Product versus Process Innovation and the Global Engagement of Firms

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Abstract

How can product innovation and process innovation have different effects on firms' internationalization strategies? Recent literature on the relationship between innovation and firms' participation in foreign markets is dominated by models of innovation and export behavior. However, foreign direct investment by multinational enterprises may also be associated with firms' innovative activities. In order to assess the role of innovation in firms' international engagement strategies, we develop a theoretical model and present new empirical evidence on firms' choice of entry – exports and FDI – based on firm-level data. Our theoretical and empirical results suggest that product innovation is more strongly positively correlated with transition from being a domestic firm to exporting, while process innovation is more strongly correlated with transition from exporting to FDI.

Keywords: Process Innovation, Product Innovation, Foreign Direct Investment, Export

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1. Introduction

Innovation is a key source of core competence in firms, and a considerable amount of research has analyzed its role in firms' strategy. Most of these studies classify firm innovation into two types: process innovation and product innovation. Process innovation is defined as improvements in existing processes and the development and implementation of new processes, while product innovation is defined as an improvement in existing products, and the development and commercialization of new products (Zakic, Jovanovic and Stamatovic, 2008). Innovation is particularly important in enhancing firms' viability and growth in foreign market as well as domestic market because globalization exerts strong upward pressure on competition and causes rapid change in consumer preference. This complementary relationship between innovation and trade has been well documented in recent literature (Castellani and Zanfei, 2007; Ito and Lechevalier, 2010; Lileeva and Trefler, 2010; Damijan et al., 2010).

There are several possible economic reasons why firms are more likely to invest in innovation in order to become exporters. One strand of literature shows that trade liberalization is positively related to innovation via expansion into foreign markets (i.e., demand-driven). In a model featuring heterogeneous plants and quality differentiation, Southern exporters produced export goods that were higher quality than those meant for the domestic market in order to serve high-income Northern consumers (Verhoogen, 2008). Lileeva and Trefler (2010) examine the complementarity between export and investment in raising productivity and find that Canadian exporters engage in more product innovation than non-exporters. Using Argentinean firm-level data, Bustos (2011) also shows that exporters respond to trade liberalization by adopting new technology. Another strand of literature shows that tighter competition with foreign firms (i.e., supply-driven) through trade openness may induce firms to invest in innovative activities in anticipation of liberalization (Constantini and Melitz, 2007, Iacovone and Javorcik, 2012). Caldera (2010) shows that both process and product innovation have a positive effect on the probability of participation in export markets.

While most recent literature on the relationship between innovation and firms' access to foreign markets is dominated by models of innovation and exporting behavior, the relationship between innovation and foreign direct investment (FDI) has not been explored. However, FDI from multinational enterprises may also be associated with firms' innovative activities. How can product innovation and process innovation have different impacts on varying strategies for global engagement? In order to more thoroughly assess the importance of innovation on firms' globalization strategies, we develop a theoretical model and present new empirical evidence on firms' choices of entry mode – exports and FDI – from strategies for both types of innovation, based on Melitz-type theoretical models[1] and firm-level data, respectively. We first attempt to analyze the different roles of product and process innovation on firms' choices between exports and FDI.

Our theoretical model suggests that greater product innovation is performed as a means of switching a firm's status from that of a purely domestic producer to that of an exporter, while an exporter is more likely to perform process innovation in order to initiate FDI. First, this argument is based on the fact that a firm increasingly returns to scale in order to perform process innovation but its marginal product innovation costs increase as its size increases (Cohen and Klepper, 1996; Plehn-Dujowich, 2009). As the total sales of an exporter are greater than those of a domestic producer (Helpman, Melitz and Yeaple, 2004), process innovation will be more significant for an exporter to initiate FDI.

Second, when domestic producers want to initially export in a foreign market, their product quality should be adjusted to meet foreign consumers' preferences above everything else. In other words, the demand-driven factors are more important for domestic producers to begin exporting and thus they are more likely to perform product innovation (Becker and Egger, 2006; Cassiman and Martinez_Ros, 2007; Cassiman et al., 2010; Caldera, 2010)[2]. On the other hand, as incumbent exporters are accustomed to foreign consumers' preference, it is more important to reduce production cost to begin FDI which is the subsequent step of exporting in a foreign market (Helpman et al, 2004). Consequently, the supply-driven factors, such as intense competition with foreign firms, are more related to process innovation because most exporting sectors are in the mature stages of the product lifecycle, and product efficiency becomes increasingly important in these later stages (Scherer, 1983).

As a result, we hypothesize that process innovation is more significant in raising a firm's

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[1] See Helpman (2006) for a genealogy of Melitz-type models in detail.

[2] These studies find that product innovation is relatively more important in raising a firm's propensity to export (i.e. the extensive margin of exports), emphasizing that this phenomenon is more pronounced for small non-exporting firms.

propensity to perform FDI and less significant in raising a firm's propensity to export. On the other hand, product innovation is more significant in raising a firm's propensity to export and less significant in raising a firm's propensity to perform FDI.

Our paper attempts to test these hypotheses by linking firms' different innovative activities to their decisions regarding exports and FDI using a panel of Korean firms over the period of 2006-2012. As our unique data set contains information on innovation output (number of patent citations and Enterprise Resource Planning [ERP]) as well as innovation input (R&D investments), we were able to assess the impact of different types of actual innovative activities on firms' participation in foreign markets. We employ a random probit model as our baseline model and an average treatment effect model to perform robustness checks. Our empirical results are in line with the theoretical predictions that process innovation is important, particularly in raising firms' propensity to become multinationals, while product innovation vis-à-vis process innovation is more significantly associated with firms' export decisions.

The remainder of the paper is organized as follows: Section 2 develops a theoretical framework using a firm's globalization strategies and innovation modes, and proposes a hypothesis for the empirical test. Section 3 provides empirical specifications to test theoretical results and describes the data. Section 4 provides the empirical results from the main regression and the robustness check. Section 5 provides a conclusion.

2. Theoretical Framework

2.1. Basic Assumptions

We employ two country-related classifications – domestic (*1*) and foreign (*2*) – assuming that they are symmetric in every respect. In each country there are homogeneous consumers and heterogeneous firms. Each firm produces one variety of product, and labor is the only production factor. It is essential to consider both product quality and productivity in firm heterogeneity when analyzing the roles of product innovation and process innovation on overseas expansion. In this respect, we can predict whether a firm might become a multinational or an exporter by upgrading its product quality and/or reducing its marginal production cost.

Accordingly, there are two firm heterogeneities: First, firm productivity is defined as the ability to produce a variety of goods with lower variable costs. Each firm draws its productivity exogenously from specific distributions, such as a Pareto distribution. Second, product quality represents different characteristics of a product such as design, shape and color. A consumer evaluates the quality of a good and consumes it if he or she values it highly. A firm does not know a consumer's preference in advance, implying that product qualities do not have any initial hierarchy on the production side. However, after a firm is exogenously given its quality, a consumer grants their preference to the good; product quality then functions as a demand-shifter. Hence product quality hierarchy arises later in accordance with consumer preference on the consumption side. In sum, higher product quality is represented as closer to consumer preference, whereas lower product quality is farther away. All these assumptions for product quality and consumer preference ensure that there is no *ex ante* correlation between firm productivity and its product quality.

2.2. Consumption

Based on Plehn-Dujowich (2009), the demand function should be satisfied with the following conditions with respect to product quality and product innovation:

$$\frac{\partial q}{\partial \lambda} > 0,\ \frac{\partial q}{\partial e} > 0,\ \frac{\partial^2 q}{\partial e^2} < 0 \text{ and } \frac{\partial^2 q}{\partial \lambda \partial e} = \frac{\partial^2 q}{\partial e \partial \lambda} = 0 \tag{1}$$

where q is the demand, λ is the corresponding quality, and e is product innovation. In (1), the first two conditions ensure that the higher the innate product quality, or the greater its product innovation, the greater its demand. Thus quality upgrade from product innovation is positively functioned as a demand shifter.[3] The second condition represents decreasing returns to scale for production innovation. Plehn-Dujowich (2009) empirically shows that the greater the product innovation, the fewer citations and patents occur per dollar of product innovation. Similarly, we consider that quality upgrade from product innovation increases demand, but at a decreasing rate.[4] The last condition ensures that firms with higher innate quality do not have an *ex ante* comparative advantage of performing product innovation. As higher quality (λ) is

[3] Rosenkranz (2003) shows the positive relationship between consumers' willingness to pay and product innovation.

[4] See Weiss (2003) on this argument. Similarly, followers can more easily perform product innovation by spillover effects from their frontiers (Abramovits, 1986; Gerschenkron, 1962; Maddison, 1987).

determined by consumer preference rather than a firm's ability on the consumption side, the level of λ is unrelated to prior product innovation performance. Hence, the last condition in (1) controls for an *ex ante* bias between innate product quality and innovation strategy.

We consider the specific form of the utility function of which demand function can satisfy all conditions in (1). A representative consumer has income M and CES preferences over a set of differentiated goods indexed by x,

$$U = \left[\int_{x\in X} q(x)^{\rho}(\lambda + d\ln e)^{1-\rho}dx\right]^{\frac{1}{\rho}} \tag{2}$$

where X is a set of all potentially available goods, $d > 1$ is a constant, and ρ is the elasticity of substitution between any two goods with $0 < \rho < 1$. In (2) we consider the demand-side effect as a means of identifying product quality.[5] Also, product innovation is considered to be a means of improving existing product quality, as each firm should produce one variety of product in our model. Our research model considers that an "improvement" in product quality refers to a product's closer proximity to a consumer's existing preference so that its demand increases from product innovation. When the portion of the elasticity of substitution decreases (i.e., decrease in ρ), product quality and product innovation become more important to increase a consumer's utility. M consists of wages, paid for inelastically supplied labor.

From the consumer maximization problem, the demand for x is derived as

$$q = p^{-\sigma}P^{\sigma-1}M(\lambda + d\ln e) \tag{3}$$

where $\sigma = \frac{1}{1-\rho} > 1$ and the aggregate price index, $P = \left[\int_{x\in X} (p(\lambda + d\ln e))^{1-\sigma}dx\right]^{\frac{1}{1-\sigma}}$. We assume that each firm's influence on the overall price level, P, is negligible. Consequently, the demand function in (3) satisfies all conditions in (1).

2.3. Production

On the production side, there is a monopolistically competitive market with X firms. As in Melitz (2003), the production involves two types of cost: variable (τ) and fixed costs (f).

[5] Typical examples of a model with the CES utility function with demand-side effects of product quality can be found in Schott (2004), Hallak (2006), Crozet, Head and Mayer (2009), Hallak and Schott (2011), Baldwin and Ito (2011), Fajgelaum, Grossman and Helpman (2011), Feenstra and Romalis (2012), and Antoniades (2012).

Before performing any innovation, the firm decides whether to exit the market or to produce only in the domestic market or to export to the foreign market or to perform FDI under the given consumer preference after realizing its productivity (θ) and product quality (λ). In this respect, both θ and λ are exogenous and heterogeneous among the firms, while τ and f are the same for all types of firms.

Given θ and λ, as process innovation is understood as a means of reducing marginal production costs, it is possible to consider it in the cost function.[6] Also, a firm might increase its product quality by paying relevant costs in a production process. Meanwhile, as in the consumption part, the marginal cost function (*MC*) on the production side should be satisfied with the following conditions with respect to innate productivity and process innovation:

$$\frac{\partial MC}{\partial \theta} < 0,\ \frac{\partial^2 MC}{\partial \theta^2} > 0 \quad \frac{\partial MC}{\partial z} < 0,\ \frac{\partial^2 MC}{\partial z^2} > 0 \ \text{ and } \ \frac{\partial^2 MC}{\partial \theta \partial z} = 0 \tag{4}$$

The first four conditions imply that the higher the productivity of the firm, or the greater its process innovation, the lower its production cost, but at a decreasing rate.[7] The last condition ensures that more highly productive firms do not have an *ex ante* comparative advantage of performing process innovation.

We also consider that marginal costs increase alongside product innovation, but highly productive firms do not have an *ex ante* comparative advantage for performing product innovation. The corresponding conditions are:

$$\frac{\partial MC}{\partial e} > 0,\ \frac{\partial^2 MC}{\partial e^2} > 0 \ \text{ and } \ \frac{\partial^2 MC}{\partial e \partial \theta} = \frac{\partial^2 MC}{\partial \theta \partial e} = 0 \tag{5}$$

The first and second conditions ensure that the marginal cost of quality upgrading is convex: product innovation can deteriorate efficiency growth due to the process of product development and adjustment, but at an increasing rate (Gerschenkron, 1962; Maddison, 1987; Lee and Kang, 2007). The last condition controls for an *ex ante* bias between innate firm productivity and innovation strategy. Finally, the marginal cost function in (5) is satisfied with $\frac{\partial^2 MC_l}{\partial z \partial e} = \frac{\partial^2 MC_l}{\partial e \partial z} =$

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[6] Typical examples of a model with process innovation strategy in a production part can be found in Bustos (2009) and Caldera (2010), based on the Melitz's (2003) model. Bustos (2009) and Caldera (2010) demonstrate that process innovation has a positive effect on the probability of participation in export markets.

[7] The second and forth conditions in (4) also represent that followers can more easily perform process innovation by spillover effects from their frontiers (Abramovits, 1986; Gerschenkron, 1962; Maddison, 1987)

0, representing that both innovations are not related each other.[8]

Accordingly, we consider the specific form of the marginal cost function with process and product innovations which satisfies all conditions in (4) and (5) as follows:

$$MC_l = \frac{\tau}{\theta} - d \ln z + e^2 \tag{6}$$

where $\theta \geq 1$ is the firm's heterogeneous productivity and l = D (domestic production) or X (export) or I (FDI). $\tau > 1$ is a per-unit iceberg cost for exporting, where $\tau = 1$ for $l = D$ or I and $\tau > 1$ for $l = X$, hereafter. z denotes process innovation.

Based on (6), the total cost (TC) for domestic sales or export or FDI is provided by

$$TC_l = MC_l q_l + f_l + z + e \tag{7}$$

In the setting of introducing process innovation, it is more important to consider how much benefit a firm gains from reducing production variable costs. In other words, we focus more on economies of scale with regard to process innovation and suppose that its fixed cost is not related to a firm's other characteristics, such as productivity. Thus, the fixed cost function of performing process innovation is the same for all firms, and we only consider z as a fixed cost of process innovation for the sake of simplicity. Similarly, the fixed cost function of performing product innovation is assumed to be e.

2.4. Strategies to Innovate

The firm maximizes its profits while taking its status of θ and λ given:

$$\max_{p,z,e} \pi_l = p_l q_l - (MC_l q_l + f_l + z + e) \tag{8}$$

Given the demand function in (3), the first-order condition (FOC) with respect to price in the profit maximization problem yields:

[8] Without this condition, firstly it is necessary to investigate whether the relationship between process innovation and product innovation is substitute or complement or independent (see Tang, 2006; Weiss, 2003; Martines-Ros, 1999; Mirayete and Pernias, 2006; Parisi et al, 2006 for the relationship between process innovation and product innovation). This will complicate the model, deflecting from the main purpose of the paper which identifies the relationship between each innovation and firm strategy in a foreign market, not between two types of innovation.

$$p_l = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta} - d\ln z + e^2\right) \quad (9)$$

where the equilibrium price, p_l, depends on firm's markup (i.e., $\frac{\sigma}{\sigma-1}$) and its marginal cost (i.e. $\frac{\tau}{\theta} - d\ln z + e^2$).

The FOC with respect to process innovation (z) is:

$$\frac{dp^{-\sigma}P^{\sigma-1}M(\lambda+d\ln e)}{z} = 1 \quad (10)$$

Substitute (9) into (10) to obtain:

$$\frac{d\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta}-d\ln z+e^2\right)\right)^{-\sigma}P^{\sigma-1}M(\lambda+d\ln e)}{z} = 1 \quad (11)$$

where $\tau = 1$ if a firm is a domestic producer or a multinational, while $\tau > 1$ if a firm is an exporter. Noting that the left side of (11) represents the marginal benefits of performing process innovation (MB_z), we address the following proposition:

Proposition 1. *Firms with high productivity and/or product quality are more likely to perform process innovation.*

Proof. See Appendix B.

The result from Proposition 1 is consistent with previous literatures, which show the positive effects of firm size on performing process innovation (Mansfield, 1981; Scherer, 1991; Cohen and Klepper, 1996; Yin and Zuschovitch, 1998; Baldwin and Sabourin, 1999; Kaufmann and Tödtling, 1999; Baldwin and Gu, 2004; Petsas and Giannikos, 2005; Tang, 2006; Forfás Innovation Survey, 2006; Plehn-Dujowich, 2009). Additionally, some literature show the same result when considering various types of firm size and benefits from process innovation; the return to process innovation and firm output (Cohen and Klepper, 1996); cost savings from process innovation and firm market share (Scherer, 1983); process innovation and market size (Guerzoni, 2010); process innovation and number of goods produced by a firm (Petsas and Giannikos, 2005); process innovation and labor productivity (Baldwin and Gu, 2004); and process innovation and firm efficiency (Plehn-Dujowich, 2009). In this paper we address increasing returns to scale on process innovation and consider both firm productivity and product quality as determinants of firm size. In our firm-level dataset, Table 2 empirically supports this feature of the relationship between a firm's heterogeneous characteristics and process innovation.

The FOC with respect to product innovation (e) is:

$$p^{-\sigma}P^{\sigma-1}M\frac{d}{e}\left(p-\frac{\tau}{\theta}+d\ln z-e^2\right)=2ep^{-\sigma}P^{\sigma-1}M(\lambda+d\ln e)+1 \qquad (12)$$

Substitute (9) into (12) to obtain:

$$P^{\sigma-1}M\frac{d}{e}\frac{1}{\sigma}\left(\left(\frac{1}{\sigma-1}\right)\left(\frac{\tau}{\theta}-d\ln z+e^2\right)\right)^{1-\sigma}$$

$$=2e\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta}-d\ln z+e^2\right)\right)^{-\sigma}P^{\sigma-1}M(\lambda+d\ln e)+1 \qquad (13)$$

Noting that the left hand side of (13) represents the marginal benefits of performing product innovation (MB_e), while the right side of (13) represents its marginal costs (MC_e), we address the following proposition:

Proposition 2. *Firms with high productivity and/or product quality are less likely to perform product innovation.*

Proof. See Appendix B.

Our theoretical result addresses that a firm's high innate product quality and/or productivity negatively affects the implementation of product innovation. In reality, firms with low product quality can incur lower marginal costs in upgrading their product quality because they can easily imitate firms with high quality products, while a firm performing a higher level of quality upgrade should create a new type of quality when performing product innovation.[9] Thus, the additional cost for upgrading product quality by one unit will be higher at the level of high product quality (i.e., $\frac{\partial MC_e}{\partial\lambda}>0$). In addition to this relatively higher marginal cost of performing product innovation, our theoretical result shows that the additional benefit for upgrading product quality by one unit is not related with the level of innate product quality (i.e.,

[9] For this phenomenon, Gerschenkron (1962) introduced the term of "the advantage of backwardness". Also, Maddison (1987) named it "catching-up bonus".

$\frac{\partial MB_e}{\partial \lambda} = 0$) because the equilibrium price consists of mark-up and marginal cost, irrespective of λ in the model's basic setup. Also, a firm's marginal cost is more likely to be greater than its marginal benefit from performing product innovation if its productivity is greater. As a result of performing product innovation, a firm with high productivity should pay more additional costs from greater production than take advantage of charging lower price.

The outcome of product quality and that of firm productivity in Proposition 2 appear consistent with previous literature, which demonstrate that small firms are more likely to perform product innovation (Scherer, 1991; Cohen and Klepper, 1996; Yin and Zuschovitch, 1998; Badwin an Sabourin, 1999; Petsas and Giannikos, 2005; Plehn-Dujowich, 2009). The result can also be justified with regard to the relationship between market competition and product innovation, as some literature show that firms favor product innovation against a high level of competition (Weiss, 2003; Tang, 2006). As small domestic firms are more likely to be exposed to tighter competition due to an increase in import penetration from international trade (Helpman, 2006), they might have stronger incentive for product innovation.

2.5. Hypotheses on Innovation Mode and Firm Decision to Export or perform FDI

As in HMY (2004) and in Hallak and Sivadasan (2009), the innate levels of productivity and product quality exogenously determine a firm's original position on whether: 1) to exit the market; 2) to serve only the domestic market; 3) to serve both the domestic and the foreign markets via exports; or 4) to serve both markets engaging in FDI. Fig. 1 as a reference depicts a firm's status in the relationship between productivity and product quality[10]: a firm with productivity $\theta < \bar{\theta}_D$ or product quality $\lambda < \bar{\lambda}_D$ will decide not to produce and to exit the market, while a firm with $\theta \geq \bar{\theta}_D$ or $\lambda \geq \bar{\lambda}_D$ will operate. Among the surviving firms, a firm with $\bar{\theta}_D \leq \theta < \bar{\theta}_X$ or $\bar{\lambda}_D \leq \lambda < \bar{\lambda}_X$ will serve only the domestic market, while a firm with $\theta \geq \bar{\theta}_X$ or $\lambda \geq \bar{\lambda}_X$ will expand its business abroad. Finally, a firm with $\bar{\theta}_X \leq \theta < \bar{\theta}_I$ or $\bar{\lambda}_X \leq \lambda < \bar{\lambda}_I$ will export, while a firm with $\theta \geq \bar{\theta}_I$ or $\lambda \geq \bar{\lambda}_I$ will perform FDI in order to create an inroad into overseas markets.

[10] The original feature of Fig.1 is found in Hallak and Sivadasan (2009). The condition for fixed costs is assumed to be $0 < f_D < \tau^{\sigma-1} f_X < f_I$ to obtain these orderings.

Insert [Figure 1]

Accordingly, the ordering of three cut-off levels on each firm's heterogeneity confirms the relationship between firm productivity, or product quality, and self-selection into markets. Firms with low productivity or product quality will exit the market; firms with low-middle productivity or product quality will serve only the domestic market; firms with high-middle productivity or product quality will export; and firms with high productivity or product quality will perform FDI. Our firm-level dataset also illustrates this theoretical feature, as represented in detail in Fig. 2.

Given a firm's innate status in the ordering of the cut-off levels on firm's heterogeneity and Proposition 1 and 2, we subsequently identify two properties of innovation mode and firm decision to export or perform FDI. First, as the total sales of an exporter are greater than those of a domestic producer in our model (also see HMY, 2004), the former is more likely to perform process innovation than the latter in order to obtain better status (i.e., a multinational). In addition, our conjecture on the effect of process innovation on a firm's global engagement is quite consistent with Damijan et al.'s (2010) empirical results, ensuring that the firm improves its efficiency by stimulating process innovation once it becomes an exporter. Although Damijan et al.'s (2010) do not directly consider FDI as a firm's global engagement, we predict that an exporter's improvement in efficiency caused by process innovation will drive the self-selection into performing FDI.

Second, with regard to firm evolution, some previous empirical studies show that product innovation is relatively more important in raising a firm's propensity to export, but it does not increase subsequent export intensity, which is conditional on entering export markets (Becker & Egger, 2006; Cassiman & Martinez-Ros, 2007; Belderbos *et al.*, 2009; Cassiman *et al.*, 2010; Caldera, 2010; Beveren & Vandenbussche, 2010; Ganotakis & Love, 2011; Bocquent & Musso, 2011; Higon & Driffield, 2011; Van Beveren & Vandenbussche, 2013). Based on our model's cut-off levels with regard to both firm productivity and product quality, it seems that domestic firms, when first creating inroads into foreign market via exports, should adjust their product innovation to suit foreign preferences for product quality. However, once they successfully enter foreign markets and adapt to foreign preferences, firms do not prioritize changes in product quality. Instead, it becomes more important to save production costs for an incumbent's market strategy in a foreign market. Specifically, it is very important for an exporter to pursue switching its status to a multinational to significantly reduce its production variable costs in order to overcome the high fixed costs of a production facility in a foreign market (HMY, 2004). Hence, process innovation should be more closely associated with a firm's propensity to perform FDI than product innovation. Also, references in Table A1 of Appendix A show that conditional on entering export markets, product innovation does not increase subsequent export intensity (i.e. the intensive margin of exports).

Consequently, we build up the following two hypotheses to empirically determine the impact of innovation mode on firm's decisions to export and perform FDI:

Hypothesis 1. *Product innovation is more important in the extensive margins of export than process innovation.*

Hypothesis 2. *Process innovation is more important in the extensive margin of FDI than product innovation.*

Hypothesis 1 and 2 are the main objectives of our empirical test in the next section. In Hypothesis 1 and 2, we predict that product innovation is more important in raising a firm's propensity to export in its globalization strategies. Process innovation is relatively less significant in determining the firm's propensity to export than product innovation. Also we predict that process innovation is more significant for a firm's propensity to perform FDI, due to increasing returns to scale, than product innovation. Hence we should identify the effects of process and product innovation on a firm's global engagement empirically.

3. Empirical Specification

3.1 Empirical Model

In this section we build an empirical strategy to test the hypothesis 1 and 2 of the theoretical model on a firm's choice between exporting and FDI, with respect to two different types of innovation. A firm will decide to export if export profits exceed those from another type of entry mode, and this similarly applies to decisions to perform FDI. These conditions can be formally specified as a binary choice model of firms' internationalization strategies. Thus, we model binary decisions to export and invest abroad separately, and we estimate the model using the random effects panel probit model. Given the incidental parameter problem and the inconsistent estimates of the fixed effects, we employ random effect probit model. The index models used to analyze decisions to export and perform FDI can be specified respectively as:

$$EXP_{it} = \begin{cases} 1 & if\ \alpha_1 Product\_Innov_{it-1} + \alpha_2 Process\_Innov_{it-1} + \alpha_3 Z_{it-1} + \gamma_k + \delta_t + \epsilon_{it} > 0 \\ 0 & otherwise \end{cases} \quad (14)$$

$$FDI_{it} = \begin{cases} 1 & if\ \beta_1 Product\_Innov_{it-1} + \beta_2 Process\_Innov_{it-1} + \beta_3 Z_{it-1} + \mu_k + \theta_t + \omega_{it} > 0 \\ 0 & otherwise \end{cases} \quad (15)$$

where *i*, *k* and *t* represent index firms, industry and time, respectively. *EXP* is a dummy variable that takes the value of 1 if the non-exporting domestic firm in year *t-1* starts exporting in year *t*, otherwise it takes the value of 0. *FDI* takes the value of 1 if the exporter in year *t-1* starts FDI in year *t*, and otherwise takes a value of 0.[11] *Product_Innov* is a dummy variable that takes the value of 1 if the firm invested in product innovation, and otherwise takes the value of 0. *Process_Innov* is a dummy variable that takes the value of 1 if the firm invested in process innovation and otherwise takes a value of 0. We use information on the patent citation dummy, the number of patent citations per employee, the R&D dummy and R&D expenditure intensity as a percentage of total sales in order to measure firms' product innovation activities. In the case of process innovation, we employ firms' propensity to adopt ERP (Enterprise Resource Planning). *Z* is the set of other firm characteristics that can influence decisions related to export or FDI.

In order to estimate the role of innovation in decisions regarding the initiation of export activities or FDI, and to control for potential simultaneity problems, we eliminate firms that formerly experienced either exporting or FDI and restrict the data sample to domestic firms

[11] Based on our theoretical model, we exclude the case in which a domestic firm directly performs FDI without prior exporting experience.

and exporting firms at time *t-1*,as in the following equation:[12]

$$\text{Prob}(EXP_t = 1|Domestic_{t-1} = 1) = \text{f}(Innov_{t-1}) \tag{16}$$

$$\text{Prob}(FDI_t = 1|EXP_{t-1} = 1) = \text{f}(Innov_{t-1}) \tag{17}$$

Following equations (16) and (17), the probit model with two equations can be defined. The first equation of the baseline model specifies the probability of domestic firm i becoming an exporter:

$$EXP_{ikt} = \beta_0 + \beta_1 \ln Size_{ikt-1} + \beta_2 \ln TFP_{ikt-1} + \beta_3 Foreign\_ownership_{ikt-1} + \beta_4 Product\_Innovation_{ikt-1} + \beta_5 Process\_Innovation_{ikt-1} + \sum \beta_{5+k} Industry\_dummy_k + \varepsilon_{ikt} \tag{18}$$

The second equation specifies the effects of the same group of explanatory variables on the probability that a former exporter serves foreign markets via FDI:

$$FDI_{ikt} = \beta_0 + \beta_1 \ln Size_{ikt-1} + \beta_2 \ln TFP_{ikt-1} + \beta_3 Foreign\_ownership_{ikt-1} + \beta_4 Product\_Innovation_{ikt-1} + \beta_5 Process\_Innovation_{ikt-1} + \sum \beta_{5+k} Industry\_dummy_k + \varepsilon_{ikt} \tag{19}$$

3.1.2 Robustness Check

For robustness check, we employ average treatment effect. Although we restrict our sample to domestic firms and exporters in order to investigate the effect of innovative activities on decisions related to exporting and FDI, the potential endogeneity problem may still remain due to the difficulty in finding appropriate instrument variables in our firm-level data. To resolve this potential endogeneity problem and confirm empirical test results on the impact of innovative activities on firms' exporting and FDI decisions using probit estimation, we employ a propensity score matching estimation technique, combined with an average treatment effect model. This methodology is particularly useful in addressing potential endogeneity problems in the absence of appropriate instrumental variables (Damijan et al., 2010). For our empirical

[12] Also, this restriction is consistent with our theoretical model, which considers only the extensive margins of export and FDI.

test, we first identify the probability of firms conducting product or process innovation, which provides us with a propensity score. Second, we match innovators and non-innovators and estimate the average treatment effects of lagged innovation on exporting. The same procedure is replicated to test the average treatment effects of past innovative activities on FDI decisions.

3.2. Data

This study uses annual firm-level survey data for the period 2006-2012, which was compiled from “The Survey on Business Activity” conducted by the National Statistical Office (NSO) of Korea. The NSO performed annual surveys of Korean enterprises with financial capital over USD 300,000 and over 50 employees. The data set is highly representative of Korean manufacturing industry accounting for 90 percentage of the total sales and 70 percentage of value added of manufacturing sector. The survey contains information on financial statements, organizational structure, global engagement such as exports and FDI status, and various types of innovation-related activities. Initially, the survey data included over 10,000 firms each year. However, after the data cleaning process (which dropped unlikely values such as zero values for sales, labor and capital in order to resolve the measurement error problem in the survey data), our unbalanced panel dataset includes 8,653 manufacturing firms[13] during 2006-2012. Table 1 defines the variables used in our empirical tests. The binary indicator of decisions regarding export or FDI, which measures extensive margins of entry mode on innovative activities, is used as a dependent variable.

Insert [Table 1]

Measurement of Innovation

The NSO survey asks firms to report their innovative activities. To measure product innovation, as described in the previous section, we use information from four indicators: a binary indication of whether or not patents are cited, the number of patent citations per employee, whether or not the firm invested in R&D, and R&D intensity (measured as R&D

[13] The number of observation in our dataset is 40,101.

investment as a share of total sales). Pavitt (1984) shows the relative importance of product innovation as positively associated with patent intensity and R&D. Also, Baldwin and Sabourin (1999) assert that R&D activities are important for product innovations. For the process innovation measurement, we use information indicating whether or not a firm introduced an ERP (Enterprise Resource Planning) system among various types of e-business system. The NSO survey defines the e-business as network based transfer and exchange of goods, services, information and knowledge. It excludes simple individual software of accounting and human resource management. Among these e-business systems, ERP is business management software which integrates all facets of an operation, including development, manufacturing, sales and marketing. It includes modules for product planning, material purchasing, inventory control, distribution, accounting, marketing, finance and human resources. Since its primary purpose and advantage is to facilitate efficiency in business processes, the introduction of ERP is found to be highly associated with process innovation in business practices. The firm-wide database generated and updated by the ERP system, for example, provides every employee with necessary data in real time, thus making data-mining obsolete and enabling the workers to be more innovative and flexible (Davenport 1998, Engelstatter, 2012). Thus, ERP system provides the potential for enhanced knowledge capabilities for process innovation (Srivardhana and Pawlowski, 2007).

Other Variables

We also use information about firm characteristics drawn from financial statements contained in the NSO dataset. This rich information, which includes number of employees, value of fixed capital assets, total sales value, and share of foreign ownership, is used to construct control variables. The number of employees is used as a proxy for firm size. This variable can have a positive impact on global engagement, since larger firms have greater resources, such as liquid funds and higher collaterals, with which to enter foreign markets through additional fixed costs. (Wakelin, 1998, Oberhofer and Pfaffermayr, 2012)

Firm productivity is measured as a residual of the regression of real output on labor input, real input and real capital. In order to construct TFP, we use the natural log of real total sales as a proxy for real output, the log of the number of employees as labor input, and the real tangible as fixed capital assets. Intermediate inputs are computed as the sum of sales costs, operating costs, net wage, depreciation costs, and expenses for purchased materials. Fixed capital assets include the value of buildings, machinery and vehicles purchased. The total sales and nominal intermediate inputs of each firm are deflated by the output and input deflator, based on the KSIC (Korea Standard Industrial Classification) 2-digit industry-level classification, drawn from the 2013 Korea Industrial Productivity (KIP) Database. Fixed asset is deflated using capital asset formation in the NSO data base and the 2013 KIP Database.

3.3. Productivity, Innovation and Global Engagement

The productivity differences across firms' internationalization strategies are documented in recent literature on heterogeneous firm trade models (Melitz, 2003; Helpman et al., 2004) Helpman et al. (2004) suggest that only the most productive firms, which can bear the higher fixed costs of investment in host foreign countries, engage in FDI, whereas less productive firms export, and the least productive firms serve only their domestic market. This order is also represented in our theoretical structure in Section 2. The data reported in Fig. 2 confirms this argument. The graphical representation of the cumulative distribution function of productivity, measured as a natural log of TFP, shows that the distribution of exporters' TFP lies to the right of domestic firms, and the distribution of multinationals lies to the right of exporters – which supports the productivity order of entry mode as suggested in our theory.

Insert [Figure 2]

Table 2 shows the firm attributes of innovators and non-innovators. Panel A compares the basic firm characteristics of product innovators and non-product innovators, while Panel B compares those of process innovators and non-process innovators within each group of entry mode. Both panels show that multinational enterprises that adopted innovation are largest, and exporters that adopted innovation are larger than domestic firms, irrespective of the type of innovation. In terms of productivity measured as total factor, multinationals with process innovation are most productive, exporters are less productive, and domestic firms are least productive; thus the order of productivity holds as predicted by our theoretical model as well as Helpman et al. (2004). Within each group of entry mode, firms that invested in process innovation are more productive than non-innovators, on average. This is in line with our proposition 1, suggesting that the relationship between firm productivity and process innovation is positive.

However, when it comes to product innovation, ranking is reversed among multinationals. Non-innovative multinationals are more productive than innovative multinationals. Interestingly, there is no difference in productivity between innovators and non-innovators within the group of exporters and domestic firms. This is in line with our proposition 2, suggesting that the relationship between firm productivity and product innovation is not clear cut.

Insert [Table 2]

Table 3 reports the pattern of innovation performance by mode of entry to foreign markets in 2006 and 2012. We compare firms serving only domestic markets, exporters, and multinationals that conduct FDI, with respect to innovative activities. The results show that in terms of average number of patent invention per labor, firms exposed to foreign markets have a higher intensity of patent invention than purely domestic firms. In 2006, approximately 58% of firms conducting FDI and more than 45% of firms that export engage in R&D, while only 26% of firms serving only domestic market engage in patent citation. Among the firms with access to foreign markets, multinationals are more innovative than exporters. Both exporters and multinationals are also more innovative than domestic firms. This order holds in the case of the R&D intensity and dummy. When the cost of investment in R&D per sales and R&D dummy are measured as product innovation, multinationals invest more in R&D than exporters and domestic firms. For process innovation measured as ERP, a greater portion of multinationals than exporters conduct process innovation on average, and more exporters than domestic firms appear to engage in process innovation. Similar patterns are found in the relationship between firms' innovative activities and their status in the 2012 data, with increasing participation in both product and process innovation in each group of firms.

Insert [Table 3]

Since the analysis in Table 3 is static (when we do not consider the potential endogeneity problem between innovation and firms' global strategies), we conduct dynamic analysis to relate firms' entry decisions to prior innovation activities. Table 4 reports the transition matrix of entry mode of manufacturing firms in year *t*, conditional on the decision to innovate in year *t-1* for the period 2006-2012. The table examines the effect of production and process innovation on transition probabilities from purely domestic firms to exporters, and exporters to multinationals, respectively. In our sample, among non-exporting firms 22% of product innovators start exporting and 18.8% of process innovators switch their status from domestic firms to exporters. With regard to the FDI decision, among exporters 12.8% of product innovators and 12.1% of process innovators made the transition from exporting to FDI. This result suggests that both product and process innovation may affect firms' decisions to switch their mode of entry to foreign markets.

Insert [Table 4]

4. Empirical Results

4.1 Baseline Model

Table 5 reports the effects of the decision to switch to exporting or FDI, based on the baseline specification models (18) and (19). Columns (1) through (4) use four different measures of product innovation variables. Column (1) presents the estimation results for the baseline model. Controlling for the number of employees as a measure of firm size and the total factor productivity as a measure of firm productivity, purely domestic firms with higher intensity of patent citation in year *t-1* are more likely to export in the preceding year than firms with lower intensity of product innovation to start exporting. Column (2) also shows that among exporters, firms that cited more patents in the previous year had a greater tendency to serve foreign markets via FDI the following year. Process innovation also has a positive impact on export decision, but this is statistically insignificant in column (1). With regard to the FDI decision, however, exporters undertaking process innovation are significantly more likely to switch their position to multinationals in year *t* than firms that did not introduce process innovation in year *t-1*.

Similarly, columns (3) and (4) demonstrate that product innovation measured as R&D intensity significantly raises the probability of firms participating in exports and serving foreign markets via FDI. The likelihood ratio test of ρ rejects the model of no correlation in the error terms, that is, it approves the correlation between the error terms of equations (18) and (19). These results suggest that product innovation positively affects both export and FDI. Process innovation also consistently has a positive impact on export decision, but the effect is statistically not significant. In FDI decision, the size of the effect of process innovation is larger than that of product innovation. Thus, in terms of the impact of the type of innovation on firms' mode of entry, the impact of product innovation is relatively more important in export decision compared to FDI decision while the process innovation is more significant in FDI decision by exporters than exporting decision by domestic firms. Thus, our empirical results support our theoretical prediction (i.e., Hypothesis 1 and 2).

In terms of the control variables, the effects of firm size on export decisions and FDI are positive and statistically significant, with a 1% significance level. Firm productivity is also positively related to both modes of entry to foreign markets. This result is in line with our theoretical model and previous literature (Melitz, 2003; Helpman et al., 2004).

Insert [Table 5]

4.2 Robustness Check

To control for potential endogeneity problem of baseline model, we employed average treatment effects model as additional robustness checks. Table 6 reports empirical results on the estimates and standard errors of the average treatment effects of lagged innovation on current exporting or FDI status, based on the propensity score matching estimation. We compare estimates of three different types of matching: one-to-one matching, nearest neighbor matching, and local linear regression matching. Standard errors are estimated using bootstrap with 100 repetitions. Table 6 shows that matching confirms the link between lagged innovative activity and the probability of exporting in the current year, which can vary depending on the nature of innovation. The product innovation in lagged terms has significantly positive impacts on the current propensity to export. The process innovation is positively correlated with exporting status, but statistically insignificant in nearest neighbor matching and local linear regression matching and significant in one-to-one matching only at a 10% significance level. In terms of FDI decisions, product innovators are more likely to conduct FDI than non-innovators in product development. Also, the results on process innovation support the baseline model, in that lagged process innovation has a significant and positive impact on the probability that a firm will serve foreign markets via FDI. Thus, our empirical results for the robustness check again confirm the baseline model tests. The results support our theoretical prediction in that the positive effect of process innovation is more evident in FDI than in exporting while product innovation is relatively more important in exporting.

Insert [Table 6]

5. Conclusion

In this paper, we assessed the importance of innovation on a firm's global strategy and investigated how product innovation and process innovation can have different impacts on different internationalization strategies, export and FDI. Based on a Melitz-type model of firm heterogeneity, our theoretical framework hypothesizes the potential impact of firms' innovative activities on their choice of entry mode; both product and process innovation positively affect FDI and exports, but these effects are more pronounced between process innovation and the extensive margin of FDI on one hand and between product innovation and the extensive margin of export on the other. This theoretical prediction is supported by empirical tests, in that both innovative activities positively affect firms' decision to invest abroad and a firm conducts product innovation in order to become an exporter, while the significant and positive association between process innovation and export decisions is not clearly evidenced by the data. These results imply that domestic firms should adjust according to foreign preferences for product quality when they first create inroads into foreign markets via exports because product innovation is more important in raising a firm's propensity to export in its globalization strategies. Once a firm enters the foreign market successfully and adapts to foreign preference, saving on production costs becomes more important for the incumbent's market strategy.

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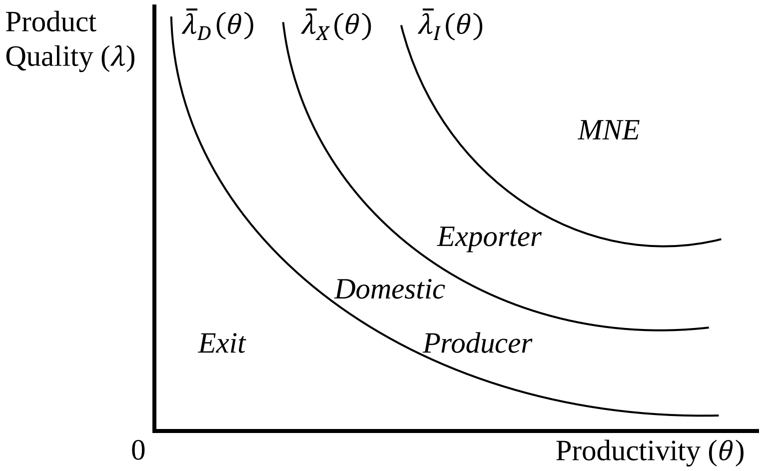
[Figure 1] Profit and Three Cut-off Levels of Firm Heterogeneity[14]

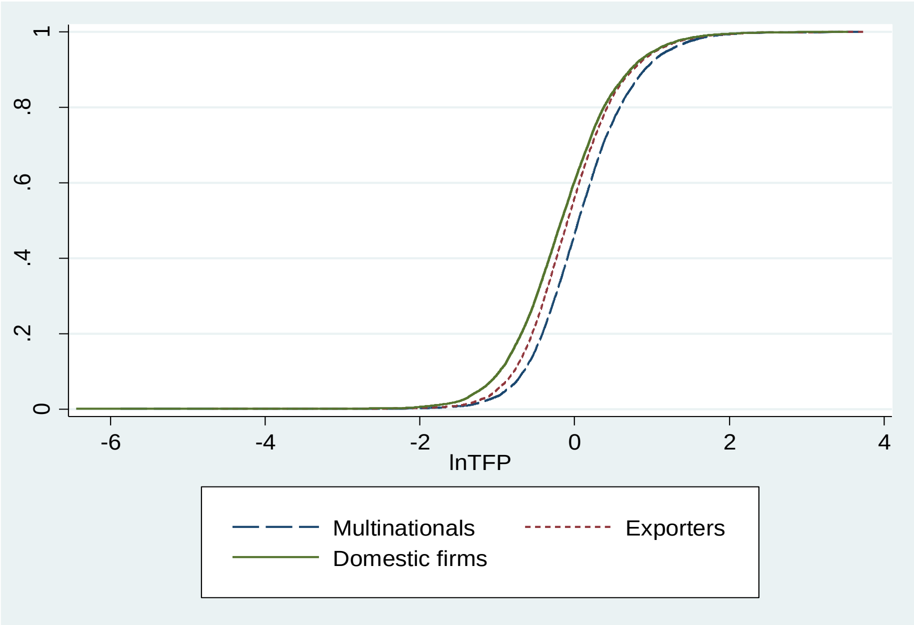


Source: Hallak and Sivadasan (2009)

[14] The original feature of Fig. 1 is found in Hallak and Sivadasan (2009).

[Figure 2] Productivity and Firms' Mode of Entry:

Cumulative Distribution of Total Factor Productivity



[Table 1] Definition of Key Variables

Variables	Definition
Process Innovation	
ERP(Enterprise Resource Planning) dummy	A dummy variable that takes a value of 1 if the firm reports the introduction of ERP, and 0 otherwise
Product Innovation	
Patent invention intensity	Number of patents invented per sales
R&D intensity	Expenditure on R&D per Sale
Patent citation dummy	A dummy variable that takes the value of 1 when the firm reports citing a patent, and 0 otherwise
R&D dummy	A dummy variable that takes a value of 1 if the firm reports conducting R&D, and 0 otherwise
Other Control Variables	
Size	Natural log of the number of employees
Productivity	Natural log of total factor productivity

[Table 2] Firm Characteristics of Each Group of Firms

Panel A.	Domestic Firms		Exporters		Multinationals	
	Product Innovator	Non-product innovator	Product Innovator	Non-product innovator	Product Innovator	Non-product innovator
Size(Number of Employees)	127.21	108.00	149.81	127.12	258.34	208.82
Size(Sales, million won)	42403.41	37205.42	55469.00	54002.58	118778.60	132730.00
Productivity(Natural log of total factor productivity)	-0.15	-0.15	-0.06	-0.06	-0.01	0.15
Number of Observations	2293	5353	689	869	640	396

Panel B.	Domestic Firms		Exporters		Multinationals	
	Process Innovator	Non-process innovator	Process Innovator	Non-process innovator	Process Innovator	Non-process innovator
Size(Number of Employees)	127.87	102.50	152.17	120.03	274.29	175.55
Size(Sales, million won)	51304.17	28754.77	67554.79	39939.43	148860.30	78805.82
Productivity(Natural log of total factor productivity)	-0.03	-0.24	0.02	-0.15	0.10	-0.04
Number of Observations	3394	4252	830	728	670	366

Notes: Mean values are reported for each group. Each group is classified based on firms' global engagement in year t. Product innovators are those firms that cited patent, and process innovators are those firms that introduced ERP systems in year t-1.

Sources: NSO and authors' calculations.

[Table 3] Innovation and Firms' Mode of Entry

	Year 2006			Year 2012		
	Domestic Firms	Exporters	MNEs	Domestic Firms	Exporters	MNEs
	(N=2120)	(N=1536)	(N=2305)	(N=1931)	(N=1926)	(N=2197)
Patent citation dummy	0.263	0.452	0.581	0.377	0.566	0.713
Patent invention	0.016	0.032	0.056	0.032	0.054	0.097
R&D dummy	0.443	0.691	0.798	0.562	0.739	0.843
R&D intensity	0.018	0.022	0.024	0.013	0.019	0.024
ERP dummy	0.312	0.464	0.506	0.543	0.674	0.784

Notes: For each cell, the indicated summary statistics are means. Patent invention is the number of patents invented per labor. R&D intensity is R&D per sales of a firm. ERP=enterprise resource planning.

[Table 4] Transition Probabilities of Export and FDI Conditional on Product or Process Innovation

	$Export_t$		FDI_t	
	0	1	0	1
$Product_{t-1}$				
0	5564(86.5)	869(13.5)	3922(91)	396(9)
1	2412(77.8)	689(22.2)	4353(87.2)	640(12.8)
$Process_{t-1}$				
0	4402(85.8)	728(14.2)	3397(90.3)	366(9.7)
1	3574(81.2)	830(18.8)	4878(87.9)	670(12.1)

Notes: For each cells, the indicated numbers are those of firms that switch or do not switch their status, either from domestic firms to exporters, or from exporters to multinationals. The numbers of firms in transition are shown in parentheses.

[Table 5] Baseline Model

	(1)	(2)	(3)	(4)
VARIABLES	Export	FDI	Export	FDI
Size	0.279***	0.274***	0.253***	0.273***
	(0.0413)	(0.0645)	(0.0426)	(0.0638)
Productivity	0.152***	0.136**	0.122***	0.119*
	(0.034)	(0.062)	(0.034)	(0.061)
Product Innovation				
Patent invention intensity	0.0208***	0.0285***		
	(0.003)	(0.006)		
R&D intensity			0.0158***	0.016***
			(0.0024)	(0.0055)
Process Innovation				
ERP dummy	0.062	0.174**	0.063	0.181**
	(0.045)	(0.087)	(0.045)	(0.086)
Rho	0.371	0.484	0.372	0.478
Log Likelihood	-3938.55	-1375.34	-3944.49	-1381.8
Observations	9,528	7,538	9,529	7,538
Number of Firms	3,528	2,986	3,529	2,986

Notes: Random effect probit models are estimated. Standard errors are in parentheses. Industry and year dummies are included but are not reported. *** p<0.01, ** p<0.05, * p<0.1 The dependent variable Export indicates whether a domestic firm in time t-1 switches its status to export at time t or not. The FDI dummy variable indicates whether an exporter at time t-1 starts FDI at time t or not.

[Table 6] Robustness Checks: Average Treatment Effect

	Product Innovation					
	Probability of Exporting			Probability of FDI		
	ATT	SE	Obs.	ATT	SE	Obs.
One-to-One Matching	0.053***	0.011	3,100 (6,429)	0.023**	0.009	4,348 (3,190)
Nearest Neighbor Matching	0.053***	0.0103	3,100 (6,429)	0.021**	0.01	4,348 (3,190)
Local Linear Regression Matching	0.059***	0.008	3,100 (6,429)	0.02**	0.008	4,348 (3,190)
	Process Innovation					
	Probability of Exporting			Probability of FDI		
	ATT	SE	Obs.	ATT	SE	Obs.
One-to-One Matching	0.014*	0.008	4,401 (5,128)	0.022***	0.008	4,910 (2,628)
Nearest Neighbor Matching	0.012	0.009	4,401 (5,128)	0.018**	0.008	4,910 (2,628)
Local Linear Regression Matching	0.011	0.007	4,401 (5,128)	0.016**	0.008	4,910 (2,628)

Notes: Bootstrapped standard errors with 100 repetitions are reported. Number of treated observations and number of untreated observations in parentheses.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix A.

Table A.1. Previous Research on Product and Process Innovations: Economic Results of Firm Performance

Topic	Study	Findings
Export	Becker & Egger(2006), Cassiman & Martinez-Ros(2007), Belderbos *et al*.(2009), Cassiman *et al*.(2010), Caldera(2010), Beveren & Vandenbussche(2010), Ganotakis & Love(2011), Bocquent & Musso(2011), Higon & Driffield(2011), Van Beveren & Vandenbussche(2013)	- Causality appears to stem from good performance to entering export markets with respect to a firm's self-selecting into innovation in anticipation of entering export markets. - Product innovation is relatively more important in raising a firm's propensity to export (the extensive margin in product space for a firm's entry into export markets). - This phenomenon is more pronounced for small non-exporting firms. - However, conditional on entering export markets, successful innovation does not increase subsequent export intensity.
Productivity	Baldwin & Gu(2004), Parisi *et al*.(2006), Lee & Kang(2007)	- Process innovation is more important than product innovation for labor productivity growth. - Process innovation has a large impact on a firm's total factor productivity (TFP). - Product innovation can deteriorate efficiency growth relative to other types of innovation due to the process of product development and adjustments required for new innovations.
Market Share & Survival	Baldwin & Gu(2004)	- Process innovation is associated with higher plant survival rates, while product innovation is related to lower survival rates. - Plants that introduce process innovation have faster productivity growth, which in turn leads to market share gains.
Employment	Harrison *et al*.(2008)	- Displacement effects induced by productivity growth in the production of old products are large, while those associated with process innovations appear to be small. - However, the effects related to product innovations are strong enough to overcompensate these displacement effects.
	Lachenmaier & Rottmann (2011)	- Innovations have a positive effect on employment with a time lag, and process innovations have higher effects than product innovations.

Appendix B.

Proposition 1. ***Proof.***

The proof of Proposition 1 is evidenced by the fact that firms with high productivity and/or product quality enjoy greater marginal benefits through process innovation, i.e., $\frac{\partial MB_z}{\partial \theta} = \frac{\frac{d\tau\sigma^2 P^{\sigma-1}M(\lambda+d\ln e)}{\theta^2(\sigma-1)}\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta}-d\ln z+e^2\right)\right)^{-\sigma-1}}{z} = \frac{d}{z}\frac{\partial q_l}{\partial \theta}$ >0 and $\frac{\partial MB_z}{\partial \lambda} = \frac{d\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta}-d\ln z+e^2\right)\right)^{-\sigma} P^{\sigma-1}M}{z} = \frac{d}{z}\frac{\partial q_l}{\partial \lambda} > 0$. Note that the underlying source of Proposition 1 comes from in process innovation; since firms with higher productivity and/or product quality have larger markets, i.e. $\frac{\partial q}{\partial \theta} > 0$ and $\frac{\partial q}{\partial \lambda} > 0$, they also have greater payoff to a cost reduction. □

Proposition 2. ***Proof.***

The relationship between product quality (λ) and product innovation (e) is derived from the following two facts: First, considering MB_e, we obtain $\frac{\partial MB_e}{\partial \lambda} = 0$ as the equilibrium price consists of mark-up and marginal cost and thus is not related with λ, implying the innate product quality does not affect the production cost in our original framework. Meanwhile, considering MC_e, we obtain $\frac{\partial MC_e}{\partial \lambda} = 2\mathrm{e}\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta} - d\ln z + e^2\right)\right)^{-\sigma} P^{\sigma-1}M = \frac{\partial MC_l}{\partial e}\frac{\partial q}{\partial \lambda} > 0$ as $\frac{\partial q}{\partial \lambda} > 0$ and $\frac{\partial MC_l}{\partial e} > 0$ in (3) and (6), respectively. In other words, if the firm with high innate product quality performs the quality upgrade via product innovation, then its marginal cost is relatively high because the original demand or production for that good was greater. Hence there exists the decreasing return to scale in product innovation. As a result, firms with high innate product quality are less likely to perform product innovation.

With regard to the relationship between firm productivity (θ) and product innovation (e), first we obtain $\frac{\partial MB_e}{\partial \theta} = \frac{d}{e}\left(\left(\frac{1}{\sigma-1}\right)\left(\frac{\tau}{\theta} - d\ln z + e^2\right)\right)^{-\sigma} \frac{\tau}{\theta^2} P^{\sigma-1}M > 0$ as $\sigma > 1$ and $MC_l = \frac{\tau}{\theta} - d\ln z + e^2 > 0$. The underlying source for this result comes from the fact that $\frac{\partial \mathrm{MC_l}}{\partial \theta} < 0$ and thus $\frac{\partial \mathrm{p}}{\partial \theta} < 0$ in (5). In other words, even though firms perform the same level of product innovation, a firm with innate high productivity enjoys higher marginal benefits because it can charge lower price for the same quality of good. Hence firms with high innate productivity reap the greater benefit from product innovation.

Meanwhile, we obtain $\frac{\partial MC_e}{\partial \theta} = 2e\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta} - d\ln z + e^2\right)\right)^{-\sigma-1}\left(\frac{\sigma^2}{\sigma-1}\right)\frac{\tau}{\theta^2}P^{\sigma-1}M(\lambda + d\ln e) = \frac{\partial MC_l}{\partial e}\frac{\partial q}{\partial \theta} > 0$ as $\frac{\partial MC_l}{\partial e} > 0$, $\frac{\partial p}{\partial \theta} < 0$ and thus $\frac{\partial q}{\partial \theta} > 0$ in (6) and (9), respectively. In other words, firms with high innate productivity should pay the higher marginal cost from product innovation because their production levels are greater. As in the effect of innate product quality on the marginal cost of performing product innovation (i.e., $\frac{\partial MC_e}{\partial \lambda}$), there exists the decreasing return to scale in that of innate firm productivity.

Finally, $\frac{\partial MB_e}{\partial \theta} - \frac{\partial MC_e}{\partial \theta} = \frac{\tau}{\theta^2}P^{\sigma-1}M\frac{d}{e}\frac{\sigma}{\sigma-1}\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta} - d\ln z + e^2\right)\right)^{-\sigma-1}\left[\left(\frac{\tau}{\theta} - d\ln z + e^2\right) - \frac{2e^2\sigma}{d}(\lambda + d\ln e)\right]$. Therefore, if $MC_l\left(= \frac{\tau}{\theta} - d\ln z + e^2\right)$ is greater than $\frac{2e^2\sigma}{d}(\lambda + d\ln e)$, then $\frac{\partial MB_e}{\partial \theta} > \frac{\partial MC_e}{\partial \theta}$. As innate firm productivity (θ) is greater, MC_l is lower and it is more likely to have $\frac{\partial MB_e}{\partial \theta} < \frac{\partial MC_e}{\partial \theta}$. Hence, the firm with high productivity is less likely to perform product innovation because the marginal cost is more likely to be greater than the marginal benefit in performing product innovation. □