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Why Do Some Firms Persistently Outperform Others? An investigation of the interactions between innovation and export strategies

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Why Do Some Firms Persistently Outperform Others?
An investigation of the interactions between innovation and export strategies

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Abstract

Although heterogeneity in the performance of firms is a well-established stylized fact, we still lack full understanding of its origins and the reasons why it persists. Instead of assuming that performance differences are exogenous, this paper focuses on two endogenous strategies - innovation and global engagement - and interprets them as two ways to accumulate knowledge and improve firms' capabilities. We are particularly interested in analyzing interactions between these strategies and their effect on firms' performance. By using a firm-level panel dataset drawn from a Japanese large-scale administrative survey for the years 1994 - 2003, we first find that innovation and exporting strategies are characterized by complementarities, which define coherent productive models or patterns of learning. Second, we show that these different strategies lead to various performances in terms of productivity and survival. Third, by using a propensity score matching approach, we show that these differences in performance are lasting. Overall, our paper shows that the interaction of innovation and export investments is a source of permanent differences in performance among firms.

Key words: heterogeneity of firms, productivity, exports, R&D, Japanese economy
JEL classification: L23, L25, O33, B52

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Introduction

Heterogeneity in the performance of firms has long been recognized, and it has been studied as a well-established fact since before the seminal papers of Nelson (1981, 1991). Further, it has been found that performance differences are persistent, concern firms of similar size, and pertain within narrowly defined industry sectors (Bartelsman & Doms, 2000). However, understanding of why some firms or plants *persistently* perform better is still limited. We know that technology and governance explain many observed differences,[2] but we have not fully identified the origin of this heterogeneity. Moreover, economic models generally assume that performance differences are exogenous, making it difficult to explain how firms' endogenous strategic choices interact.

This is particularly important because complementarities between strategic choices may help to define few possible strategies and explain why performance differences may be structural and therefore persistent.[3] This set of difficulties has been clearly identified by Bartelsman and Doms (2002): "What are the factors underlying productivity growth? Some of the factors that have recently been examined include managerial ability, technology, human capital, and regulation. Although these factors are all thought to be important, not much is known about their relative importance or about the way they interact. … In summary, the issue of technology is a component of the many choices facing individual producers. By trying to isolate the effects of technology choice on productivity, one may obscure the rich set of concerns facing producers as they attempt to meet the market."

The theoretical and empirical literature on international engagement and productivity at the micro level offers a good example of this difficulty and may be central in understanding performance dispersion among firms, especially during the recent decades characterized by globalization. The prediction of Helpman et al. (2004) has been verified by several empirical contributions: internationally engaged firms (through export and/or FDI) are larger and perform better. We have here an unambiguous stylized fact regarding differences of performance among firms. However, we are far from any convincing explanations of the origins of these different performances. In the model of Helpman et al. (2004), productivity levels are assumed to be drawn casually from a probability distribution, and firms' strategies depend on the level of their production costs (including trade costs and costs of operating abroad).The same applies to the

[2] As for technology, see, for example, Nelson (1991), Dosi & Malerba (1996) Dosi et al. (2000). Furthermore, Bloom and Van Reenen (2007) have recently analyzed the impact of diverse modes of organization (including governance) on performance. Geroski et al. (2009) is another interesting contribution, which shows that innovation, combined with sound financial status (e.g., low debt), is a source of persistently superior performance.

[3] Among other possible reasons for this persistence, one has been emphasized by various authors: the nature of technological knowledge is tacit, and it is difficult to transfer or to imitate best practices (see Dosi et al., 2000).

more specific relation between exports and productivity. Since the seminal paper of Bernard and Jensen (1999), hundreds of papers have investigated this link. The basic finding is that there is a selection process through which "better" firms enter the export market; however, there is no clear evidence that they learn from exporting. This double result is characteristic of the problem mentioned earlier. First, identifying a self-selection process is an initial step in understanding the heterogeneous performance of firms, but it does not explain the origin of performance differences. In particular, it does not allow us to evaluate the role of firms' *deliberate* investment decisions to increase productivity. Second, disregarding the potential learning effects of exporting impedes us from analyzing how global engagement may be a further source of intra-industry diversity. To overcome these difficulties, some papers have tried to explain why it is difficult to trace an effect from export to performance and have identified a possible missing link between them, which improves the absorptive capacity of firms, their ability to learn from exporting: innovation (Aw et al., 2005, 2009; Castellani & Zanfei, 2007).

Therefore, what has to be done is clear. First, analyze the endogenous source of performance differences by investigating the impact of strategies in innovation and international engagement. Then analyze the interrelations of these strategies to determine if their complementarities create permanent differences in performance. Our focus has to be understood as follows. The meaning of these complementarities is that a specific firm's choice to invest in one activity is conditioned by another investment, especially if the effect of this particular investment depends on previous investments. If these complementarities are significant, they may help to define coherent alternative *productive models* (Oï, 1983) or patterns of learning (Dosi & Malerba, 1996). Of course, firms are not locked into any given productive pattern of learning and may switch successfully from one productive model to another. An important task is then to identify coherent and viable strategies.

This paper takes up this challenge by investigating the case of Japanese firms. This case is particularly interesting, because an increasing dispersion of performance has been observed since the mid-1990s (Fukao & Kwon, 2006; Ito & Lechevalier, 2009). A key issue is to determine if this increasing dispersion is temporary or lasting. Moreover, Ito and Lechevalier (2009) investigate the determinants of intra-industry productivity dispersion and report three findings at the industry level: (1) the effect of exports and imports is positive; (2) the effect of information and communication technologies (ICT) is negative; (3) the effect of R&D intensity is insignificant.

Notwithstanding these results, it may be misleading to conclude that export strategies are a source of performance dispersion and innovation strategies are not. In this paper, we go one step further in analyzing how things operate at the micro level and which types of firms performed better than others. As an alternative to approaches that implicitly postulate that initial differences in productivity come from luck of the draw, we aim to define underlying modes of production that may be defined by the interaction of internationalization and R&D strategies. Following recent papers (Aw et al., 2005, 2009; Baldwin & Gu, 2004; Criscuolo et al., 2005; Damijan et al., 2008; Roper & Love, 2002; Castellani & Zanfei, 2007), we distinguish firms according to their decisions to export and to innovate.

Our contribution can be summarized as follows. First, we confirm the complementarities between investments in R&D and exporting. Based on these investment choices, we define four strategies that are stable enough to constitute different *productive models or cognitive models*. Second, we show that these four strategies are associated with various performances in terms of productivity and survival. In fact, it is possible to establish a performance ranking with the exporting and innovative firms being the best-performing, followed by the innovative firms, exporting firms, and firms that do not participate in either activity. Third, by using propensity score matching, we examine the effect of a change in firms' strategy on the evolution of their performance. We find that firms enjoy higher productivity growth after they start exporting if they had already conducted R&D activities and accumulated some knowledge internally. Moreover, even three years after they started exporting, such firms exhibit higher productivity growth than firms that did not start exporting, suggesting that the differences in performance are long lasting. In sum, our paper shows that innovation and exporting interact to produce permanent differences in performance among firms. To obtain these results, we use the *Basic Survey of Japanese Business Structure and Activities* (BSBSA, or *kigyo katsudo kihon chosa*), a large-scale administrative survey conducted annually by the Japanese Ministry of Economy, Trade and Industry (METI), for the years 1994–2003.

The remainder of this paper proceeds as follows. In Section 1, we argue that literature concerning international engagement, innovation, and productivity performance is potentially important for understanding the causes of persistent performance dispersion among firms. This is particularly true if it is interpreted from the perspective of cognitive approaches of the firm. In Section 2, we present basic facts about productivity dispersion among Japanese firms, and we specify how patterns of innovation and export strategies may be creating a new divide among Japanese firms. In Section 3, we model firms' strategies in innovation and export as well as productivity patterns. In Section 4, we present empirical results showing that the innovation and export decisions are highly path-dependent and that these two decisions are interrelated. Moreover, our empirical results suggest that R&D and export involvement have complementary effects on productivity growth. In Section 5, using the propensity score matching technique, we examine how changes in innovation and export strategies affect productivity growth. The final section concludes.

1. Heterogeneity of firms and interactions between innovation and exporting strategies: theoretical background

1.1 Why do firms differ?

The recognition and analysis of heterogeneity among firms have become widespread and no longer demarcate differing theoretical approaches. However, it is fair to credit evolutionist approaches for making heterogeneity a central object of research and for proposing several theoretical models whose explanatory power has not yet been challenged. Nevertheless, important empirical contributions outside these theoretical frameworks have been made for more than 15 years. This is particularly true for the question of why some firms persistently perform better than others, for which our understanding is still poor. The answer to this question depends heavily on which micro theory of the firm is adopted. If one assumes that an optimal form of corporate organization exists, then differences among firms are only temporary and due to a process of convergence that is imperfect because of adjustment costs and frictions. However, many empirical studies have emphasized that these differences across firms are persistent and concern firms of similar size within identical institutional and sector contexts. Therefore, another theory of the firm is needed. An evolutionist approach is a good candidate, as it allows thinking of *discretionary* firm differences (Nelson, 1991; Lechevalier, 2007). In a world where optimization is far from the norm and adaptive approaches to organizational problems are often the solutions, one may understand why firms differ in their organization and performance.

The purpose of this paper is not to test the validity of evolutionary or standard approaches. However, beyond the distinction between these two paradigms, we are particularly interested in cognitive approaches to the firm, results of which are summarized by Dosi and Marlerba (1996) as follows: "The answer stemming from the 'evolutionary' theory of the firm here is, on the contrary, that ... one should expect persistent differences in strategies and performances grounded in diverse learning patterns." Cognitive approaches (or a "competence-based theory of the firm") regard firms as "learning organizations." Because competencies are highly appropriable by firms and difficult to transfer across firms, they may also be related to the notion of "intangible assets" (Itami, 1987). In this perspective, the key source of productivity advantages, and hence of heterogeneity, is firms' accumulation of technological capabilities. Firms intentionally accumulate knowledge to increase competitiveness relative to their main rivals in the final product market.

How might we define different patterns of learning and test their existence empirically? We face here a well-known difficulty, as there are no fully satisfying proxies for "dynamic capabilities." Our strategy is to reinterpret variables available in government surveys—R&D spending and export intensity—from the cognitive point of view of the analysis of firms' capabilities. The cognitive dimension of R&D has been well known since the seminal paper of Cohen and Levinthal (1989). However, the cognitive dimension of exports has been recognized only recently and less unanimously. The process of learning-by-exporting possibly explains why globally engaged firms are more productive than domestic firms, but the empirical evidence remains mixed (Bernard & Jensen, 1999; Aw et al., 2005; Wagner, 2007; Greenaway & Kneller, 2007; Castellani & Zanfei, 2007). In particular, Greenaway and Kneller (2007) distinguish among three types of learning effects associated with exports: interaction with foreign competitors, increasing scale, and increased competition as stimulus for innovation. Combined, R&D and exports give a satisfying (albeit incomplete) picture of the cognitive problem that firms face.[4] Moreover, they should be considered as central from a strategic point of view, which should be differentiated from the capabilities point of view (Dosi & Malerba, 1996). R&D and export strategies are indeed parts of firms' strategies to accumulate competences and are therefore crucial for firms' success.

The next question is the following: if R&D and export are efficient sources of new knowledge, why do not all firms commit to them?[5] One reason is a self-selection process through which highly productive firms have higher probability to engage in R&D and exports. But there are more important reasons. First, learning is a costly and multidimensional process and thus difficult to replicate (Dosi & Malerba, 1996). More important, the benefits of investments will not be identical for all firms because of differences in absorptive capacity. Ultimately, these differences lead to the emergence and are the consequences of different "patterns of learning" (Dosi & Malerba, 1996), for which the benefits of R&D and exporting differ. We call these patterns of learning "productive models," and we define them as follows, by reference to Oï

[4] We do not claim to be exhaustive with this approach of the firm focusing on R&D and exports. Other variables could be analyzed from the viewpoint of a cognitive approach: FDI and import ratio, for example, are similar ways to acquire knowledge. Also, human resource management is a condition of the diffusion of the knowledge within the firm.

[5] For example, 45% of firms in our sample invest neither in R&D nor in exports, approximately 50% are not conducting R&D, and 75% are not exporting (see Section 2.3).

(1983): a productive model refers not only to the cost and profit functions but also to different knowledge modes.[6] To put it differently, firms are on different productive tracks.

Finally, let us emphasize a merit of focusing on innovation and exporting strategies. A potential problem for any analysis focusing on heterogeneity is to recognize patterns in the ocean of diversity and therefore avoid tautological or idiosyncratic statements such as "firms are diverse because each firm is unique." In focusing on R&D and export, we exclude other important sources of heterogeneity. However, our discrete approach enables us to recognize four basic strategies (no R&D and no export, only export, only R&D, R&D and export). Finding some complementarities allows us to identify a limited number of "models" and notable persistent or structural differences among them. Then, it is interesting to check whether differences in innovation and exporting strategies (e.g., exporting or not-exporting) are discrete or continuous. In this latter case, levels of R&D spending and of export intensity matter, and we may find additional differences within given productive models defined by discrete investment choices. Thus, we consider discrete and continuous variables in our empirical investigation.

1.2 Defining productive models based on the interactions between innovation and exporting strategies

Even if, *a priori* and theoretically, examining interactions between innovation and exporting strategies is useful for analyzing different patterns of learning, we must first understand the possible sources of interactions between these two variables.

First, let us recall that the initial goal of the literature investigating interactions between innovation and exporting strategies is to assess whether a learning-by-exporting effect exists. As already mentioned, the literature produces little evidence that firms learn from exporting and that exports enhance productivity (Wagner, 2007; Greenaway & Kneller, 2007). Then, considering the prospect of a missing link between exports and productivity gains, some papers have introduced "innovation" to better explain the potential positive impact of exporting on productivity (Aw et al., 2005, 2009; Damijan et al., 2008; Roper & Love, 2002; Castellani & Zanfei, 2007, among others). Basically, these papers conclude that there are complementarities between exporting and innovation.[7] Moreover, innovation strategies may explain why exporting improves productivity in some cases but not in others. The crucial point is that firms differ in their international

[6] For example, Criscuolo *et al.* (2005) give an idea of the nature of the "productive mode" of globally engaged firms: "firms that operate globally devote more resources to assimilate knowledge from abroad and generate more innovations and productivity improvement."

[7] Some studies contradict this general story. For example, Damijan & Kostevc (2006) find that exporting increases the capacity utilization rate rather than stimulating efficiency.

engagement according to their endogenous choices to invest in competence-creation and innovation.

Then, it is important to specify the nature of the interactions between export and innovation strategies that make them substitutes or complements. While most studies that investigate these interactions find a significant positive relationship, it is worth noting that the results of Wakelin (1998) are more ambiguous. Estimated across all firms, Wakelin's results suggest that innovating firms are less likely to enter export markets than non-innovating firms. Also, large innovative firms are more likely to export than smaller innovative firms. The most probable explanation is the cost of entering export markets. The basic explanation for substitution effects between exports and innovation is therefore related to a simple trade-off in the affectation of limited resources.

However, the majority of studies find a complementary effect between exports and innovation. To understand this positive relationship, it is first useful to refer to trade theories (Roper and Love, 2002). Resource-based or endowment models help us to understand why firms that invest in innovation have incentives to export goods with high technological content. An alternate (but non-exclusive) interpretation emphasizes the technological advantage of firms that invest in R&D in implementing new technologies or in developing new products or processes. The distinction between product and process innovations is a second way to analyze two possible bases of the complementary relations between exports and innovation and their influence on productivity (Damijan et al., 2008). On one hand, the firm's decision to innovate a product may drive its decision to start exporting; on the other hand, an increase in exporting may increase a firm's sales and thus its productivity by increasing process innovations.

As a whole, the presiding rationale for positive interactions between exporting and innovation is that both are potential channels for acquiring knowledge (Aw et al., 2005; Criscuolo et al., 2005; Castellani & Zanfei, 2007). This interpretation is therefore sympathetic to cognitive approaches to the firm presented in Section 1.1.[8]

2. The increasing heterogeneity of Japanese firms and the role of exporting and R&D strategies in defining a new divide across firms

[8] Although we recognize there are other possible interpretations, our paper does not intend to discriminate between these different interpretations. For example, Wakasugi *et al.* (2008) emphasize the cost motive as one possible source of the positive interactions between exports and innovation. On the one hand, innovative firms have to seek a larger market in order to cover R&D costs. Therefore, R&D firms are more likely to start exporting. On the other hand, firms have to pay some fixed costs to start exporting. In order to pay these fixed costs, firms should be more productive. In order to become more productive, firms conduct R&D.

2.1 Increasing heterogeneity of performance during the Lost Decade and its determinants

Studies using different methodologies have found that productivity dispersion increased in Japan from the mid-1990s (Fukao & Kwon, 2006; Lechevalier, 2007; Ito & Lechevalier, 2009).[9] For example, in Ito and Lechevalier (2009), using an approach similar to that employed by Faggio et al. (2007), we find that both manufacturing and non-manufacturing industries experienced increasing heterogeneity of performance (measured by labor productivity and TFP) at the micro level between 1994 and 2003. Moreover, contrary to the case of the UK, which Faggio et al. (2007) focused on, Ito and Lechevalier (2009) finds that the increase in dispersion is more pronounced in the case of the manufacturing than the non-manufacturing sector.

Then, investigating the determinants of this increasing dispersion in the case of the manufacturing industries, Ito and Lechevalier (2009) finds that increasing export ratios at the industry level increases the intra-industry productivity dispersion at the firm level. This finding contradicts predictions by Antras and Helpman (2004). Therefore, the following issue is at stake: is this finding explained by cumulative learning-by-exporting effects in conjunction with self-selection effects (more productive firms self-select to the export market and then become more productive because of learning effects)? One motivation of this paper is to detect this cumulative effect.

Another characteristic of Japanese firms' increasing dispersion since the mid-1990s deserves mention: although size and sector still matter, the increasing dispersion and the emergence of different productive models extend beyond former size and sector categories. It means that we observe the emergence of different productive models and different productivity within the narrowly defined sectors and for firms of similar size.

2.2 Description of the dataset, measurement of productivity, and variables

We use firm-level panel data underlying the BSBSA conducted annually by METI.[10] Our data cover the period from 1994 to 2003. As we are analyzing R&D and internationalization strategies, we focus on manufacturing industries.

[9] Fukao & Kwon (2006) and Ito & Lechevalier (2009) used the BSBSA database presented in Section 2.2.

[10] The survey covers all firms with at least 50 employees or 30 million yen of paid-in capital in the Japanese manufacturing, mining, commerce, and several other service sectors. The survey contains detailed information on firm-level business activities such as the 3-digit industry in which the firm operates, its number of employees (including a breakdown of the number of employees by firm division), sales, purchases, exports, and imports (including a breakdown of the destinations of sales and exports and the origin of purchases and imports), R&D and patents, the number of domestic and overseas subsidiaries, and various other financial data such as costs, profits, investment, and

Although three-digit industry information is available in the survey, our analysis is based on the JIP micro-data industry classification, which consists of 30 manufacturing sectors.[11] We drop from our dataset all firms for which data on sales, number of employees, total wages, tangible fixed assets, depreciation, or intermediate inputs are not positive or are missing for at least one year. After this screening, our unbalanced panel dataset contains approximately 12,000 firms.

Utilizing the firm-level panel data, we construct two kinds of productivity measures—labor productivity and total-factor productivity (TFP). Although we are aware of some limitations in the interpretation of TFP, we use both measures for robustness check purpose. We have no information about working hours at the firm level, so we calculate labor productivity as the real value added per employee. Real value added is calculated as real output minus real intermediate input using industry-level price deflators from the JIP Database 2006. We calculate TFP for each firm based on the production function estimated using the semi-parametric estimation technique suggested by Levinsohn and Petrin (2003).[12,13]

2.3 Toward a new divide among Japanese firms? Patterns of export and R&D strategies and their effect on performance

As mentioned in Section 1, we divide our sample of firms into four groups: (A) firms that do not invest in R&D or export, (B) firms that invest only in R&D, (C) firms that export only, and (D) firms that invest in R&D and export.[14] That is, among non-exporters we distinguish between

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assets. The compilation of the micro data of the METI survey was conducted as part of the project "Japan's Productivity and Economic Growth" at the Research Institute of Economy, Trade and Industry (RIETI).

[11] The list of these 30 sectors is shown in Appendix Table 4. Deflators for output, input, and capital prices, etc. are not available at the three-digit industry level. In order to utilize the JIP Database 2006 price deflators, we reclassified industries according to the 40 JIP micro-data industry classifications.

[12] For details of the definition and source of each variable for the TFP calculation, see the Appendix.

[13] We also calculated TFP in a non-parametric way, following Good et al. (1997). Although we obtained consistent results regardless of the methodology, the Levinsohn and Petrin TFP measure looks less cyclical than the relative TFP measure and we therefore employ the Levinsohn and Petrin TFP measure in this paper.

[14] As for R&D investment, we basically use R&D expenditure data. For a given firm, if R&D expenditure > 0, we define this firm as a R&D firm. The same principle applies to the definition of exporters: if exports > 0, we define the firm as an exporter. Of course, some may criticize this definition of R&D firms because there would be several alternative measures to define R&D firms (Wakelin, 1998; Roper & Love, 2002; Castellani & Zanfei, 2007; Damijan et al., 2008). Although our database includes information on firms' R&D activities, information on product innovation or process innovation is unfortunately not available. We primarily use R&D expenditure data, although we also examined

non-innovators (A) and innovators (B). We make the same distinction among exporters who do not invest in R&D (C) and exporters who do (D). Table 1 reports the number and share of firms for each category among manufacturing industries in 1994 and 2003.

The first fact emerging is that A is the largest group of firms, with a proportion stable over time (45% in 2003). Second, contrary to what has been found in other countries, the number of Japanese firms engaged only in R&D (type B) is much larger than the number of firms engaged only in exporting (type C). Around 50% of firms are engaged in R&D (types B and D), whereas the share of exporters (types C and D) fluctuates around a level of 30% during the period.[15] We have uncovered an important characteristic of Japanese manufacturing firms.[16] Type D's share is much larger than that of type C and is equivalent to that of type B (only R&D) in 2003. It is important to note that the share of exporters increased from 26% to 31% between 1994 and 2003, whereas the share of firms engaged in R&D decreased from 51% to 47%.

Table 1: Summary of investment activities among Japanese manufacturing firms

	Investment activities						
	A	B	C	D	C+D	B+D	A+B+C+D
	No R&D, No Exporting	Only R&D	Only Exporting	Both R&D and Exporting	Exporters	R&D firms	Total
1994	5062 (44%)	3537 (30%)	619 (5%)	2386 (21%)	3005 (26%)	5923 (51%)	11604 (100%)
2003	5236 (45%)	2859 (24%)	978 (8%)	2653 (23%)	3631 (31%)	5512 (47%)	11726 (100%)

Note: The share of the number of firms for each category is shown in parentheses.

other measures for firms' R&D activities as described in detail below. Moreover, as for international engagement strategies, we focus on exports and do not take FDI into account. Although our database includes information on FDI and it would be interesting to examine differences in exporting firms and FDI firms, we decided to focus on exports for several reasons. First, previous studies, such as Head and Ries (2001) and Kiyota and Urata (2008), confirmed the complementary relationship between exports and FDI. Kiyota and Urata (2008) find that multinational firms emerge from being exporters and that exporters make a decision on whether to undertake FDI. Second, in our database, the total number of exporting firms is much larger than the total number of FDI firms (respectively 34,526 and 22,939 for the period 1994–2003); moreover, approximately half of all exporting firms (17,188) are engaged in FDI, while three-quarters of all FDI firms are exporting. Third, while our database contains information on the value of firms' exports, the only information we have for FDI is the number of firms' foreign affiliates, so we have no detailed information that would allow us to gauge the size or importance of firms' FDI. Therefore, in this paper, we define firms with international engagement strategies as exporting firms.

[15] For example, in the case of Taiwanese firms in the electrical machinery sector, Aw et al. (2005) report that slightly more than 50% of all firms have R&D expenditures while almost 75% participate in the export market. In the case of Japan, the distribution of firms across these four types is very similar to the one in Table 1 if we limit the sample to the electrical machinery industry. In the Japanese electrical machinery industry, the share of exporters (C+D in Table 1) is 42% in 2003, which is 10 percentage-points larger than the corresponding share for all manufacturing firms. However, it is still much smaller than the corresponding figure for the case of Taiwan's electrical machinery sector.

[16] This feature of Japanese firms is confirmed by several studies. For example, Wakasugi et al. (2008) find that the percentage of exporters in Japan is relatively low compared to their European counterparts.

The analysis based on Table 1 is largely static. A dynamic analysis needs to be performed indicating how investment decisions in R&D and in exports persist or change over time. Table 2 reports the average transition matrix of investment activities for Japanese manufacturing firms between years *t* and *t + 1* for the period 1994 − 2003. More precisely, the columns report the number and share of firms that initiate or cease investment activity in year *t + 1* compared to year *t*. Several broad transition patterns emerge. First, the more investment activities a firm has in year *t*, the lowest probability it has to exit in year *t + 1*. Second, the more investment activities a firm has, the higher is the probability it will undertake other investments. R&D-only and export-only firms are more likely to initiate investment activity than are firms with no R&D and no exports. Third, the flows regarding exporting decisions (stop/start) are lower than the flows regarding R&D decisions. As a whole, the results suggest a strong path dependence in the investment strategies of firms.[17] This stability corresponds to a first condition that allows us to consider these various strategies as different *productive models* as emphasized in Section 1.

Table 2: Average transition matrix of investment activities between years *t* and *t + 1* (1994–2003)

Investment activity in year *t* (Average number of firm in year *t*)	Average number of firms by New activity in *t+1*				
	Start R&D	Stop R&D	Start Exporting	Stop Exporting	Exit
No R&D, No Exporting (5215)	354		110		772
	(6.8%)		(2.1%)		(14.8%)
R&D only (3232)		384	170		360
		(11.9%)	(5.3%)		(11.2%)
Exporting only (796)	129			79	110
	(16.2%)			(9.9%)	(13.8%)
R&D and Exporting (2504)		144		143	258
		(5.8%)		(5.7%)	(10.3%)

Note: The share of the number of firms which started or stopped an activity in year t+1 for each of the four categories in year t is shown in parentheses.

The next question is to identify whether there are regularities that characterize each of these four groups of firms. Table 3a reports some basic indicators. The most obvious stylized fact is that R&D and exporting firms are the largest (irrespective of the indicator considered), oldest, and most productive. Moreover, some indicators deserve specific attention. Human resources

[17] Of course, a firm is never definitively locked into a productive model. It can change its status. Section 5 investigates the impact of these changes of status on performance.

management is different across the four types of firms: the highest wages are found, in decreasing order, in D, B, C, and A firms. This ranking corresponds to the productivity ranking of firms but also to the education ranking of the workforce, when it is proxied by the share of administrative workers. As for financial variables, differences among groups of firms are also striking. Not surprisingly, D firms have the highest foreign capital ratio (5.12%). Higher foreign capital ratios also distinguish exporting firms (C) in comparison to A and B firms (3.12% versus 0.51% and 0.89%). The picture that emerges is clear: the four groups of firms differ significantly in their output (productivity) and cost structures (e.g., wage rate).

Table 3a: Basic characteristics of each group of firms in 2003

	A	B		C		D	
	No R&D, no exporting	R&D only	*t-test*	Exporting only	*t-test*	R&D and exporting	*t-test*
Value added per employee (mil. yen per person)	7.93	10.20	***	10.61	***	14.56	***
lnTFP	-2.52	-1.73	***	-2.25	***	-1.23	***
Capital per employee (mil. yen per person)	10.51	13.58	***	11.77	***	15.66	***
R&D intensity (R&D expenditure/sales, %)	0	1.32	***	0	*n.a.*	2.63	***
Research worker share	1.31	5.32	***	3.18	***	8.77	***
Export ratio (exports/sales, %)	0	0	*n.a.*	10.67	***	12.90	***
Size (employment, persons)	164.83	329.65	***	203.99	***	790.23	***
Size (capital, mil. yen)	1,894	5,606	***	3,407	***	16,851	***
Size (sales, mil. yen)	5,836	14,689	***	10,048	***	60,453	***
Debt asset ratio (%)	69.97	64.89	***	68.30	*	58.66	***
Foreign ownership share (%)	0.51	0.89	**	3.12	***	5.12	***
Annual wage payment (mil. yen per person)	4.36	4.96	***	4.78	***	5.79	***
Administrative worker share	11.62	14.93	***	13.29	***	17.09	***
Firm age (years)	37.33	42.36	***	40.84	***	46.75	***
Number of firms	4,964	2,683		920		2,511	

Notes: The figures for value added, capital per employee, capital, and sales and wage rate are reported in million yen. R&D intensity, research worker share, export ratio, debt asset ratio, and foreign capital share and administrative worker share are expressed in %. All figures are mean values for each group in 2003.
*Two-tailed t-tests are conducted to check whether the mean values for each group B, C, or D are statistically different from the mean values for group A.***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively.*
n.a. = not applicable.

Closer investigation into the differences in innovative behavior between exporters and non-exporters reveals differences in their patterns of learning (Table 3b). The use of a unique criterion such as R&D expenditures to capture innovative behavior has been constantly criticized, especially in the literature on export, innovation, and productivity (Wakelin, 1998; Roper & Love, 2002; Castellani & Zanfei, 2007; Damijan et al., 2008). The BSBSA asks additional questions related to the innovation behavior of firms (e.g., number of in-house developed patents in use, R&D collaboration with firms in Japan and overseas). Although these questions are not asked every year, responses indicate the innovation strategy of each group of firms.[18]

Table 3b allows us to focus on the comparison between exporting (C+D) and non-exporting (A+B) firms. First, as mentioned above, the percentage of firms conducting R&D among exporters is much larger than among non-exporters, regardless of the measure of innovative behavior. Differences in the R&D collaborative behavior of exporting and non-exporting firms are also striking, particularly in regard to the R&D collaboration with firms overseas. From these simple statistics it appears that innovation behavior is systematically different between exporters and non-exporters. Investment in exports seems to go hand-in-hand with a more intense focus on innovation; innovation and exporting are not substitutes, but rather are complementary.

In addition, Table 3b suggests that the number of R&D firms is largest when we employ the R&D expenditure measure, suggesting that this is the broadest definition of whether firms conduct R&D. However, all three measures—R&D expenditure, in-house R&D expenditure, and whether the firm has a formal R&D unit—yield similar figures, implying that these measures overlap substantially. Therefore, in the analyses in the following sections, we continue to use the R&D expenditure measure as our main variable for innovative behavior variable, although we occasionally use the other measures for robustness checks.

[18] However, it is worth noting that this exercise has limits: data on patent numbers, for example, do not distinguish between firms that failed to answer the question and firms that replied but had no patents in a given year.

Table 3b: Basic indicator of firms' innovative behavior by internationalization status in 1994 and 2003

(a) Year 1994		
	Exporters	**Non-exporters**
No. of firms	3005	8599
	(100.0)	(100.0)
R&D expenditure >0	2386	3537
	(79.4)	(41.1)
In-house R&D expenditure >0	2354	3442
	(78.3)	(40.0)
No. of in-house developed patents in use >0	1678	1642
	(55.8)	(19.1)
Had a formal unit devoted to conducting R&D	2124	3416
	(70.7)	(39.7)
(b) Year 2003		
	Exporters	**Non-exporters**
No. of firms	3631	8095
	(100.0)	(100.0)
R&D expenditure >0	2653	2859
	(73.1)	(35.3)
In-house R&D expenditure >0	2610	2784
	(71.9)	(34.4)
No. of in-house developed patents in use >0	2005	1580
	(55.2)	(19.5)
Had a formal unit devoted to conducting R&D	2433	3082
	(67.0)	(38.1)
Had R&D collaboration with firms in Japan	339	286
	(9.3)	(3.5)
Had R&D collaboration with firms overseas	79	19
	(2.2)	(0.2)

Note: We assume that firms that did not reply to R&D-related questions are not involved with the activity. The percentage share of the number of firms is in parentheses.

The final question we pose in this section is whether these different strategies affect performance. To evaluate the effect of investment strategies on performance, we compare labor productivity premiums for B, C, and D firms versus A firms (Table 4).[19] To estimate productivity premiums, we run a series of regressions in which the dependent variable is productivity and in which we introduce industry dummies, year dummies, and investment status dummies for B, C, and D firms. We run these regressions for each year and for the entire period 1994–2003. The largest premium we find is for investment decisions combining R&D and exports (32.47% over the period 1994–2003). Moreover, the R&D premium is larger than the exporting premium.[20]

[19] We did the same exercise with TFP and found that the pattern is similar.
[20] We do a more systematic exercise in Section 4.2 by introducing survival probability.

Table 4: Labor productivity premiums for different categories of firms by comparison to No-R&D and No-exporting firms

Labor productivity	B	C	D
	Only R&D premium	Only Exporting Premium	Both R&D and Exporting Premium
1994	17.83	15.85	28.76
1995	18.58	13.56	32.41
1996	17.75	15.57	33.19
1997	16.67	15.72	32.9
1998	17.01	14.46	30.2
1999	17.72	12.24	31.16
2000	18	13.21	32.41
2001	15.77	10.94	30.65
2002	15.43	13.84	33.66
2003	16.48	15.87	35.8
1994-2003	17.32	14.26	32.47

Note: Numbers are the coefficients of a regression in which labor productivity is the dependent variable; years and industry dummies have been introduced; all coefficients are significant at 1%.

The following points emerge from this basic statistical analysis. First, exporting and innovation strategies are complementary. Second, taking their interaction into account makes it possible to define groups of firms according to different productive models that produce lasting differences. This statistical picture must be confirmed by econometric estimation.

3. Empirical methodology

To investigate complementary effects of R&D and exporting on the persistent dispersion in performance among firms, we borrow the analytical framework in Aw et al. (2005). For the first step, we examine the determinants of decisions to invest in R&D and to participate in the export market, and we examine the determinants of the intensity with which firms engage in these two activities. Our second step is to examine the effect these two activities have upon the firm’s productivity growth.

3.1 Determinants of investment in R&D activities and exporting

Before analyzing the complementary effect of R&D and exporting on productivity, we first examine the link between R&D and exporting. We wish to test whether firms’ innovation decisions affect export performance and, conversely, whether export performance affects innovation decisions. Following Aw et al. (2005) and Damijan et al. (2008), we model joint decisions to export and to invest in R&D, and we estimate the model using bivariate probit regression.

We assume that expected profits of firm i, which is engaged in R&D or exporting in year $t + 1$, depend on the firm's characteristics in the current year t. Those characteristics include the firm's age, size, foreign ownership ratio, credit constraints, level of productivity, and stocks of knowledge accumulated through R&D and from international engagement. Therefore, the probabilities of R&D and exporting for firm i in year $t + 1$ are written as

$$Prob(R\&D_{i,t+1} = 1) = f(X_{i,t}, \omega_{i,t}, D_{i,t}) \tag{1}$$

$$Prob(EXP_{i,t+1} = 1) = f(X_{i,t}, \omega_{i,t}, D_{i,t}) \tag{2}$$

where $R\&D$ denotes an indicator variable for innovator status and EXP denotes an indicator variable for export status.[21] As described in the previous section, we use information on R&D expenditures to define the firm's status as an innovator. That is, the $R\&D$ variable takes 1 if a firm reports positive R&D expenditures and 0 otherwise. In the case of export status, the EXP variable takes 1 if a firm is an exporter and 0 otherwise. X is a vector of variables for firm characteristics that affect decisions to innovate and export. For X, we include firm age, size measured by the log of capital stock, wage rate, a dummy variable with a value of 1 for firms with more than one plant, foreign capital ratio, debt-asset ratio, and capital-labor ratio (only for the labor productivity specification). We also include the level of productivity (ω) to capture the possibility that more productive firms self-select into R&D activities or exporting. We employ labor productivity (value added per employee) and TFP as the productivity measures. Following Aw et al. (2005), we include the productivity level squared to account for nonlinear effects of productivity on the probabilities of R&D and exporting. D represents dummy variables indicating whether the firm i is engaged in R&D and/or exporting.

The dummy variables for R&D and/or exporting status are of primary interest for studying the link between R&D and exporting. We include three dummy variables: a dummy for firms engaged in R&D and exporting, a dummy for firms that are only exporters, and a dummy for firms engaged only in R&D. The corresponding coefficients show whether current R&D/exporting status affects the decision to conduct R&D activities/exporting in the next period. If there are complimentary effects of R&D and exporting on a firm's profitability, we can expect that exporters (innovators) are more likely to be innovators (exporters).

[21] It is worth noting that while firms' decision whether to participate in exporting is widely discussed in the trade literature, this is not the case in the R&D literature, with the study by Bond et al. (2003) being a notable exception.

Moreover, we can expect that firms that already export are more likely to export in the next period because their export-related costs—for example, fixed costs for collecting information on foreign markets and creating sales channels in foreign countries—are lower for exporters than for non-exporters. By the same token, we can expect that firms already engaged in R&D will remain engaged in R&D. Similar to the case of exporting, conducting R&D activities would incur some fixed costs such as costs for researching promising technologies, creating R&D divisions, and looking for people who can be engaged in R&D activities. Therefore, if such fixed costs are lower for firms already engaged in R&D, firms with R&D activities are more likely to conduct R&D in the next period. Given the complementary effects of R&D and exporting and the cost effects, we can expect that firms engaged in R&D and exporting are more likely to be innovators or exporters in the next period. By estimating equations (1) and (2) simultaneously as a bivariate probit model, we allow for correlation between their residuals. Table 5 describes the variables used in our econometric analysis.[22]

Table 5: Definition of variables

Variables	Definition
log (age)	Years in operation in logarithm
log (K)	Real capital stock in logarithm
log (wage rate)	Annual total wage payment per employee (millon yen per person) in logarithm
Multiplant dummy	A dummy variable that takes 1 if the firm has more than one production establishment.
Foreign capital ratio	Foreign ownership share (%)
Debt-asset ratio	Debt asset ratio measured as total liabilities divided by total assets
ln (KL ratio)	Capital-labor ratio calculated as the real capital stock divided by the number of employees (million yen per person), in logarithm
lnVAP	Labor productivity, Value added per employee in logarithm
lnVAP^2	Labor productivity squared
lnTFP	TFP level calculated by the Levinsohn-Petrin method
lnTFP^2	TFP squared
RDEXP	A dummy variable that takes 1 if the firm invests in both R&D and exporting.
EXPONLY	A dummy variable that takes 1 if the firm invests in only exporting.
RDONLY	A dummy variable that takes 1 if the firm invests in only R&D.
EXP intensity	Export intensity, calculated as the ratio of exports to total sales
R&D intensity	R&D intensity, calculated as R&D expenditure divided by total sales

[22] We realize that firm-level and industry-level factors are important in analyzing a firm's strategy and performance. However, we control only for industry-level factors by including industry dummy variables because we are more interested in the interaction of current firm-level strategies—i.e., R&D and exporting—in determining the firm's strategy and performance in the next period.

Although we can analyze determinants of investing in R&D or of exporting by estimating the discrete choice models, we cannot examine determinants of R&D intensity and export intensity with discrete-choice models. Therefore, we estimate the following intensity equations in order to examine impacts of knowledge accumulated from firms' current R&D activities and/or international engagement on the R&D or export intensities in the next period. As with the discrete choice models presented in equations (1) and (2), we assume that R&D or export intensities in year $t + 1$ depend on firm characteristics, the level of productivity, and R&D and export intensities in the current year t.

$$R\&D\ intensity_{i,t+1} = f(X_{i,t},\ \omega_{i,t},\ R\&D\ intensity_{i,t},\ EXP\ intensity_{i,t}) \qquad (3)$$

$$EXP\ intensity_{i,t+1} = f(X_{i,t},\ \omega_{i,t},\ R\&D\ intensity_{i,t},\ EXP\ intensity_{i,t}) \qquad (4)$$

where *R&D intensity* denotes the ratio of R&D expenditure to total sales and *EXP intensity* denotes the ratio of exports to total sales.

3.2 Complementary effects of R&D and exporting on productivity growth

After examining the link between R&D and exporting, we estimate the complementary effect of investment in R&D and participation in export markets on a firm's productivity growth. We follow Aw et al. (2005) in estimating jointly a productivity evolution equation and an equation for firm survival, taking into account the selection bias arising from random factors affecting a firm's survival in period $t + 1$ as well as its productivity in that year. If a firm's productivity falls below a certain threshold level, the firm is likely to go bankrupt, so that it drops out from our dataset. As for surviving firms, we assume that their productivity level evolves over time following a Markov process where a firm's acquisition of knowledge through R&D and/or exporting affects the probability distribution of future productivity levels. Therefore, the productivity evolution equation is specified as

$$\omega_{i,t+1} = f(\omega_{i,t},\ D_{i,t}) \qquad (5)$$

where ω_{it} denotes the level of productivity for firm i in year t and D_{it} denotes dummy variables indicating that firm i is engaged in R&D activities and/or exporting in year t. We assume that firm i's survival in year $t+1$ ($SURV_{i,t+1}=1$) depends on its productivity, ω_{it}, other firm characteristics, X_{it}, and R&D and exporting status, D_{it}.

The survival equation is specified as:

$$Prob(SURV_{i,t+1}=1) = f(X_{i,t},\ \omega_{i,t},\ D_{i,t},\ \omega_{i,t}*D_{i,t}) \qquad (6)$$

The selection equation for existing firms is:

$$SURV_{i,t+1} = \begin{cases} 1 \ \ if \ \ Z'_{i,t}\gamma + v_{i,t+1} \geq 0; \\ \\ 0 \qquad otherwise. \end{cases} \tag{7}$$

where *SURV* denotes a dummy variable with a value of 1 if a firm continues operating in year $t + 1$ and 0 otherwise, $\omega_{it}*D_{it}$ denotes the interaction terms of firm productivity and R&D and export status. $Z'_{i,t}$ is a transposed vector of variables representing firm characteristics, X_{it}, productivity, ω_{it}, R&D and exporting status, D_{it}, and the cross-terms of productivity and R&D and exporting status, $\omega_{it}* D_{it}$. γ denotes a vector of coefficients for $Z'_{i,t.}$ Following Aw et al. (2005), we jointly estimate equations (5) and (7) employing Heckman's sample selection framework to examine whether firms' R&D/exporting status (represented by *D*) affects their future productivity.

4. Analyzing the interactions of innovation and exporting strategies and their effect on performance

The goal of our empirical investigation is to analyze how innovation and export strategies interact and affect performance. Therefore, our first step is not a systematic analysis of the determinants of these two investment decisions but rather an analysis of the complementarities between them. As we outlined in Section 3 concerning empirical methodology, our investigation does not rest on a structural model of investment decisions but on a reduced form allowing us to study the interactions of innovation and export decisions. Having then shown that complementarities do exist, in the second step of this empirical analysis, we study the independent impact of these decisions on the performance of firms and, more importantly, their joint effect on performance.

4.1 Investigating complementarities between investments in R&D and exports

Results from the bivariate probit model presented by equations (1) and (2) in Section 3 are reported in Table 6.[23] The first two columns show the results using labor productivity as a measure of productivity while the second two columns show the results using TFP.[24]

[23] We also used a multi-nominal probit model to specify the probability of choosing one of four possible combinations: No R&D and No Exporting, R&D only, Exporting only, and R&D and Exporting. The multi-nominal probit estimation also provides results that are consistent with the bivariate probit estimation results. These results are available upon request to the authors.

[24] As for the modeling of the lagged structure, we test the impact of all present characteristics in year t on the investment decisions in year $t + 1$. That is, we consider a one-year lag. We also assume that present investment decisions are exogenous, and look at the impact of current decisions on future investment decisions. Therefore, the

Table 6: Discrete investment activity equation (Bivariate probit estimation)

Dependent varriable: R&D or Export decision in year (t+1)

	(1)		(2)	
	R&D	Exporting	R&D	Exporting
log (age)	0.064***	0.067***	0.072***	0.077***
	(0.011)	(0.014)	(0.011)	(0.014)
log (K)	0.201***	0.140***	0.102***	0.063***
	(0.009)	(0.009)	(0.006)	(0.006)
log (wage rate)	0.161***	0.088***	0.086***	0.019
	(0.027)	(0.034)	(0.026)	(0.032)
Multiplant dummy	0.039***	0.110***	0.066***	0.133***
	(0.013)	(0.015)	(0.012)	(0.015)
Foreign capital ratio	-0.162**	0.403***	-0.167**	0.431***
	(0.072)	(0.085)	(0.069)	(0.082)
Debt-asset ratio	-0.102***	-0.124***	-0.103***	-0.124***
	(0.027)	(0.031)	(0.026)	(0.031)
ln (KL ratio)	-0.162***	-0.127***		
	(0.011)	(0.013)		
lnVAP	0.137***	0.074		
	(0.042)	(0.052)		
lnVAP^2	-0.030***	-0.020*		
	(0.009)	(0.010)		
lnTFP			0.081***	0.071***
			(0.016)	(0.019)
lnTFP^2			-0.012***	-0.004
			(0.002)	(0.002)
RDEXP	2.428***	3.063***	2.506***	3.209***
	(0.071)	(0.085)	(0.026)	(0.032)
EXPONLY	0.448***	3.038***	0.402***	3.031***
	(0.086)	(0.112)	(0.033)	(0.042)
RDONLY	2.056***	0.294***	2.369***	0.251***
	(0.060)	(0.076)	(0.025)	(0.028)
lnVAP*RDEXP	0.020	0.064		
	(0.035)	(0.042)		
lnVAP*EXPONLY	-0.032	0.009		
	(0.044)	(0.058)		
lnVAP*RDONLY	0.141***	-0.015		
	(0.032)	(0.040)		
lnTFP*RDEXP			0.005	0.002
			(0.008)	(0.010)
lnTFP*EXPONLY			0.003	-0.013
			(0.010)	(0.013)
lnTFP*RDONLY			0.020**	-0.012
			(0.008)	(0.009)
Rho	0.118***		0.126***	
	(0.014)		(0.013)	
No. of observations	91580		92932	
Chi-squared	57063.5		58109.7	
Log likelihood	-45706.3		-46545.3	

*Note: Heteroskedasticity-robust standard errors (clustered within a firm) are in parentheses with ***, **, and * indicating the 1%, 5%, and 10% significance levels, respectively. A constant term is not reported. All equations include three-digit industry dummy variables and year dummy variables.*

estimated coefficients may be biased due to endogeneity and serial correlation, but it is difficult to find a strictly exogenous instrumental variable. We therefore estimated the same model using a three-year lag, which should mitigate such problems, and obtained very similar results. These results are available from the authors upon request.

We start our comments with an analysis of how a firm's current status as an innovator or exporter affects future decisions to invest in R&D or exporting. The status variables we consider are proxies for the knowledge stock internally accumulated through R&D and the knowledge stock externally accumulated through exporting. We find significantly positive coefficients for all status variables (*RDEXP*, *EXPONLY*, and *RDONLY*) in all cases. Our findings are contrary to previous studies which found that results differ depending on the type of investment. For example, Aw et al. (2005) found greater persistence in the case of exports than in the case of R&D. However, we find an strong persistence for both investments. Firms that presently export are likely to export in the next period, and firms that conduct R&D are likely to continue R&D in the next period. A possible reason is that their current involvement in R&D (or exporting) lowers the fixed costs of engaging in R&D (or exporting) in the next period.

Moreover, firms not exporting but engaged in R&D in the current period are more likely to become an exporter in the next period than firms that are currently engaged in neither. Similarly, firms not engaged in R&D but exporting in the current period are more likely to conduct R&D in the next period than firms currently engaged in neither.[25] This result implies there are complementarities between R&D and exporting. In addition, we find that firms engaged in R&D and exporting are most likely to continue R&D or exporting. This finding also suggests complementarities between R&D and exporting. One possible explanation is that returns on exporting may be greater for firms with in-house capabilities to assimilate knowledge gained from exporting. At the same time, returns on R&D also may be greater for firms that export to sell their high-tech and higher value-added products in foreign markets.

As for the interaction terms of the current productivity level and the current R&D/exporting status (the final three interaction terms in Table 6), we find that among all firms engaged only in R&D, the more productive firms are more likely to continue R&D in the future. This conclusion is implied by the significantly positive coefficients of *lnVAP*RDONLY* and *lnTFP*RDONLY*. On the other hand, looking at productivity variables (*lnVAP*, *lnVAP^2*, *lnTFP*, and *lnTFP^2*), we find that the current level of productivity affects positively with diminishing effects R&D investment decisions, but not export decisions (in the case of labor productivity

[25] However, this result should be interpreted with caution. Both R&D and exporting represent endogenous choices of the firm. Even though we allow for correlation between the residuals of the R&D decision equation and the exporting decision equation by employing a bivariate probit estimation, the endogeneity problem still remains because of the unavailability of good instruments. Therefore, we cannot say anything about the causal effects of R&D (or exporting) on exporting (or R&D) decisions. Our results suggest that current R&D (or exporting) decisions are positively associated with future exporting (or R&D) decisions, but we cannot say that current R&D (or exporting) activity leads to future exporting (or R&D) activity. Damijan et al. (2008) identify the causality between the R&D and the exporting decision employing propensity score matching. Although we tried to follow this approach to examine the causal effect, the matching results in very few instances satisfied the balancing property test and we abandoned this approach.

specification). These results suggest that productivity strongly affects future R&D decisions and may imply that given increasing uncertainties in R&D outcomes, only high-productivity firms can afford sunk costs attendant to R&D investment.

Our results identify several other determinants of firms' future investment decisions. Older, larger, or multi-plant firms are more likely to conduct R&D and/or to initiate exporting. In the majority of cases, we obtain significantly positive coefficients suggesting that firms with higher wages are more likely to be innovators and/or exporters. It may be interpreted that human resource management policies and investment decisions are connected and that firms with more skilled and high-paid workers tend to be innovators and/or exporters. As for financial variables, debt-asset ratio affects negatively all investment decisions, which is particularly consistent with arguments that financial constraints are important determinants of R&D investment (e.g., Hall, 2002). The foreign capital ratio affects export decisions positively and R&D decisions negatively. Foreign investors may provide information about foreign markets to help firms begin exporting, or foreign investors prefer firms with a higher potential to export. Although it is difficult to interpret the significantly negative coefficient of the foreign capital ratio on the R&D decision, foreign investors may avoid firms that try to initiate R&D because R&D activities are less likely to bring short-run profits. Finally, we mention that Rho values are positive and statistically significant for both labor productivity and TFP specifications, suggesting a positive correlation between residuals of the R&D decision equation and the export decision equation. It means that shocks that lead a firm to participate in one activity tend to lead it to participate in both.

We should mention that our status dummy variables (*RDEXP*, *EXPONLY*, and *RDONLY*) may be inappropriate proxies for the knowledge stocks accumulated internally through R&D and/or accumulated externally through exporting. We construct other measures for the knowledge stock accumulated through R&D and estimate the bivariate probit model presented by equations (1) and (2) in Section 3. Our first alternative measure is a dummy variable that takes a value of 1 if a firm has a formal unit devoted to conducting R&D and 0 otherwise. Our second alternative measure is a dummy variable that takes a value of 1 if a firm has a positive number of in-house developed patents in use and 0 otherwise. The estimation results are shown in Appendix Table 1. We obtain results largely consistent with those in Table 6 and find strong persistence in both R&D and exporting decisions. Moreover, as in Table 6, firms engaged in both R&D and exporting are most likely to continue exporting and R&D in all cases in Appendix Table 1. However, the persistence in the R&D decision is weaker if we use the patent dummy variable as a proxy for internal knowledge stock.

Although it is important to consider alternative measures for knowledge stocks, we continue primarily using R&D expenditure as its proxy for several reasons. First, in the following econometric analyses, it is easier to construct a variable for R&D intensity with R&D expenditure information than by enumerating the units devoted to R&D or the number of internally developed patents in use. Second, R&D expenditure better indicates the size and importance of R&D than does the number of units formally devoted to R&D. Third, many firms do not report patent information; therefore, we lose many observations by employing the patent variable in our analysis.

Table 7: Intensity of investment for firms with positive investment (System GMM estimation)

Dependent variable: R&D or Exporting intensity in year (t+1)

	All mfg.		All mfg.	
	(1)	(2)	(3)	(4)
	R&D	Exporting	R&D	Exporting
log (age)	0.006	-0.028	0.009	-0.064
	(0.017)	(0.113)	(0.011)	(0.145)
log (K)	0.013	0.065	0.005	0.064
	(0.009)	(0.067)	(0.005)	(0.061)
log (wage rate)	0.055	-0.311	0.006	-0.113
	(0.043)	(0.194)	(0.025)	(0.159)
Multiplant dummy	-0.008	0.002	-0.010	-0.031
	(0.020)	(0.161)	(0.016)	(0.193)
Foreign capital ratio	-0.000	0.000	-0.001**	-0.001
	(0.001)	(0.004)	(0.000)	(0.003)
Debt-asset ratio	-0.125***	-0.214	-0.074**	-0.083
	(0.044)	(0.222)	(0.035)	(0.251)
ln (KL ratio)	-0.048**	-0.106		
	(0.020)	(0.100)		
lnVAP	0.002	0.318**		
	(0.026)	(0.149)		
lnVAP^2	-0.002	-0.045		
	(0.006)	(0.031)		
lnTFP			0.005	-0.006
			(0.003)	(0.019)
lnTFP^2			-0.000	-0.002
			(0.001)	(0.005)
EXP ratio	0.047	0.641***	0.018	0.650***
	(0.067)	(0.083)	(0.051)	(0.082)
R&D intensity	0.362***	2.603	0.436***	0.912
	(0.085)	(1.898)	(0.060)	(1.744)
No. of Observations	40155	24011	40823	24405
No. of groups	8366	4962	8434	5005
AR(2) (p-value)	0.629	0.082	0.758	0.163
Hansen test (p-value)	0.601	0.102	0.17	0.005
Diff Hansen test (p-value)	0.583	0.035	0.112	0.002

*Notes: Two-step estimators are reported. Arellano-Bond robust standard errors are in parentheses with ***, **, and * indicating significance at the 1%, 5%, and 10% level, respectively. Year dummies are included in all equations, but are not reported in the Table. For equations (1) and (3), we use as instruments the year dummies and the first, second, third, and fourth lags of the R&D intensity variable. For equations (2) and (4), we use as instruments the year dummies and the first, second, third, and fourth lags of the EXP ratio variable*

The next step is to consider the intensity with which firm engage in R&D or exporting (Table 7). We estimate intensity equations (3) and (4) in Section 3. It is difficult to construct useful measures of interactions between a firm's current export intensity and R&D intensity.[26] Therefore, we replace the three R&D/exporting status variables with two intensity measures. Although we can estimate the equations via the Tobit method, including observations with zero R&D intensity or zero export intensity, we estimate each equation using only firms with positive R&D or export intensities. This approach accounts for possibilities that there are significant differences in the impact of the independent variables on the probabilities of R&D (or exporting) and on propensity to R&D (or export).[27] Moreover, to address potential endogeneity problems we estimate both equations using the GMM method proposed by Blundell and Bond (1998) and present the results in Table 7. Compared with results of the probit specifications in Table 6, the GMM estimation results in Table 7 show that many independent variables lose their significance and that R&D and export intensities have been largely determined by these intensities in the past. Although R&D intensity is affected negatively by the debt-asset ratio, we find strong persistence in R&D intensity and export intensity. These results suggest that firms with higher R&D (or export) intensity are more likely to have a higher R&D (or export) intensity in the next period. We do not find a significant interaction effect in the case of the intensity equations: firms with a higher export (or R&D) intensity do not necessarily have a higher R&D (export) intensity in the next period. Moreover, we do not find a significant role of productivity in determining the intensities of R&D and exporting. This is consistent with findings by Aw et al. (2005) that productivity is not significant in determining export intensity.

4.2 Survival and productivity equations: estimating the joint impact of exporting and innovation strategies on performance

So far, we have found a strong persistence in investments in R&D and in exporting. In addition, we have discovered an interaction effect that makes firms engaged in R&D (or exporting) more likely to continue these activities in the next period. Our results suggest that investments in R&D and exporting are complementary. Therefore, in this sub-section, we

[26] The simple reason is that both the export intensity and R&D intensity variables are less than one by definition, so that the interaction term of these two variables becomes smaller than the original non-interacted term. One possible alternative would be to use an interaction term of export intensity and R&D dummy variables (or, R&D intensity and exporter dummy variables).

[27] Wakelin (1998) and Roper and Love (2002), estimating the determinants of export decisions and propensity to export, show that the restricted Tobit model was rejected, implying there are important differences between determinants of export decisions and determinants of propensity to export.

examine whether R&D and exporting have complementary effects on a firm's productivity by jointly estimating equations (5) and (7) presented in Section 3.2.

Table 8 reports results of the joint estimation of survival and productivity equations.[28] Columns (1) and (2) show the results using status dummy variables (*RDEXP#*, *EXPONLY#*, and *RDONLY#*) defined based on R&D expenditure information. In order to check robustness, columns (3), (4), (5) and (6) show the results using two alternative definitions for the status dummy variables. For the columns (3) and (4), the criterion is whether the firm has a formal unit devoted to R&D; for the columns (5) and (6) it is whether the firm has a positive number of in-house developed patents in use. We employ both labor productivity and TFP as a productivity variable.

As for the survival equations, the most important result is that investment decisions in R&D and export affect probability of survival except in instances where patent information is the measure of R&D status (columns (5) and (6)). In sum, we find that R&D is the best insurance against failure. That is particularly so for firms doing only R&D, for which the coefficient is larger than for firms engaged in both R&D and export. Our result is consistent with results concerning export-only firms, whose decision has no significant impact on probability of survival, whatever the case we consider. Our result contradicts previous results by Bernard & Jensen (1999), according to whom exporting improves a firm's probability of survival.[29] As for cross terms regarding productivity level and investment choices, nearly all estimated coefficients are not statistically significant, except for a slightly significant negative coefficient for the interaction term of labor productivity and R&D only (columns (1) and (3)). Although it is difficult to interpret this negative coefficient, it may imply that firms doing R&D try to operate as long as possible because of high fixed R&D costs even though their productivity is not high.

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[28] We also tried to estimate the same model using a three-year lag and obtained very similar results to those in Table 8. We should note that there is a risk of identifying a firm as having exited if its number of employees fell below 50, because the BSBSA covers only firms with 50 employees or more. In order to avoid this threshold effect, we conduct the same estimations restricting our sample to firms with 70 employees or more. Again, we obtained similar results. These results are available from the authors upon request.

[29] Bernard and Jensen (1999) define "exit" as the case where a plant closes down. However, in our firm-level dataset, we cannot distinguish whether a firm was really shut down, merged with another firm, or just dropped in size to less than 50 employees. Therefore, our contradicting results for the relationship between exporting and survival may come from a misidentification of exit firms. Although, as mentioned in the previous footnote, we checked the robustness of our results to the threshold employment size, we do not have information to identify whether firms that dropped out of the dataset merged with another firm. In theory, it may be possible to check whether a firm merged by using information such as M&A data compiled by private think tanks; however, matching such data would be an extremely onerous task because such privately published databases do not use the same firm identification code as the METI survey that we employ. Because of this difficulty to reliably identify firm exits, our results should be interpreted with caution.

As for other determinants of firm survival, we find without surprise that the older, larger (as proxied by the capital stock), or more productive firms (with a diminishing effect) are more likely to survive in the next period. Firms with a higher debt-asset ratio or foreign capital ratio are more likely to fail. As regards the survival equations in columns (5) and (6), the coefficients on R&D/export status variables are neither significant nor consistent with those in columns (1) to (4), even though coefficients of other variables are generally consistent for all cases. As shown in Table 8, the number of observations for columns (5) and (6) is smaller because patent information is limited. The small sample size may contribute to the insignificant results for survival equations in columns (5) and (6).

Table 8: Survival and productivity equations

	(1)		(2)		(3)		(4)		(5)		(6)	
	Survival	Productivity	Survival	Productivity	Survival	Productivity	Survival	Productivity	Survival	Productivity	Survival	Productivity
Productivity variable	lnVAP		lnTFP		lnVAP		lnTFP		lnVAP		lnTFP	
R&D variable	R&D expenditure		R&D expenditure		R&D department		R&D department		Patents		Patents	
log (age)	0.057***		0.073***		0.058***		0.072***		0.114***		0.132***	
	(0.011)		(0.011)		(0.011)		(0.011)		(0.023)		(0.023)	
log (K)	0.187***		0.052***		0.193***		0.053***		0.141***		0.049***	
	(0.008)		(0.006)		(0.008)		(0.006)		(0.014)		(0.010)	
log (wage rate)	0.021		-0.082***		0.030		-0.076***		0.028		-0.047	
	(0.027)		(0.025)		(0.027)		(0.025)		(0.050)		(0.049)	
Multiplant dummy	-0.014		0.014		-0.010		0.023*		0.024		0.048**	
	(0.013)		(0.012)		(0.013)		(0.012)		(0.024)		(0.024)	
Foreign capital ratio	-0.463***		-0.456***		-0.463***		-0.455***		-0.363***		-0.356***	
	(0.063)		(0.060)		(0.063)		(0.060)		(0.094)		(0.094)	
Debt-asset ratio	-0.229***		-0.217***		-0.232***		-0.218***		-0.161***		-0.150***	
	(0.027)		(0.027)		(0.027)		(0.027)		(0.050)		(0.050)	
ln (KL ratio)	-0.181***				-0.185***				-0.144***		-0.144***	
	(0.011)				(0.011)				(0.021)		(0.021)	
Productivity	0.453***	0.765***	0.153***	0.892***	0.448***	0.767***	0.155***	0.893***	0.411***	0.760***	0.122***	0.909***
	(0.050)	(0.006)	(0.016)	(0.008)	(0.052)	(0.006)	(0.016)	(0.008)	(0.108)	(0.011)	(0.032)	(0.012)
Productivity^2	-0.096***		-0.021***		-0.094***		-0.021***		-0.086***		-0.014***	
	(0.013)		(0.002)		(0.013)		(0.002)		(0.020)		(0.003)	
RDEXP#	0.121*	0.083***	0.086***	0.089***	0.139**	0.077***	0.058**	0.093***	-0.063	0.078***	-0.081	0.080***
	(0.067)	(0.004)	(0.024)	(0.008)	(0.067)	(0.003)	(0.023)	(0.009)	(0.143)	(0.007)	(0.053)	(0.017)
EXPONLY#	0.033	0.044***	-0.015	0.051***	-0.018	0.047***	0.033	0.047***	0.408*	0.025**	-0.007	0.023
	(0.078)	(0.005)	(0.031)	(0.012)	(0.072)	(0.004)	(0.031)	(0.011)	(0.219)	(0.011)	(0.073)	(0.024)
RDONLY#	0.175***	0.038***	0.107***	0.035***	0.147***	0.028***	0.092***	0.034***	-0.054	0.029***	-0.087*	0.032**
	(0.048)	(0.003)	(0.021)	(0.006)	(0.047)	(0.003)	(0.021)	(0.006)	(0.135)	(0.006)	(0.052)	(0.016)
*Productivity*RDEXP#*	-0.041		-0.005		-0.064*		-0.010		-0.020		-0.002	
	(0.034)		(0.007)		(0.034)		(0.007)		(0.075)		(0.017)	
*Productivity*EXPONLY#*	-0.024		-0.009		0.010		0.005		-0.207*		-0.019	
	(0.041)		(0.009)		(0.038)		(0.009)		(0.111)		(0.023)	
*Productivity*RDONLY#*	-0.046*		-0.001		-0.047*		0.002		-0.019		-0.000	
	(0.026)		(0.007)		(0.026)		(0.007)		(0.073)		(0.017)	
No. of observations	103620		105174		103620		105174		35361		35941	
Rho	0.0712***		0.133***		0.0612***		0.135***		0.0261		0.0346	
	(0.017)		(0.022)		(0.018)		(0.022)		(0.029)		(0.023)	
Wald test for H_0: Rho=0	17.43***		34.24***		10.98***		35.29***		0.79		2.33	
Chi-squared	89579.6		781881.4		88365.8		784392.1		32602.6		345958.4	
Log likelihood	-60203.7		-152058.0		-60273.3		-152068.7		-19173.7		-52146.3	

*Note: Heteroskedasticity-robust standard errors (clustered within a firm) are in parentheses with ***, **, and * indicating the 1%, 5%, and 10% significance levels, respectively. A constant term is not reported. All equations include three-digit industry dummy variables and year dummy variables.*

As for the productivity evolution, our main result in Table 8 is that decisions regarding investment in export and R&D strongly affect future productivity. This result holds for both labor productivity and TFP, regardless of how the R&D variable is defined. Coefficients for the firm's engagement in both R&D and exporting (*RDEXP#*) are larger than those of firms engaged only in exporting (*EXPONLY#*) or only in R&D (*RDONLY#*), suggesting that R&D and export involvement have complementary effects on productivity. The estimated result in the productivity equation (1) in Table 8 shows that firms that invest in both R&D and exporting in the current year have 8.3% higher labor productivity than firms that do not invest in either of these two activities in the next year. In addition, firms that only export or conduct only R&D have, on average, 4.4% and 3.8% higher productivity, respectively, than firms without these activities in the next period. This indicates that firms investing in either exporting or R&D can realize higher productivity in the next period. However, the much larger coefficients for *RDEXP#* than *EXPONLY#* and *RDONLY#* suggest that strong complementarities exist for R&D and exporting activities. A similar hierarchy is observed in most cases. Finally, in all the cases in Table 8, the coefficient of the current productivity level is positive and significant, suggesting the strong persistence of performance ranking among firms.

5. Does a change in investment status improve productivity?

5.1 Matching approach

In the previous section, we found that R&D and export experience have complementary effects on a firm's productivity. Moreover, the results suggested that R&D and/or exporting status were highly path-dependent: firms that presently conduct R&D and/or export are highly likely to continue such activities in the next period. We can interpret these results as implying that the complementary effects and path-dependence of these strategies create persistent differences in performance among firms. However, the analysis in the previous section says nothing about the mechanisms behind the interaction of innovation and export on performance. Moreover, if firms' investment status is not only an important determinant of performance but also highly persistent, there appears to be room for policy intervention to change firms' investment status.

Therefore, in this section, we employ propensity score matching in combination with a difference-in-difference (DID) estimator to examine whether firms' productivity growth rate improves when they change their R&D and/or investment strategies. Although we cannot directly determine the mechanisms underlying the interaction between innovation and export in their effect on performance—that is, how R&D and exporting interact and whether this interaction has lasting effects on productivity—the following analysis should provide some clues to understanding these mechanisms. By undertaking propensity score matching and the DID technique, we also address possible endogeneity problems.[30] First, we identify the probability of initiating R&D or exporting for firms in our dataset (a "propensity score"). The propensity score is defined by Rosenbaum and Rubin (1983) as the conditional probability of assignment to a particular treatment given the pre-treatment characteristics:

$$p(x) \equiv \Pr\{z = 1 \mid x\} = E\{z \mid x\} \qquad (7)$$

where $z = \{0, 1\}$ is the indicator of receiving the treatment and x is a vector of observed pre-treatment characteristics. Rosenbaum and Rubin (1983) show that if the recipient of the treatment is randomly chosen within cells defined by x, it is also random within cells defined by the values of the single-index variable $p(x)$. Therefore, for each treatment case, if the propensity score $p(x)$ is known, the Average effect of Treatment on the Treated (ATT) can be estimated as follows:

$$\begin{aligned}\hat{\alpha}_{ATT} &= E\{y^1 - y^0 \mid z = 1\} = E\{E\{y^1 - y^0 \mid z = 1, p(x)\}\} \\ &= E\{E\{y^1 \mid z = 1, p(x)\} - E\{y^0 \mid z = 0, p(x)\} \mid z = 1\}\end{aligned} \qquad (8)$$

where y^1 and y^0 denote the potential outcomes in the two counterfactual situations of treatment and no treatment, respectively. Therefore, ATT can be estimated as the average difference between outcome of recipients and non-recipients of the treatment for which propensity scores $p(x)$ are identical.

We focus on the difference in *ex post* performance between treated firms and non-treated firms. Treatment z denotes whether a firm initiates R&D or exporting. The propensity score is calculated by estimating a probit model that represents a firm's probability of initiating R&D or exporting. Our probit estimation model is specified as equation (1) in the case of determinants of R&D investment and equation (2) in the case of determinants of exporting. However, we replace the dummy variables indicating whether a firm engages in R&D or exporting with variables indicating the intensity of its R&D or exporting activities. We then match a non-R&D (or non-exporting) firm which did not start R&D (or exporting) in the subsequent period with a firm that had the "closest" propensity score in terms of starting R&D (or exporting) with this non-R&D (or non-exporting) firm and that actually did initiate R&D (or exporting). We match firms separately

[30] This is another (technical) reason for the matching approach. Although the Heckman sample selection approach employed in the previous section controls for selection bias that arises from endogenous firm exit, other possible endogeneity problems are not solved: for example, firms that expect higher productivity in the future may invest in R&D and exporting.

for each year and industry using the one-to-one nearest neighbor matching method.[31] In the second stage, we estimate a DID estimator to evaluate the causal effect of the treatment on performance variables. The propensity score matching technique should identify matched firms that satisfy an assumption that, conditional on observables, the non-treated outcomes are independent of treated status. Nonetheless, the propensity score is conditional on only a limited number of observable characteristics, implying that unobservable, time-invariant, firm-specific effects may not be fully removed after propensity score matching. Therefore, by comparing productivity growth rates of treated firms and non-treated firms (DID estimator), we can reduce these unobservable effects and obtain more robust estimates. The ATT can be estimated as equation (8) above, which, in this study, is equivalent to the following equation:

$$\hat{\alpha}_{ATT-DID} = \frac{1}{n}\sum_{1}^{n}\left(y^{1}_{treatment\,year+s} - y^{1}_{pre-treatment\,year}\right) - \frac{1}{n}\sum_{1}^{n}\left(y^{0}_{treatment\,year+s} - y^{0}_{pre-treatment\,year}\right) \tag{9}$$

where n denotes the number of observations and y denotes productivity variables.

In order to examine complementary effects of R&D and exporting on productivity growth, we first examine the effect of participation in export markets for firms engaged in R&D but not exporting and for firms that are neither engaged in R&D nor exporting. Then, we examine the effect of conducting R&D for firms already engaged in exporting but not R&D and for firms that are neither engaged in R&D nor exporting.

5.2 The matching results

For the first case, we select firms that were not engaged in exporting but were conducting R&D in year $t-1$. We compare productivity growth rates of firms that began exporting in year t and firms that did not begin exporting in year t. We exclude firms that were not exporting in year $t-1$ but were exporting before year $t-1$; we did so in order to eliminate biases that may arise from firms' earlier experience in exporting. DID results are shown in panel (a) in Table 9. The upper panels show the DID estimators measured as equation (9) using labor productivity as a productivity variable. The lower panel shows the DID estimators based on TFP. Both upper and lower panels show that productivity growth is significantly higher for firms that started exporting in year t and that the difference in productivity growth does not clearly diminish over time. In the case of labor productivity, for example, firms that started exporting in year t show 4.6% higher productivity growth during the period from pre-treatment year ($t-1$) to year $t+1$, compared

[31] Our matching procedure is implemented in Stata 10 using a modified version of the procedure provided by Leuven and Sianesi (2003). The probit estimation results and the balancing property test results are shown in Appendix Tables 2 and 3.

with firms that did not start exporting in year *t*. Moreover, firms that started exporting in year *t* still show 4.6% higher productivity growth three years after they started exporting. For firms already engaged in R&D, we observe that exporting produced a significant and persistent impact on productivity growth regardless of the productivity indicator we consider.

Table 9: Difference in differences (DID) results

(a) Non-Exporting but R&D firms at *t-1* (Treatment: Start Exporting in *t*)

Dep. Variable	Labor productivity growth		
	One year later	Two years later	Three years later
Effect of Exporting	0.0460 **	0.0400 *	0.0459 *
	(0.019)	(0.023)	(0.025)
Obs.	1724	1495	1365

Dep. Variable	TFP growth (LevPet)		
	One year later	Two years later	Three years later
Effect of Exporting	0.0826 *	0.1341 **	0.1132 ***
	(0.049)	(0.067)	(0.061)
Obs.	1737	1513	1378

(b) Non-Exporting and Non-R&D firms at *t-1* (Treatment: Start Exporting in *t*)

Dep. Variable	Labor productivity growth		
	One year later	Two years later	Three years later
Effect of Exporting	0.0430	0.0261	0.0297
	(0.031)	(0.033)	(0.042)
Obs.	892	774	686

Dep. Variable	TFP growth (LevPet)		
	One year later	Two years later	Three years later
Effect of Exporting	-0.0149	0.0062	0.0174
	(0.104)	(0.105)	(0.111)
Obs.	899	786	691

(c) Non-R&D but Exporting firms at *t-1* (Treatment: Start R&D in *t*)

Dep. Variable	Labor productivity growth		
	One year later	Two years later	Three years later
Effect of R&D	0.0112	-0.0284	0.0517
	(0.027)	(0.032)	(0.045)
Obs.	834	741	679

Dep. Variable	TFP growth (LevPet)		
	One year later	Two years later	Three years later
Effect of R&D	0.0534	-0.1068	-0.0121
	(0.084)	(0.085)	(0.106)
Obs.	844	757	691

(d) Non-Exporting and Non-R&D firms at *t-1* (Treatment: Start R&D in *t*)

Dep. Variable	Labor productivity growth		
	One year later	Two years later	Three years later
Effect of R&D	0.0217	0.0291	0.0354 *
	(0.014)	(0.020)	(0.019)
Obs.	2777	2441	2107

Dep. Variable	TFP growth (LevPet)		
	One year later	Two years later	Three years later
Effect of R&D	0.0104	0.0095	0.0506
	(0.041)	(0.042)	(0.058)
Obs.	2829	2499	2164

*Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively.*

However, when we examine the effects of initiating exports on firms inexperienced in R&D and exporting, no DID estimator is statistically significant (panel (b) in Table 9). The insignificant DID estimators in panel (b) suggest that exporting does not contribute to productivity growth when the firm does not engage in R&D. We may interpret the results as firms without technological capabilities cannot enjoy a return on their exposure to the export market.

For the next step, we select firms that were not engaged in R&D but were exporting in year $t - 1$. We compare productivity growth of firms that initiated R&D in year t and firms that did not. Panel (c) in Table 9 shows that productivity growth for exporters that initiated R&D in year t is not significantly higher than for exporters that did not initiate R&D in year t. This result may indicate a substantial time lag before R&D contributes to productivity. That lag may be because firms need time to build technological capabilities to absorb external knowledge acquired from the export market. Another possibility is that initiating R&D may incur start-up costs that lower productivity. On the other hand, panel (d) shows the result for effects of starting R&D for firms without experience in R&D and exporting. The only significant DID estimators pertain to labor productivity growth rate three years after initiating R&D. In addition, firms that started R&D in year t show 5.1% higher TFP growth compared with firms not starting R&D in year t, although the DID estimator is not statistically significant. The result implies that starting R&D may have somewhat positive effects on productivity growth with at least a three-year time lag.

In sum, we find that initiating exports improves productivity significantly and persistently among firms that have accumulated internal knowledge through R&D. This finding implies strong complementarities between R&D and exporting for productivity growth. However, mechanisms behind these complementarities are not straightforward. That is, exporting firms lacking R&D cannot boost productivity in the short run, even after undertaking R&D activities.

Some may interpret these results as suggesting that firms with R&D experience possess absorptive capacity for external knowledge through exporting. In other words, firms can learn from exporting. However, the complementarities between R&D and exporting may be more than learning-by-exporting. This particularly could be the case in developed countries such as Japan. As the importance of the international division of labor grows for Japanese manufacturers, only firms with technological capabilities can improve productivity by shifting domestic production toward high value-added activities and moving low value-added production overseas. Clearly, in order to understand the mechanisms underlying the complementarities between R&D and exporting, we would need to examine firms' core technologies, the destinations of their exports, and the types of products that they export. While this unfortunately is not possible, what the results of our analysis do show is that firms that already have accumulated internal knowledge may be able to further improve productivity by starting to export, whereas, on the other hand, it is likely to take time for non-R&D firms to build technological capabilities through R&D activities.

Conclusion

In this study we use a large-scale administrative survey conducted by METI to analyze why some Japanese firms persistently performed better than others during the period 1994–2003. We focus on innovation and export as two strategies for a firm to increase its knowledge stock and therefore its capabilities. Our main findings can be summarized as follows. First, we find strong persistence in R&D and export decisions. Second, strong complementarities exist between R&D investment and exporting. This pair of results confirms that interactions between innovation and exporting strategies define coherent *productive models* or patterns of learning. Third, we show that firms' endogenous choices regarding innovation and exports affect their performance, both in terms of productivity and survival. It is possible to establish a stable ranking of performance based on firms' strategies. Fourth, our matching analysis results reveal that a change in firm strategy significantly and persistently improves productivity in the case of firms that have accumulated internal knowledge through R&D and that start exporting. Moreover, the complementary effects of innovation and exporting strategies are lasting, not temporary. As a whole, these results show that the interplay of innovation and export is a source of permanent differences in performance among firms.

We believe our research suggests several implications for understanding the heterogeneity of firms and their performance. First, it is true that technology is one major source of performance differences among firms (Nelson, 1981 & 1991; Dosi et al., 2000), but this conclusion must be nuanced: choices of technology interact with other strategic choices such as global engagement, including export decisions. It is misleading to focus solely on the impact of technology on the performance dispersion of firms; adopting a cognitive approach to the firm may define patterns of learning based on innovation and exporting strategies. This approach allows integrating, in a unified framework, varieties of firms' choices that influence learning processes. By adopting a broader view we can understand why, beyond the trade-offs implicit in investing limited resources, firms have incentives to invest in R&D and exports: namely, they benefit from the complementarities existing between these investments. The greater accumulation of knowledge is not only due to the investment of more resources; it is also related to the fact that they learn more from more sources such as suppliers and customers.

The second implication of this paper concerns the permanent/temporary nature of performance differences among firms. The literature discussing exports, innovation, and performance offers contradictory results. For example Roper & Love (2002) find some permanent differences between innovators and non-innovators, whereas Damijan & Kostevc (2006) find that differences in performance are transitory. As a whole, our results conform to Geroski et al. (1993), who explicitly distinguish between the transitory benefits of introducing a new product and the permanent benefits of innovation process that transform firms' internal capabilities. We are able to give an example related to exports that supports their conclusion that innovators are better able than non-innovators to realize the benefits of spill-overs, thus improving relative performance.

Third, the results of this paper have some important policy implications. The strong path-dependence and complementarities of R&D and exporting strategies can lead to a persistent dispersion in performance among firms, unless some form of policy intervention effectively alters firms' strategies. In other words, there is room for policy intervention to improve firms' productivity by altering their strategies. Our results suggest that appropriate policies to promote exporting by R&D firms are likely to boost their productivity. On the other hand, non-R&D firms may benefit more from policies to assist them with efficient knowledge accumulation through R&D activities than from export promoting policies.

However, our contribution faces some limitations. First, learning-behavior is not the only possible explanation for complementarities between innovation and exporting strategies. For example, costs may be a mechanism behind the complementarities we find. Our paper does not allow discriminating between different interpretations. In regard to this first limitation, it is important to underline that what can be learned from exporting depends deeply on the firm's standing on the technological frontier. From this point of view, the mechanisms can be variables depending on the country, the sectors, and the firms. Second, even if we tried to introduce better proxies for innovation strategies and knowledge, our approach, which heavily relies on R&D data, would not be completely satisfying from this point of view; the same applies with regard to exporting, which constitutes only part of global engagement, even if, in the case of Japanese firms, it has been found to be strongly complementary with other dimensions such as FDI. Third, the analysis of complementarities between innovation and exporting strategies is certainly an important step. However, from this analysis, we cannot conclude anything regarding the *causality* between the two strategies. As already mentioned above, both innovation and exporting strategies are endogenously determined, and it would be extremely difficult to identify the causal effects of one on the other unless we were able to find appropriate exogenous instrument variables. Although estimating a structural model, as done, for example, by Aw et al. (2009), or employing a matching technique, as done, for example, by Damijan et al. (2008) may help to identify the causal effect, it would be still challenging to identify the direction of causality. Yet, it is certainly important to understand the causal relationship between R&D and exporting activity to understand the complementary effects of these strategies on productivity. Fourth, we did not identify the reasons why firms changed their innovation and/or exporting status, though we did find a strong path-dependence in the status. This is another challenging issue because shocks which affect the status are often unobservable to researchers. Finally, it is necessary to better understand the interactions between innovation and global engagement, on the one hand, and firms' organizational characteristics on the other hand. These are directions for future research.

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Appendix: Variable construction and data sources

Output: Except for the commerce sector, gross output is defined as firms' total sales. For the commerce sector, gross output is measured as sales minus expenses for purchased materials. Gross output is deflated by the output deflator taken from the JIP Database 2006.

Intermediate inputs: For the commerce sector, intermediate inputs are calculated as (Cost of sales + Operating costs) – (Wages + Depreciation costs + Expenses for purchased materials). The intermediate inputs of other sectors are defined as (Cost of sales + Operating costs) – (Wages + Depreciation costs). Intermediate inputs are deflated by the intermediate input deflator taken from the JIP Database 2006.

Labor input: As labor input, we used each firm's total number of workers multiplied by the sector's working hours taken from the JIP Database 2006.

Capital Stock: For capital stock, the only data available are the nominal book values of tangible fixed assets. Using these data, we calculated the net capital stock of firm *i* in industry *j* in constant 1995 prices as follows:

$$K_{it} = BV_{it} * (INK_{jt} / IBV_{jt})$$

where BV_{it} represents the book value of firm *i*'s tangible fixed assets in year *t*, INK_{jt} stands for the net capital stock of industry *j* in constant 1995 prices, and IBV_{jt} denotes the book value of industry *j*'s capital. INK_{jt} was calculated as follows. First, as a benchmark, we took the data on the book value of tangible fixed assets in 1975 from the *Financial Statements Statistics of Corporations* published by Ministry of Finance. We then converted the book value of year 1975 into the real value in constant 1995 prices using the investment deflator taken from the JIP Database 2006. Second, the net capital stock of industry *j*, INK_{jt}, for succeeding years was calculated using the perpetual inventory method. The sectoral depreciation rate used is taken from the JIP Database 2006.

Appendix Table 1: Bivariate probit estimation results using alternative measures for R&D activities

Dependent varriable: R&D or Exporting choice in year (t+1)

	(1)		(2)		(3)		(4)		(5)		(6)	
	R&D	Exporting	R&D	Exporting	R&D	Exporting	R&D	Exporting	R&D	Exporting	R&D	Exporting
Productivity variable	lnVAP		lnTFP		lnVAP		lnTFP					
Dependent variable for R&D choice	R&D department		R&D department		R&D expenditure		R&D expenditure		R&D department		R&D department	
Explanatory variable for R&D status	R&D department		R&D department		Patents		Patents		Patents		Patents	
log (age)	0.074***	0.067***	0.085***	0.075***	0.070**	-0.002	0.091***	0.014	0.047	-0.002	0.081**	0.015
	(0.012)	(0.014)	(0.012)	(0.014)	(0.030)	(0.024)	(0.029)	(0.024)	(0.033)	(0.024)	(0.032)	(0.024)
log (K)	0.160***	0.144***	0.084***	0.064***	0.243***	0.151***	0.147***	0.068***	0.297***	0.152***	0.185***	0.069***
	(0.008)	(0.009)	(0.005)	(0.006)	(0.022)	(0.013)	(0.014)	(0.010)	(0.020)	(0.013)	(0.014)	(0.010)
log (wage rate)	0.031	0.103***	-0.037	0.039	0.194***	0.075	0.138**	-0.012	-0.096	0.071	-0.189***	-0.017
	(0.028)	(0.034)	(0.026)	(0.032)	(0.060)	(0.053)	(0.059)	(0.052)	(0.062)	(0.053)	(0.062)	(0.052)
Multiplant dummy	-0.111***	0.135***	-0.090***	0.160***	0.051	0.071***	0.077**	0.095***	-0.431***	0.069***	-0.402***	0.093***
	(0.013)	(0.015)	(0.013)	(0.015)	(0.032)	(0.024)	(0.031)	(0.024)	(0.034)	(0.024)	(0.033)	(0.024)
Foreign capital ratio	-0.134*	0.399***	-0.131*	0.425***	-0.147	0.094	-0.134	0.154	-0.437***	0.080	-0.396***	0.140
	(0.072)	(0.084)	(0.069)	(0.082)	(0.141)	(0.120)	(0.134)	(0.121)	(0.147)	(0.120)	(0.141)	(0.121)
Debt-asset ratio	-0.099***	-0.122***	-0.092***	-0.120***	-0.125*	-0.245***	-0.109	-0.222***	-0.237***	-0.247***	-0.208***	-0.224***
	(0.027)	(0.031)	(0.026)	(0.031)	(0.068)	(0.050)	(0.067)	(0.049)	(0.072)	(0.050)	(0.072)	(0.049)
ln (KL ratio)	-0.118***	-0.132***			-0.186***	-0.162***			-0.232***	-0.163***		
	(0.011)	(0.013)			(0.030)	(0.021)			(0.029)	(0.021)		
Productivity	0.080**	0.111**	0.061***	0.072***	0.237***	0.151	0.072**	0.072**	0.089	0.150	0.060	0.073**
	(0.038)	(0.055)	(0.016)	(0.019)	(0.090)	(0.102)	(0.036)	(0.033)	(0.095)	(0.102)	(0.038)	(0.033)
Productivity^2	-0.030***	-0.019*	-0.008***	-0.004	-0.042***	-0.021	-0.017***	-0.006*	-0.051***	-0.021	-0.011**	-0.006*
	(0.009)	(0.011)	(0.002)	(0.002)	(0.016)	(0.014)	(0.004)	(0.003)	(0.017)	(0.015)	(0.004)	(0.003)
RDEXP#	2.563***	3.220***	2.784***	3.193***	0.741***	3.024***	0.651***	3.045***	0.260*	3.024***	0.573***	3.046***
	(0.071)	(0.084)	(0.027)	(0.031)	(0.148)	(0.181)	(0.060)	(0.061)	(0.151)	(0.181)	(0.062)	(0.061)
EXPONLY#	0.272***	2.915***	0.235***	2.994***	0.178	2.947***	0.159**	2.860***	0.272	2.938***	0.188**	2.860***
	(0.085)	(0.105)	(0.032)	(0.040)	(0.229)	(0.292)	(0.077)	(0.086)	(0.226)	(0.293)	(0.079)	(0.086)
RDONLY#	2.142***	0.331***	2.551***	0.212***	0.353**	0.309*	0.396***	0.004	0.091	0.311*	0.280***	0.004
	(0.059)	(0.076)	(0.026)	(0.028)	(0.137)	(0.174)	(0.054)	(0.059)	(0.139)	(0.174)	(0.056)	(0.059)
*Productivity*RDEXP#*	0.084**	-0.025	0.017*	-0.003	-0.062	-0.014	0.004	0.014	0.143*	-0.014	0.004	0.014
	(0.035)	(0.042)	(0.009)	(0.010)	(0.076)	(0.091)	(0.018)	(0.019)	(0.077)	(0.091)	(0.019)	(0.019)
*Productivity*EXPONLY#*	-0.043	0.046	0.024**	-0.006	0.002	-0.020	-0.011	-0.026	-0.030	-0.015	-0.014	-0.027
	(0.043)	(0.053)	(0.010)	(0.013)	(0.117)	(0.146)	(0.025)	(0.028)	(0.114)	(0.147)	(0.025)	(0.028)
*Productivity*RDONLY#*	0.198***	-0.064	0.020**	-0.006	0.031	-0.139	-0.005	-0.020	0.125*	-0.140	-0.019	-0.020
	(0.032)	(0.040)	(0.008)	(0.009)	(0.073)	(0.088)	(0.017)	(0.019)	(0.073)	(0.088)	(0.017)	(0.019)
Rho	0.0994***		0.103***		0.0947***		0.103***		0.0804***		0.0909***	
	(0.014)		(0.014)		(0.016)		(0.016)		(0.015)		(0.015)	
No. of observations	91580		92932		32341		32862		32341		32862	
Chi-squared	59937		60803		13760.7		14191.8		13417.2		13817.1	
Log likelihood	-43355.7		-44084		-22433.9		-22866.1		-24232.9		-24762.5	

*Note: Heteroskedasticity-robust standard errors (clustered within a firm) are in parentheses with ***, **, and * indicating the 1%, 5%, and 10% significance levels, respectively. A constant term is not reported. All equations include three-digit industry dummy variables and year dummy variables.*

Appendix Table 2: Probit estimation results for the R&D or exporting decision

Dependent varriable: R&D or Export decision in year (t+1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Status in year *t-1*	No-Exporting but R&D	No-Exporting but R&D	No-Exporting & No-R&D	No-Exporting & No-R&D	No-R&D but Exporting	No-R&D but Exporting	No-Exporting & No-R&D	No-Exporting & No-R&D
Treatment in year *t*	Exporting	Exporting	Exporting	Exporting	R&D	R&D	R&D	R&D
Productivity measure	lnVAP	lnTFP	lnVAP	lnTFP	lnVAP	lnTFP	lnVAP	lnTFP
log (age)	0.041	0.049	-0.003	-0.008	-0.118**	-0.104**	0.007	0.002
	(0.031)	(0.031)	(0.033)	(0.032)	(0.047)	(0.047)	(0.022)	(0.021)
log (K)	0.085***	0.040***	0.151***	0.057***	0.153***	0.075***	0.184***	0.076***
	(0.018)	(0.014)	(0.026)	(0.016)	(0.029)	(0.023)	(0.018)	(0.011)
log (wage rate)	0.109	0.113	0.157*	0.048	0.168	0.113	-0.033	-0.123**
	(0.073)	(0.069)	(0.090)	(0.084)	(0.121)	(0.117)	(0.059)	(0.054)
Multiplant dummy	0.113***	0.125***	0.133***	0.160***	0.025	0.059	0.054**	0.072***
	(0.033)	(0.032)	(0.038)	(0.037)	(0.058)	(0.057)	(0.026)	(0.025)
Foreign capital ratio	0.000	0.001	0.009***	0.009***	-0.004*	-0.004*	0.004	0.004
	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
Debt-asset ratio	-0.015	-0.019	-0.009	-0.014	-0.065	-0.052	0.093*	0.096*
	(0.071)	(0.070)	(0.081)	(0.081)	(0.122)	(0.121)	(0.054)	(0.054)
ln (KL ratio)	-0.083***		-0.118***		-0.135***		-0.154***	
	(0.028)		(0.032)		(0.047)		(0.022)	
Productivity	-0.059	0.011	-0.059	0.050	0.075	0.074	0.289***	0.110***
	(0.106)	(0.040)	(0.121)	(0.049)	(0.175)	(0.063)	(0.105)	(0.035)
Productivity^2	0.016	0.002	0.010	-0.004	-0.014	-0.006	-0.049*	-0.019***
	(0.024)	(0.006)	(0.031)	(0.007)	(0.042)	(0.009)	(0.027)	(0.005)
R&D intensity	4.414***	4.348***	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	(0.857)	(0.852)						
EXP intensity	n.a.	n.a.	n.a.	n.a.	-0.207	-0.216	n.a.	n.a.
					(0.176)	(0.171)		
No. of observations	22349	22700	30348	30711	3897	3959	30467	30839
Chi-squared	420.69	404.17	385.63	373.24	213.87	209.62	642	629.38
Log likelihood	-3916.5	-3971.5	-2538.0	-2558.8	-1372.7	-1398.7	-6071.8	-6170.3

*Note: Heteroskedasticity-robust standard errors (clustered within a firm) are in parentheses with ***, **, and * indicating the 1%, 5%, and 10% significance levels, respectively. A constant term is not reported. All equations include three-digit industry dummy variables and year dummy variables.*

n.a. = non applicable.

Appendix Table 3: Balancing tests for matching

(a) Treatment: Exporting (corresponding to equation (1) in Appendix Table 3)

Status in *t-1* — No-Exporting but R&D

productivity measure — lnVAP

Variable	Sample	Mean		%bias	%reduct	t-test	
		Treated	Control		|bias|	t	p>|t|
log (age)	Unmatched	3.6404	3.4599	32.6		45.27	0
	Matched	3.5464	3.5484	-0.4	98.9	-0.09	0.929
log (K)	Unmatched	8.0449	6.9539	69.3		101.68	0
	Matched	7.602	7.5883	0.9	98.7	0.21	0.834
log (KL ratio)	Unmatched	2.2437	1.8886	36.1		48.79	0
	Matched	2.1545	2.1526	0.2	99.5	0.05	0.964
log (wage rate)	Unmatched	1.663	1.4889	56		76.96	0
	Matched	1.5983	1.5987	-0.1	99.8	-0.03	0.976
Multiplant dummy	Unmatched	0.6918	0.49537	40.8		56.63	0
	Matched	0.62722	0.62821	-0.2	99.5	-0.05	0.963
Foreign capital ratio	Unmatched	3.5927	0.51499	28		47.11	0
	Matched	1.0069	1.125	-1.1	96.2	-0.33	0.739
Debt-asset ratio	Unmatched	0.64088	0.71453	-31.6		-44.31	0
	Matched	0.68518	0.68667	-0.6	98	-0.16	0.876
lnVAP	Unmatched	2.0538	1.7799	49.2		69.67	0
	Matched	1.9425	1.9614	-3.4	93.1	-0.83	0.406
lnVAP^2	Unmatched	4.5332	3.4718	45.7		66.89	0
	Matched	4.0302	4.1156	-3.7	92	-0.84	0.4
R&D intensity	Unmatched	0.02009	0.0051	70.7		114.7	0
	Matched	0.01712	0.01666	2.2	96.9	0.49	0.624

(b) Treatment: Exporting (corresponding to equation (2) in Appendix Table 3)

Status in *t-1*		No-Exporting but R&D					
productivity measure		lnTFP					
		Mean			%reduct	t-test	
Variable	Sample	Treated	Control	%bias	|bias|	t	p>|t|
log (age)	Unmatched	3.6404	3.4599	32.6		45.27	0
	Matched	3.5488	3.5625	-2.5	92.4	-0.6	0.549
log (K)	Unmatched	8.0449	6.9539	69.3		101.68	0
	Matched	7.6237	7.6318	-0.5	99.3	-0.13	0.898
log (wage rate)	Unmatched	1.663	1.4889	56		76.96	0
	Matched	1.6016	1.6049	-1.1	98.1	-0.26	0.797
Multiplant dummy	Unmatched	0.6918	0.49537	40.8		56.63	0
	Matched	0.62695	0.64355	-3.4	91.5	-0.78	0.435
Foreign capital ratio	Unmatched	3.5927	0.51499	28		47.11	0
	Matched	1.0008	1.0271	-0.2	99.1	-0.08	0.936
Debt-asset ratio	Unmatched	0.64088	0.71453	-31.6		-44.31	0
	Matched	0.68503	0.68338	0.7	97.8	0.17	0.863
lnTFP	Unmatched	-1.645	-2.3182	28.4		41.59	0
	Matched	-1.7233	-1.7403	0.7	97.5	0.17	0.866
lnTFP^2	Unmatched	9.4082	9.9479	-6.3		-8.72	0
	Matched	8.1907	8.2027	-0.1	97.8	-0.03	0.972
R&D intensity	Unmatched	0.02009	0.0051	70.7		114.7	0
	Matched	0.01699	0.01596	4.9	93.1	1.1	0.271

(c) Treatment: Exporting (corresponding to equation (3) in Appendix Table 3)

Status in *t-1* No-Exporting and No-R&D

productivity measure lnVAP

Variable	Sample	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|
log (age)	Unmatched	3.6404	3.4599	32.6		45.27	0
	Matched	3.3581	3.3786	-3.7	88.6	-0.58	0.564
log (K)	Unmatched	8.0449	6.9539	69.3		101.68	0
	Matched	6.8445	6.908	-4	94.2	-0.81	0.417
log (KL ratio)	Unmatched	2.2437	1.8886	36.1		48.79	0
	Matched	1.8231	1.8894	-6.7	81.3	-1.06	0.29
log (wage rate)	Unmatched	1.663	1.4889	56		76.96	0
	Matched	1.4772	1.4711	2	96.5	0.33	0.74
Multiplant dummy	Unmatched	0.6918	0.49537	40.8		56.63	0
	Matched	0.52294	0.5156	1.5	96.3	0.24	0.809
Foreign capital ratio	Unmatched	3.5927	0.51499	28		47.11	0
	Matched	0.97248	0.39229	5.3	81.1	1.33	0.185
Debt-asset ratio	Unmatched	0.64088	0.71453	-31.6		-44.31	0
	Matched	0.73817	0.72511	5.6	82.3	0.97	0.335
lnVAP	Unmatched	2.0538	1.7799	49.2		69.67	0
	Matched	1.753	1.7525	0.1	99.8	0.02	0.986
lnVAP^2	Unmatched	4.5332	3.4718	45.7		66.89	0
	Matched	3.3176	3.3194	-0.1	99.8	-0.02	0.987

(e) Treatment: R&D (corresponding to equation (5) in Appendix Table 3)

Status in *t-1*		No-R&D but Exporting					
productivity measure		lnVAP					
		Mean			%reduct	t-test	
Variable	Sample	Treated	Control	%bias	|bias|	t	p>|t|
log (age)	Unmatched	3.6024	3.4287	31		47.74	0
	Matched	3.4378	3.3813	10.1	67.5	1.32	0.188
log (K)	Unmatched	7.8287	6.7522	71.7		110.75	0
	Matched	7.3538	7.2292	8.3	88.4	1.29	0.197
log (KL ratio)	Unmatched	2.1922	1.8054	38.3		58.47	0
	Matched	1.9913	1.9602	3.1	92	0.51	0.612
log (wage rate)	Unmatched	1.6192	1.4655	48.5		74.2	0
	Matched	1.5579	1.5377	6.4	86.9	1.05	0.292
Multiplant dummy	Unmatched	0.63916	0.47215	34.1		52.55	0
	Matched	0.59175	0.5732	3.8	88.9	0.59	0.558
Foreign capital ratio	Unmatched	2.1831	0.70954	15.8		24.47	0
	Matched	2.4456	2.4406	0.1	99.7	0.01	0.995
Debt-asset ratio	Unmatched	0.65937	0.72445	-27.8		-42.75	0
	Matched	0.69879	0.69984	-0.4	98.4	-0.07	0.944
lnVAP	Unmatched	1.9956	1.7329	47.5		73.28	0
	Matched	1.8763	1.8729	0.6	98.7	0.11	0.913
lnVAP^2	Unmatched	4.2995	3.2978	44.7		69.15	0
	Matched	3.7679	3.7455	1	97.8	0.17	0.862
EXP intensity	Unmatched	0.05168	0.01665	34.6		53.62	0
	Matched	0.10429	0.09989	4.4	87.4	0.47	0.64

(f) Treatment: R&D (corresponding to equation (6) in Appendix Table 3)

Status in *t-1*		No-R&D but Exporting					
productivity measure		lnTFP					
		Mean			%reduct	t-test	
Variable	Sample	Treated	Control	%bias	|bias|	t	p>|t|
log (age)	Unmatched	3.6024	3.4287	31		47.74	0
	Matched	3.4309	3.4111	3.5	88.6	0.47	0.639
log (K)	Unmatched	7.8287	6.7522	71.7		110.75	0
	Matched	7.3883	7.3213	4.5	93.8	0.68	0.498
log (wage rate)	Unmatched	1.6192	1.4655	48.5		74.2	0
	Matched	1.5608	1.5506	3.2	93.4	0.54	0.587
Multiplant dummy	Unmatched	0.63916	0.47215	34.1		52.55	0
	Matched	0.59432	0.56795	5.4	84.2	0.84	0.402
Foreign capital ratio	Unmatched	2.1831	0.70954	15.8		24.47	0
	Matched	2.6087	2.2663	3.7	76.8	0.42	0.675
Debt-asset ratio	Unmatched	0.65937	0.72445	-27.8		-42.75	0
	Matched	0.69944	0.69907	0.2	99.4	0.02	0.98
lnTFP	Unmatched	-1.6538	-2.5616	40.2		62.01	0
	Matched	-2.0864	-2.0939	0.3	99.2	0.05	0.961
lnTFP^2	Unmatched	8.4965	11.021	-29.2		-45.04	0
	Matched	10.076	10.176	-1.2	96.1	-0.19	0.849
EXP intensity	Unmatched	0.05168	0.01665	34.6		53.62	0
	Matched	0.10605	0.10041	5.6	83.9	0.59	0.553

(g) Treatment: R&D (corresponding to equation (7) in Appendix Table 3)

Status in *t-1*		No-Exporting and No-R&D					
productivity measure		lnVAP					
		Mean			%reduct	t-test	
Variable	Sample	Treated	Control	%bias	|bias|	t	p>|t|
log (age)	Unmatched	3.6024	3.4287	31		47.74	0
	Matched	3.374	3.3604	2.4	92.2	0.65	0.515
log (K)	Unmatched	7.8287	6.7522	71.7		110.75	0
	Matched	6.7899	6.7852	0.3	99.6	0.1	0.919
log (KL ratio)	Unmatched	2.1922	1.8054	38.3		58.47	0
	Matched	1.7793	1.7975	-1.8	95.3	-0.48	0.63
log (wage rate)	Unmatched	1.6192	1.4655	48.5		74.2	0
	Matched	1.4326	1.4318	0.2	99.5	0.07	0.945
Multiplant dummy	Unmatched	0.63916	0.47215	34.1		52.55	0
	Matched	0.48263	0.48873	-1.2	96.4	-0.35	0.727
Foreign capital ratio	Unmatched	2.1831	0.70954	15.8		24.47	0
	Matched	0.49598	0.5184	-0.2	98.5	-0.11	0.915
Debt-asset ratio	Unmatched	0.65937	0.72445	-27.8		-42.75	0
	Matched	0.74383	0.73833	2.4	91.5	0.68	0.497
lnVAP	Unmatched	1.9956	1.7329	47.5		73.28	0
	Matched	1.7183	1.7142	0.7	98.5	0.25	0.804
lnVAP^2	Unmatched	4.2995	3.2978	44.7		69.15	0
	Matched	3.1782	3.1518	1.2	97.4	0.45	0.652

(h) Treatment: R&D (corresponding to equation (8) in Appendix Table 3)

Status in *t-1*		No-Exporting and No-R&D					
productivity measure		lnTFP					
		Mean			%reduct	t-test	
Variable	Sample	Treated	Control	%bias	|bias|	t	p>|t|
log (age)	Unmatched	3.6024	3.4287	31		47.74	0
	Matched	3.3692	3.3528	2.9	90.6	0.77	0.443
log (K)	Unmatched	7.8287	6.7522	71.7		110.75	0
	Matched	6.833	6.8224	0.7	99	0.23	0.821
log (wage rate)	Unmatched	1.6192	1.4655	48.5		74.2	0
	Matched	1.4356	1.4295	1.9	96	0.54	0.592
Multiplant dummy	Unmatched	0.63916	0.47215	34.1		52.55	0
	Matched	0.48079	0.4922	-2.3	93.2	-0.66	0.51
Foreign capital ratio	Unmatched	2.1831	0.70954	15.8		24.47	0
	Matched	0.48854	0.23193	2.8	82.6	1.53	0.126
Debt-asset ratio	Unmatched	0.65937	0.72445	-27.8		-42.75	0
	Matched	0.7436	0.74082	1.2	95.7	0.35	0.728
lnTFP	Unmatched	-1.6538	-2.5616	40.2		62.01	0
	Matched	-2.3085	-2.314	0.2	99.4	0.08	0.938
lnTFP^2	Unmatched	8.4965	11.021	-29.2		-45.04	0
	Matched	9.5509	9.5684	-0.2	99.3	-0.06	0.953

(d) Treatment: Exporting (corresponding to equation (4) in Appendix Table 3)

Status in *t-1*		No-Exporting and No-R&D					
productivity measure		lnTFP					
		Mean			%reduct	t-test	
Variable	Sample	Treated	Control	%bias	|bias|	t	p>|t|
log (age)	Unmatched	3.6404	3.4599	32.6		45.27	0
	Matched	3.3523	3.3447	1.4	95.8	0.2	0.839
log (K)	Unmatched	8.0449	6.9539	69.3		101.68	0
	Matched	6.8583	6.8875	-1.9	97.3	-0.36	0.72
log (wage rate)	Unmatched	1.663	1.4889	56		76.96	0
	Matched	1.4787	1.4784	0.1	99.9	0.01	0.99
Multiplant dummy	Unmatched	0.6918	0.49537	40.8		56.63	0
	Matched	0.52468	0.53199	-1.5	96.3	-0.24	0.809
Foreign capital ratio	Unmatched	3.5927	0.51499	28		47.11	0
	Matched	0.96892	0.09269	8	71.5	2.3	0.022
Debt-asset ratio	Unmatched	0.64088	0.71453	-31.6		-44.31	0
	Matched	0.73657	0.73101	2.4	92.5	0.41	0.679
lnTFP	Unmatched	-1.645	-2.3182	28.4		41.59	0
	Matched	-2.2955	-2.3187	1	96.6	0.17	0.864
lnTFP^2	Unmatched	9.4082	9.9479	-6.3		-8.72	0
	Matched	10.348	10.324	0.3	95.5	0.05	0.962

Appendix Table 4: JIP 2006 micro-data classification for the manufacturing industries

Industry code	Industry description	Annual average No. of firms
1	Food products	1 443
2	Textile products	671
3	Lumber and wood products and furniture	305
4	Pulp, paper, and coated and glazed paper	396
5	Printing and publishing	537
6	Chemicals and chemical fibers	296
7	Paint, coating, and grease	135
8	Pharmaceutical products	202
9	Miscellaneous chemical products	246
10	Petroleum and coal products	53
11	Plastic products	613
12	Rubber products	136
13	Ceramic, stone and clay products	519
14	Iron and steel	370
15	Non-ferrous metals	304
16	Fabricated metal products	903
17	Metal processing machinery	220
18	Special industry machinery	378
19	Office and service industry machines	151
20	Miscellaneous machinery	706
21	Electrical generating, distribution and industrial apparatus	376
22	Household electric appliances	146
23	Communication equipment	265
24	Computer equipment and accessories and electronic equipment	189
25	Electronic parts and devices	640
26	Miscellaneous electrical machinery equipment	202
27	Motor vehicles and parts	855
28	Other transportation equipment	209
29	Precision machinery and equipment	327
30	Miscellaneous manufacturing industries	301