R&D; (ii) the second and third rows indicate that the productivity distribution of exporters with internal or external R&D only stochastically dominates the productivity distribution of exporters with no R&D; and (iii) the fifth and sixth rows indicate that the productivity distribution of exporters with both internal and external R&D stochastically dominates the productivity distribution of exporters with internal or external R&D only. We cannot reject the hypothesis of identical distributions of TFP for exporters with internal R&D only relative to exporters with external R&D only.

Table 2

Kolmogorov-Smirnov tests statistic: Exports and R&D status (2008): Restricted sample

N. of firms		Statistic	
Type A	Type B	Two-sided	One-sided
Non-exporter, No R&D	Exporter, No R&D	H0: equality	H0: A < B
6177	1210	0.096	-0.003
(45.3)	(08.9)	[0.000]	[0.979]
Exporter, No R&D	Exporter, Internal R&D	H0: equality	H0: A < B
1210	1865	0.220	-0.003
(08.9)	(13.7)	[0.000]	[0.989]
Exporter, No R&D	Exporter, External R&D	H0: equality	H0: A < B
1210	170	0.259	-0.002
(8.9)	(1.3)	[0.000]	[0.999]
Exporter, Internal R&D	Exporter, External R&D	H0: equality	H0: A < B
1865	170	0.086	-0.019
(13.7)	(1.3)	[0.217]	[0.893]
Exporter, Internal R&D	Exporter, Both R&D	H0: equality	H0: A < B
1865	1113	0.276	0.000
(13.7)	(8.2)	[0.000]	[1.000]
Exporter, External R&D	Exporter, Both R&D	H0: equality	H0: A < B
170	1113	0.282	-0.012
(1.3)	(8.2)	[0.000]	[0.961]

Notes: The data are for Japanese firms in 2008. The Table shows the Kolmogorov-Smirnov tests statistics for type A firms versus type B firms. Asymptotic P-values are shown in brackets. The share of each firm type in all types is shown in parenthesis.

Although the results of K-S test have the advantage of allowing the distributional nature of data, other factors affecting the performance are not considered here. The following section summarizes the results of regression approach which enables to control for other influences on the performance.

5.2 The QRs

Table 3 Estimation results of the QRs

Premia (dependent variable: ln TFP): Restricted sample						
	Pooled OLS	Quantile regressions				
		0.10	0.25	0.50	0.75	0.90
Export, No R&D	0.067***	0.070***	0.056***	0.065***	0.068***	0.049***
	[0.017]	[0.014]	[0.006]	[0.006]	[0.006]	[0.014]
Export, Internal R&D	0.147***	0.182***	0.154***	0.147***	0.133***	0.108***
	[0.021]	[0.009]	[0.004]	[0.005]	[0.004]	[0.010]
Export, External R&D	0.194***	0.151***	0.176***	0.162***	0.185***	0.240***
	[0.034]	[0.023]	[0.015]	[0.013]	[0.021]	[0.026]
Export, Both R&D	0.228***	0.259***	0.235***	0.219***	0.210***	0.194***
	[0.026]	[0.013]	[0.007]	[0.008]	[0.010]	[0.012]
ln K/L	0.139***	0.179***	0.173***	0.153***	0.133***	0.121***
	[0.021]	[0.005]	[0.004]	[0.003]	[0.004]	[0.003]
Foreign ownership ratio	0.239***	0.125***	0.168***	0.221***	0.272***	0.337***
	[0.033]	[0.014]	[0.014]	[0.013]	[0.018]	[0.011]
ln Labor	1.067***	1.075***	1.070***	1.067***	1.064***	1.060***
	[0.012]	[0.002]	[0.003]	[0.002]	[0.003]	[0.004]
R square	0.865	0.552	0.610	0.651	0.680	0.697
N	79248	79248				

Notes: Constants and industry and year fixed effects are suppressed. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in brackets. Nonexporters with positive R&D expenditure are excluded.

Next, we employ the QRs. While the KS tests only focus on firm productivity, the QRs allow us to examine the relationship between firm productivity and exporting/R&D status, controlling for the other firm-specific variables such as capital-labor ratio, firms size, and foreign-ownership ratio. We also employ OLS regression as a benchmark.

Table 3 presents the results. The results from the OLS indicate that the productivity premiums are the largest for exporters with both types of R&D, followed by exporters with internal or external R&D only. Average difference in productivity between exporters with no R&D and non-exporters with no R&D is not statistically significant. The OLS estimates also shows that capital-labor ratio, foreign-ownership ratio, and firm size are all statistically significantly and positively associated with higher productivity.

The results from QRs are qualitatively similar with the results from the KS tests in the sense that the results are consistent with the theoretically predicted ranking of productivity. The results show statistically significant and positive productivity premiums for all type of exporters relative to non-exporters with no R&D in all cases.

Following Arnold and Hussinger (2010), we conduct *t*-tests to examine the statistical significance of the difference between any pairs of the coefficients. The comparison of the estimated coefficients reveals that the premium for exporters with both type of R&D are consistently and significantly higher than for exporters with internal or external

R&D only, with the exception of the highest two TFP quantile for the comparison between exporters with both type of R&D and exporters with external R&D only. It also reveals that the premiums for exporters with single type of R&D are consistently and significantly higher than for exporters with no R&D.

While the OLS estimates only reveal the average relationship, the QRs estimates show the richer description of the relationship between firm productivity and firm types. Specifically, the QRs reveal that the magnitude of internal R&D dummy is large for the less productive firms, while that of external R&D is found to be large for the more productive firms. This result suggests that the least productive exporters are easy to engage in the external R&D to internal R&D while the most productive firms are likely to prefer the internal R&D to external R&D

Regarding the covariates, the QRs shows that capital-labor ratio, foreign-ownership ratio, and firm size are all statistically significantly and positively associated with higher productivity. These results are the same with the results from the OLS.

Table A2 show the result of QRs using full sample including non-exporters engaged in R&D as control group in the dummy. Again, the results indicate statistically significant and positive productivity premiums for all type of exporters relative to non-exporters with no R&D in almost all cases with the exception of the highest TFP quantile for the exporters with no R&D dummy. One possible reason for this exception may be a lack of variation in the top quantile, since the number of exporters with no R&D decreases upon approaching the top end of the productivity distribution, as suggested in Arnold and Hussinger (2010).

5. Concluding remarks

The recent empirical literature on firm heterogeneity and international trade has attempted to associate the firm's R&D investment with exporting, and has suggested the complementarity between the two activities. Nevertheless, the rise of open innovation in this past decade as a new R&D strategy has received little empirical attention in this context. To illuminate this issue, this paper examined the relationship between the firm's productivity and joint decision of R&D strategies and exporting, using firm-level data for Japanese manufacturing industries.

First, exporting firms engaged in R&D activities are more productive than non-exporters and exporters with no R&D, regardless of the internal and external R&D strategy. Exporters engaged in the both R&D strategies are most productive. The results suggest that open innovation is complementary to in-house strategy and crucial to further promote innovations for internationalized firms. Second, in terms of whether there is a significant difference in the productivity of exporter between the two R&D strategies, the result of the non-parametric tests supports the equality. However, the results from QRs suggest that the choice between internal and external R&D by exporters is different according to productivity level. For the less productive exporters, external R&D strategy may be more applicable than internal R&D, and vice versa for the more productive exporters. This may reflect internalization by knowledge intensive firms which face transaction costs associated with higher degrees of asset specificity.

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Appendix: Results using full sample

Table A1 Kolmogorov-Smirnov tests statistic: Exports and R&D status (2008): Full sample

N. of firms		Statistic	
Type A	Type B	Two-sided	One-sided
Non-exporter	Exporter, No R&D	H0: equality	H0: A < B
9266	1210	0.054	-0.024
(68.0)	(08.9)	[0.004]	[0.301]
Exporter, No R&D	Exporter, Internal R&D	H0: equality	H0: A < B
1210	1865	0.220	-0.003
(08.9)	(13.7)	[0.000]	[0.989]
Exporter, No R&D	Exporter, External R&D	H0: equality	H0: A < B
1210	170	0.259	-0.002
(8.9)	(1.3)	[0.000]	[0.999]
Exporter, Internal R&D	Exporter, External R&D	H0: equality	H0: A < B
1865	170	0.086	-0.019
(13.7)	(1.3)	[0.217]	[0.893]
Exporter, Internal R&D	Exporter, Both R&D	H0: equality	H0: A < B
1865	1113	0.276	0.000
(13.7)	(8.2)	[0.000]	[1.000]
Exporter, External R&D	Exporter, Both R&D	H0: equality	H0: A < B
170	1113	0.282	-0.012
(1.3)	(8.2)	[0.000]	[0.961]

Notes: The data are for Japanese firms in 2008. The Table shows the Kolmogorov-Smirnov tests statistics for type A firms versus type B firms. Asymptotic P-values are shown in brackets. The share of each firm type in all types is shown in parenthesis. Non-exporters including non-exporters with positive R&D expenditure.

Table A2 Premia (dependent variable: ln TFP): Full sample

	Pooled OLS	Quantile regressions				
		0.10	0.25	0.50	0.75	0.90
Export, No R&D	0.022	0.034***	0.022***	0.026***	0.019***	-0.003
	[0.016]	[0.012]	[0.004]	[0.004]	[0.004]	[0.008]
Export, Internarl R&D	0.092***	0.130***	0.109***	0.097***	0.074***	0.047***
	[0.013]	[0.009]	[0.004]	[0.005]	[0.004]	[0.008]
Export, External R&D	0.140***	0.114***	0.131***	0.116***	0.129***	0.182***
	[0.032]	[0.025]	[0.020]	[0.011]	[0.019]	[0.037]
Export, Both R&D	0.157***	0.198***	0.172***	0.152***	0.135***	0.116***
	[0.017]	[0.009]	[0.009]	[0.007]	[0.010]	[0.007]
ln K/L	0.154***	0.194***	0.189***	0.169***	0.148***	0.135***
	[0.025]	[0.002]	[0.003]	[0.002]	[0.003]	[0.002]
Foreign ownership ratio	0.254***	0.123***	0.173***	0.228***	0.288***	0.372***
	[0.037]	[0.014]	[0.010]	[0.008]	[0.007]	[0.013]
ln Labor	1.078***	1.085***	1.081***	1.079***	1.077***	1.070***
	[0.010]	[0.003]	[0.001]	[0.002]	[0.002]	[0.003]
Pseudo R square	0.862	0.552	0.610	0.649	0.674	0.688
N	105023	105023				

Notes: Constants and industry and year fixed effects are suppressed. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in brackets.