Product versus Process Innovation and the Global Engagement of Firms

Yong Joon Jang*             Hea-Jung Hyun**

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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. Empirical results suggest that process innovation is more strongly positively correlated with transition from exporting to FDI, while product innovation is more strongly correlated with transition from being a domestic firm to exporting.

Keywords: Innovation, Foreign Direct Investment, Exporting

JEL Classification: F23, D22

* Department of International Business and Trade, Kyung Hee University, Korea. Email:yjjang@khu.ac.kr. Tel:+82-2-961-0565. Fax:+82-2-961-0622

** Corresponding Author, College of International Studies, Kyung Hee University, Korea; Email: hjhyun@khu.ac.kr. Tel:+82-31-201-2306. Fax:+82-31-201-2281
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; this is because globalization exerts strong upward pressure on competition and causes rapid change in consumer preference, which in turn induces firms to invest more in innovation. 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 (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 (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.

Some previous studies show that the demand-driven factor, such as expansion into foreign market via trade liberalization, is more likely to generate product innovation since product
quality should be adjusted to meet the preferences of foreign consumers in anticipation of future liberalization (Becker and Egger, 2006; Cassiman and Martinez_Ros, 2007; Cassiman et al., 2010; Caldera, 2010). The supply-driven factors, such as intense competition with foreign firms due to trade liberalization, 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). Accordingly, previous 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. However, conditional on entering export markets, product innovation does not increase subsequent export intensity (i.e. the intensive margin of exports).  

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 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 vis-à-vis a transition from ‘exporter’ to ‘multinational’, while an exporter is more likely to perform process innovation in order to initiate FDI. This argument is based first on the fact that the total sales of an exporter are greater, on average, than those of a domestic producer (Helpman, Melitz and Yeaple, 2004). Second, as a firm increases in size, it increasingly returns to scale

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1 See related references in Table A1, Appendix A.

2 The keystone paper is Melitz (2003). Also see Helpman (2006) for a genealogy of Melitz-type models.
in order to perform process innovation and its marginal product innovation costs increase (Cohen and Klepper, 1996; Plehn-Dujowich, 2009). As a result, we predict that process innovation is more significant in raising a firm’s propensity to perform FDI and less significant in raising a firm’s propensity to export. On the other hand, product innovation is consistently important, irrespective of firm’s strategy for global engagement. Under certain conditions, however, product innovation is more significant in raising a firm’s propensity to export.

Our paper attempts to test this theoretical prediction 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. Equilibrium before Firm’s Decision to Innovate

2.1.1. Assumptions

The theoretical framework’s basic structure is similar to that of Hallak and Sivadasan (2009), who develop a model with two attributes of firm heterogeneity. However, we expand this model to include foreign direct investment (FDI) by placing the Hallak and Sivadasan’s
(2009) model within the Helpman, Melitz and Yeaple’s (HMY, 2004) model. HMY (2004) expand upon the Melitz’s model (2003) on multinationals, illustrating that high productive firms perform FDI, high-middle productive firms become exporters, low-middle productive firms serve only the domestic market, and low productive firms exit the market.

Given that HMY (2004) only consider one attribute of firm heterogeneity (i.e. firm productivity), we will develop a model with two attributes of firm heterogeneity (i.e. firm productivity and product quality) and analyze how these affect firm decisions to export and perform FDI. 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 reducing its marginal production cost.

The study employs 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. 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 determines 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.

Each firm produces one variety of product, and labor is the only production factor. We consider two timing steps in a firm’s decision-making process. Firstly, a firm enters the market; exogenously determines its level of productivity and product quality; and decides its 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. After this, the firm endogenously decides to innovate to cut its production
costs or to upgrade product quality in order to switch its status from a domestic producer to an exporter, or from an exporter to a multinational.

These assumptions about the two timing steps are made by Cassiman and Martinex-Ros (2007), Harris and Li (2009) and Van Beveren and Vandenbussche (2010). These studies find that there is causality between innovation and entrance into a foreign market, and address firms’ self-selection with regard to innovation in anticipation of entering foreign markets. Only those firms that anticipate entering the foreign market in the next period are more likely to invest in innovation activities such as cost reduction and quality improvement. Lopéz (2005) names this phenomenon ‘firm’s conscious self-selection’.

2.1.2. Consumption, Production, Revenue and Profit

A representative consumer has income $M$ and CES preferences over a set of differentiated goods indexed by $x$, $U = \left[ \int_{x \in X} q(x)^\rho \lambda(x)^{1-\rho} dx \right]^{\frac{1}{\rho}}$, where $X$ is a set of all potentially available goods, $q(x)$ is the demand for $x$, $\lambda(x)$ is the corresponding quality for $x$ (which is assumed to be determined exogenously), and $\rho$ is the elasticity of substitution between any two goods with $0 < \rho < 1^4$. When the portion of the elasticity of substitution decreases (i.e., decrease in $\rho$, the product quality becomes 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 $q(x) = p(x)^{-\sigma} p(x)^{\sigma-1} \lambda(x) M$, where $\sigma = \frac{1}{1-\rho} > 1$ and the aggregate price index, $P = \left[ \int_{x \in X} (p(x) \lambda(x))^{1-\sigma} dx \right]^{\frac{1}{1-\sigma}}$.5

On the production side, there is a monopolistically competitive market with $X$ firms. The

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3 Also see Lopéz (2005) and Melitz and Trefler (2012) for firms’ self-selection on the causality between exporting and performances. They denominate the causality between exporting and firm performance, such as productivity and innovation activities, as the minority view.


5 We assume that each firm’s influence on the overall price level, $P$, is negligible.
production involves two types of cost: variable and fixed costs \((f)\). The total costs \((TC)\) for
domestic sales \((D)\), exports \((X)\) and FDI \((I)\) are provided by \(TC_D = \frac{1}{\theta} q_D + f_D\), \(TC_X = \frac{\tau}{\theta} q_X + f_X\) and \(TC_I = \frac{1}{\theta} q_I + f_I\), respectively, where \(\theta \geq 1\) is the firm’s heterogeneous productivity, and \(\tau > 1\) is a per-unit iceberg cost for exporting.\(^6\)

In addition, the condition for fixed costs is assumed to be \(0 < f_D < \tau^{\sigma-1} f_X < f_I\), which ensures the relationship between firm heterogeneities and self-selection into markets. After realizing its \(\theta\) and \(\lambda\), the firm decides whether to exit the market, to produce only in the domestic market, to export to the foreign market, or to perform FDI under the given consumer preference. In this respect, both \(\theta\) and \(\lambda\) are exogenous and heterogeneous among the firms, while \(\tau\) and \(f_D\) are the same for all types of firms.

The equilibrium prices and quantities for domestic sales, exports and FDI are derived from
the profit maximization problem: \(p_D(\theta) = \frac{(\sigma)}{\sigma-1} \frac{1}{\theta}, \quad p_X(\theta) = \frac{(\sigma)}{\sigma-1} \frac{\tau}{\theta}, \quad q_D(\theta, \lambda) = q_I(\theta, \lambda) = (\rho \theta)^{\sigma} P^{\sigma-1} \lambda M\) and \(q_X(\theta, \lambda) = (\frac{\rho \theta}{\tau})^{\sigma} P^{\sigma-1} \lambda M\). Note that the equilibrium price consists of mark-up and marginal cost and thus is not related with \(\lambda\). On the other hand, \(\lambda\) positively affects the equilibrium quantities, i.e., \(\frac{\partial q}{\partial \lambda} > 0\). Also note that \(\frac{\partial p}{\partial \theta} < 0\) and \(\frac{\partial q}{\partial \theta} > 0\).

Accordingly, the equilibrium revenues for domestic sales, exports and FDI are \(r_D(\theta, \lambda) = r_I(\theta, \lambda) = M \lambda (P \rho \theta)^{\sigma - 1}\) and \(r_X(\theta, \lambda) = M \lambda \left(\frac{P \rho \theta}{\tau}\right)^{\sigma - 1}\). The equilibrium profits are then defined through the following equation: \(\pi_l(\theta, \lambda) = \frac{r_l(\theta, \lambda)}{\sigma} - f_l\), where \(l = D\) or \(X\) or \(I\) hereafter.

### 2.1.3. Cut-off Levels of Firm Heterogeneity and Firm Status

As in HMY (2004), the three conditions \((\pi_D = 0, \quad \pi_X = 0 \quad \text{and} \quad \pi_I = \pi_l)\) ensure the survival cut-off functions of production quality or firm productivity:

\(^6\) Unlike Hallak and Sivadasan (2009), the initial marginal cost does not include any quality cost as it is assumed to be determined exogenously; also, a consumer determines product quality hierarchy according to his or her preference. Accordingly, a firm does not have any ability to reduce the cost of product quality, such as “caliber” in Hallak and Sivadasan (2009) and “quality ladder” in Antoniades (2012). In the stage of firm decision to innovate, however, we will consider the cost of changing quality in the cost function during the process of product innovation.
For given $\theta$,

$$\bar{\lambda}_D(\theta) = \left(\frac{1}{P_{\rho \theta}}\right)^{\frac{1}{\sigma-1}} \frac{\sigma f_D}{M}, \quad \bar{\lambda}_X(\theta) = \left(\frac{\tau}{P_{\rho \theta}}\right)^{\frac{1}{\sigma-1}} \frac{\sigma f_X}{M} \quad \text{and} \quad \bar{\lambda}_I(\theta) = \left(\frac{1}{P_{\rho \theta}}\right)^{\frac{1}{\sigma-1}} \frac{\sigma(f_I-f_X)}{M(1-\tau^{1-\sigma})},$$

For given $\lambda$,

$$\bar{\theta}_D(\lambda) = \frac{1}{P_{\rho}} \left(\frac{f_D \sigma}{M \lambda}\right)^{\frac{1}{\sigma-1}}, \quad \bar{\theta}_X(\lambda) = \frac{\tau}{P_{\rho}} \left(\frac{f_X \sigma}{M \lambda}\right)^{\frac{1}{\sigma-1}} \quad \text{and} \quad \bar{\theta}_I(\lambda) = \frac{1}{P_{\rho}} \left(\frac{(f_I-f_X) \sigma}{M \lambda (1-\tau^{1-\sigma})}\right)^{\frac{1}{\sigma-1}}.$$

Note that the condition, $0 < f_D < \tau^{\sigma-1} f_X < f_I$, ensures the ordering of these cut-off levels as follows: $0 < \bar{\lambda}_D < \bar{\lambda}_X < \bar{\lambda}_I$ and $0 < \bar{\theta}_D < \bar{\theta}_X < \bar{\theta}_I$. These results imply that for each firm productivity level, there exist minimum product qualities for surviving and serving only the domestic market ($\bar{\lambda}_D$), for export ($\bar{\lambda}_X$), and for performing FDI ($\bar{\lambda}_I$) in the foreign market. Also, for each level of product quality, there is a required minimum firm productivity level within each production mode ($\bar{\theta}_D$, $\bar{\theta}_X$ and $\bar{\theta}_I$, respectively).

After entering the market and determining its productivity and product quality, 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 (see Figure 1).

Insert [Figure 1]

In sum, 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
2.2. Introduction of Firm Strategy for Innovation

2.2.1. Process Innovation

In the previous subchapter a firm’s status can be classified into four types of entry mode: “exit the market”, “a domestic producer”, “an exporter” and “a multinational”, depending on its productivity $\theta$ and product quality $\lambda$. In this subchapter, we introduce firm’s strategy for innovation into the basic structure, assuming that a firm has an incentive to upgrade its status because its profit becomes higher when jumping from the status of “a domestic producer (equivalently, $\pi_D$)” to that of “an exporter (equivalently, $\pi_D + \pi_X$)”, and from “an exporter” to “a multinational (equivalently, $\pi_D + \pi_I$)”, respectively.\(^7\) In this respect, given its original status with $\theta$ and $\lambda$, the firm would decide to innovate so as to switch its position from the domestic producer to the exporter or from the exporter to the MNE. The two methods for switching firm status have two corresponding choices: either to reduce marginal costs of production (i.e., process innovation) or to raise product quality (i.e., product innovation).

For simplicity, we assume that a firm will select one innovation among two modes in order to upgrade its status. If we allow a firm to perform both innovations simultaneously in the model, firstly it is necessary to investigate whether the relationship between process innovation and product innovation is substitute or complement or independent.\(^8\) 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. In this respect, we will consider these two types of innovation independently, assuming that they are not related each other.

First, we consider process innovation in this subchapter, taking into account its benefits and relationships with a firm’s characteristics such as productivity and quality. As process innovation is understood as a means of reducing marginal production costs, it is possible to

\(^7\) Note that the profit of a multinational is greater than that of an exporter, i.e. $\pi_I > \pi_X$, as $\theta \geq \bar{\theta}_I$ or $\lambda \geq \bar{\lambda}_I$.

\(^8\) Tang (2006) shows that process innovation is often bundled with production innovation. Also, see Weiss (2003), Martines-Ros (1999), Mirayete and Pernias (2006) and Parisi et al. (2006) for the relationship between process innovation and product innovation.
consider it in the model with just one attribute of firm heterogeneity, i.e. firm productivity. Typical examples of a model with innovation strategy and one attribute of firm heterogeneity can be found in Bustos (2009) and Caldera (2010). Basing their work on that of Melitz (2003), Bustos (2009) and Caldera (2010) develop a model of firms’ decisions to innovate in the process of production and export, demonstrating that process innovation has a positive effect on the probability of participation in export markets.9

However, unlike Bustos (2009) and Caldera (2010), we consider process innovation with regard to multinationals as well as exporters, based on HMY (2004). In addition, we analyze the effects of process innovation on firms’ strategies for overseas expansion on the basis of the theoretical structure, which embodies both product and process innovation. Finally, unlike Caldera (2010), we control for an ex ante bias between innate firm productivity and innovation strategy by developing the following conditions on a marginal cost function ($MC_l$):

$$\frac{\partial MC_l(\theta, z, \tau)}{\partial \theta} < 0, \quad \frac{\partial^2 MC_l(\theta, z, \tau)}{\partial \theta^2} > 0 \quad \frac{\partial MC_l(\theta, z, \tau)}{\partial z} < 0 \quad \frac{\partial^2 MC_l(\theta, z, \tau)}{\partial \theta \partial z} = 0 \quad (1)$$

where $z$ denotes process innovation, and $l = D$ or $X$ or $I$. 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. More importantly, the last condition ensures that more highly productive firms do not have an ex ante comparative advantage of performing process innovation.

As in Plehn-Dujowich (2009), we consider the specific form of the marginal cost function with process innovation, which satisfies all conditions in (1): $MC_l = \frac{\tau}{\theta} - d \ln z$, where $d > 0$ is a constant, and $\tau = 1$ for $l = D$ or $I$ and $\tau > 1$ for $l = X$, hereafter. Accordingly, the firm maximizes its profits while taking its status given in the first stage10:

$$\max_{p, z} \pi_l = pq - \left(\frac{\tau}{\theta} - d \ln z\right)q - z \quad (2)$$

The first-order condition (FOC) with respect to price in the profit maximization problem

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9 Although Bustos (2009) and Caldera (2010) do not explicitly identify firm innovation as process innovation in the theoretical models, they state that firms’ decisions to innovate reduce marginal production costs.

10 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.
yields:

$$p_l = \left( \frac{\sigma}{\sigma - 1} \right) \left( \frac{\tau}{\theta} - d \ln z \right)$$  \hspace{1cm} (3)

where the equilibrium price, $p_l$, depends on firm’s markup (i.e., $\frac{\sigma}{\sigma - 1}$ ) and its marginal cost (i.e. $\frac{\tau}{\theta} - d \ln z$). The FOC with respect to process innovation is:

$$d \frac{p(x)^{-\sigma} p(x)^{\sigma-1} \lambda(x) M}{z} = 1$$  \hspace{1cm} (4)

Substitute (3) into (4) to obtain:

$$d \left( \frac{\sigma}{\sigma - 1} \right) \left( \frac{\tau}{\theta} - d \ln z \right)^{-\sigma} p^{\sigma-1} \lambda M = 1$$  \hspace{1cm} (5)

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 (5) 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 (Scherer, 1991; Yin and Zuschovitch, 1998; Baldwin and Sabourin, 1999; Kaufmann and Tödtling, 1999; Tang, 2006; Forfás Innovation Survey, 2006). 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...
2.2.2. Product Innovation

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. Given $\theta$ and $\lambda$, a firm might increase its product quality by paying relevant costs to upgrade its status from a domestic producer to an exporter, or from an exporter to a multinational, in the second stage.

On the consumption side, we consider that the demand function is satisfied with the following conditions with respect to production innovation:

\[
\frac{\partial q(\lambda, e)}{\partial \lambda} > 0, \quad \frac{\partial q(\lambda, e)}{\partial e} > 0, \quad \frac{\partial^2 q(\lambda, e)}{\partial e^2} < 0 \quad \text{and} \quad \frac{\partial^2 q(\lambda, e)}{\partial \lambda \partial e} = \frac{\partial^2 q(\lambda, e)}{\partial e \partial \lambda} = 0
\]  

(6)

where $e$ denotes product innovation. In (6), 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\(^{11}\). The second condition represents decreasing returns to scale for production innovation, as in Plehn-Dujowich (2009)\(^{12}\). The last condition ensures that firms with higher innate quality do not have an \textit{ex ante} comparative advantage of performing product innovation. As higher quality ($\lambda$) is determined by consumer preference rather than a firm’s ability, the level of $\lambda$ is unrelated to prior product innovation performance. Hence, the last condition in (6) controls for an \textit{ex ante} bias between innate product quality and innovation strategy. Particularly, we consider the specific form of the demand function with product innovation, which satisfies all conditions in (6), based on the original form in Section 2.1.2: $q(\lambda, e) = p^{-\sigma} p^{\sigma-1} M(\lambda + d \ln e)$.

\(^{11}\) Rosenkranz (2003) shows the positive relationship between consumers’ willingness to pay and product innovation.

\(^{12}\) 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. Also see Weiss (2003) on this argument.
On the production side, we consider that marginal costs increase alongside product innovation as in Hallak and Sivadasan (2009), but highly productive firms do not have an \textit{ex ante} comparative advantage for performing product innovation. The corresponding conditions are:

\[
\frac{\partial MC_l(\theta, e, \tau)}{\partial \theta} < 0, \quad \frac{\partial MC_l(\theta, e, \tau)}{\partial e} > 0, \quad \frac{\partial^2 MC_l(\theta, e, \tau)}{\partial e^2} > 0 \quad \text{and} \quad \frac{\partial^2 MC_l(\theta, e, \tau)}{\partial \theta \partial e} = 0
\]  

(7)

The first condition represents that the high innate productivity lowers the marginal cost as in (1), rendering the low equilibrium price and the high demand. The second and third 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 at an increasing rate (Lee and Kang, 2007). The last condition controls for an \textit{ex ante} bias between innate firm productivity and innovation strategy. We also consider the specific form of the marginal cost function with product innovation, which satisfies all conditions in (7):

\[
MC_l = \frac{\tau}{\theta} + e^2
\]

Accordingly, given its status in the first stage, the firm’s profit maximization problem in the second stage is:

\[
\max_{p, z} \pi_l = p^{1-\sigma}P^{\sigma-1}M(\lambda + d \ln e) - \left(\frac{\tau}{\theta} + e^2\right)(p^{\sigma}P^{\sigma-1}M(\lambda + d \ln e)) - e
\]  

(8)

The first-order condition (FOC) with respect to \( q \) in the profit maximization problem yields the equilibrium price, \( p_l = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta} + e^2\right) \), which consists of the mark-up and the marginal cost, as well as the equilibrium quantity, which is satisfied with \( \frac{\partial q_l}{\partial \lambda} > 0 \). The FOC with respect to product innovation is:

\[
\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta} + e^2\right)\right)^{1-\sigma}p^{\sigma-1}M \frac{d}{e} \left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta} + e^2\right)\right)^{-\sigma}\left(\frac{\tau}{\theta} + e^2\right) + 2e(\lambda + d \ln e) + 1
\]  

(9)

Note that the left hand side of (9) represents the marginal benefits of performing product innovation \((MB_e)\), while the right side of (9) represents its marginal costs \((MC_e)\). Substituting similar to the case of process innovation, the fixed cost function of performing product innovation is assumed to be \( e \) for the sake of simplicity (and is the same for all firms).
the equilibrium price and quantity into (9), we address the following proposition:

**Proposition 2.** Firms with high product quality are less likely to perform product innovation, while the relationship between firm productivity and implementation of product innovation is ambiguous in general.

*Proof.* See Appendix B.

**Corollary 1.** There exists the threshold of firm productivity, $\bar{\theta}_{Prod}$, such that the marginal benefit is equal to the marginal cost in performing product innovation.

(i) If firm’s innate productivity is greater than $\bar{\theta}_{Prod}$, then the firm is less likely to perform product innovation because the marginal cost is greater than the marginal benefit in performing product innovation;

(ii) If firm’s innate productivity is less than $\bar{\theta}_{Prod}$, then the firm is more likely to perform product innovation because the marginal benefit is greater than the marginal cost in performing product innovation;

*Proof.* See Appendix B.

Our theoretical result addresses that a firm’s high innate product quality negatively affects the implementation of product innovation, which is represented in Proposition 2. 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. Thus, the additional cost for upgrading product quality by one unit will be higher at the level of high product quality (i.e., $\frac{dMCE}{d\lambda} > 0$). 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., $\frac{dMB\lambda}{d\lambda} = 0$) because the equilibrium price consists of mark-up and marginal cost, irrespective of $\lambda$ in the model’s basic setup.
However, the relationship between a firm’s innate productivity and the implementation of product innovation represents the inverse U shape rather than linear in Corollary 1, while it is undetermined in general in Proposition 2.

Although we cannot perfectly generalize the result, the outcome of product quality in Proposition 1 and that of firm productivity in Corollary 1 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.

2.3. Innovation Mode and Firm Decision to Export or perform FDI

Given a firm’s innate status, Proposition 1 addresses the assertion that firms with high productivity and/or high product quality produce more and are more likely to perform process innovation to obtain higher profit in the market. Also, Proposition 2 addresses that firms with high product quality are less likely to perform product innovation. However, the relationship between product innovation and a firm’s heterogeneous productivity is not clear-cut. The relationship can be determined only when firms with low productivity (i.e. \( \theta < \bar{\theta}_{prod} \)), are more likely to perform product innovation to obtain a better status in the presence of relatively lower marginal costs and higher marginal benefits of product quality upgrade, and vice versa for firms with \( \theta > \bar{\theta}_{prod} \). Based on these results, we propose five cases that take into account a firm’s strategy for innovation and its status based on productivity and product quality in Figure 2.

Based on the firm located at point 1 in Figure 2 (hereafter, firm 1), the first case compares firm 1 and firm A (case 1). Likewise, the second, third, fourth and fifth cases compare firm 1 and firm B (case 2), firm 1 and firm C (case 3), firm 1 and firm D (case 4) and firm 1 and firm E (case 5), respectively. Note that firm 1 is currently an exporter attempting to become a multinational, while firms A-E are domestic producers attempting to become exporters.
through innovation.

In case 1, the productivity of firm 1 is greater than that of firm A, i.e. $\theta_1 > \theta_A$. However, the product quality of firm 1 is the same as that of firm A, i.e. $\lambda_1 = \lambda_A$. Thus, according to Proposition 1, we conclude that firm 1 is more likely to perform process innovation than firm A to obtain a better status. However, it is ambiguous whether firm 1 is more likely to perform product innovation than firm A to obtain a better status according to Proposition 2. A firm 1’s strategy for product innovation will depend on where $\bar{\theta}_{prod}$ is located in the order of firm productivity thresholds, based on Corollary 1: if the order of firm productivity threshold is $0 < \bar{\theta}_D < \bar{\theta}_{prod} < \bar{\theta}_X < \bar{\theta}_l$, then some firms with $\bar{\theta}_D < \theta < \bar{\theta}_{prod}$ at point A might perform product innovation but others with $\bar{\theta}_{prod} < \theta < \bar{\theta}_X$ do not, while all firms with $\bar{\theta}_X < \theta$ at point 1 do not perform product innovation as they all have $\theta > \bar{\theta}_{prod}$. Thus, firms at point A are more likely to perform product innovation than firm 1 because the latter’s productivity is greater than $\bar{\theta}_{prod}$. Meanwhile, if the order of firm productivity threshold is $0 < \bar{\theta}_D < \bar{\theta}_X < \bar{\theta}_{prod} < \bar{\theta}_l$, then some firms with $\bar{\theta}_X < \theta < \bar{\theta}_{prod}$ at point 1 might perform product innovation but others with $\bar{\theta}_{prod} < \theta < \bar{\theta}_X$ do not, while all firms at point A want to perform product innovation as they all have $\theta > \bar{\theta}_{prod}$. Thus, firms at point A are more likely to perform product innovation than firm 1 because the former’s productivity is lower than $\bar{\theta}_{prod}$. With these first two cases of the order for the firm productivity threshold, we can conclude that firm 1 is more likely to perform process innovation to become an MNE, while firm A is more likely to perform product innovation to become an exporter.

Third, if the order of firm productivity thresholds represents $0 < \bar{\theta}_D < \bar{\theta}_X < \bar{\theta}_l < \bar{\theta}_{prod}$, then both firm 1 and firm A will perform product innovation, implying that we cannot tell who is more likely to do product innovation for better status. Hence, this third case of the order seems to be the same situation as in Proposition 2 for the implementation of product innovation. Finally, if the order of firms productivity thresholds represents $0 < \bar{\theta}_{prod} < \bar{\theta}_D < \bar{\theta}_X < \bar{\theta}_l$, then both firm 1 and firm A do not perform product innovation. We, however, exclude this case because our dataset shows the evidence for product innovation in both groups.

In case 2, both firm 1 and firm B’s productivities are identical, i.e. $\theta_1 = \theta_B$, whereas the former’s product quality is greater than the latter’s, i.e. $\lambda_1 > \lambda_B$. Thus, firm 1 is more likely to perform process innovation by Proposition 1, but is less likely to perform product
innovation than firm B. In other word, firms at point 1 prefer process innovation, while firms at point B prefer product innovation in order to obtain better status. In case 3, both the productivity and product quality of firm 1 are greater than that of firm C, i.e. \( \theta_1 > \theta_C \) and \( \lambda_1 > \lambda_C \), respectively. This implies that firm 1 is more likely to perform process innovation than firm C according to Proposition 1, while it is ambiguous whether product innovation is preferred in general in Proposition 2. If the particular conditions (i.e. \( 0 < \bar{\theta}_D < \bar{\theta}_{prod} < \bar{\theta}_X < \bar{\theta}_I \)) are satisfied, as in case 1 above, then firm C might be more likely to perform product innovation than firm 1 for better status. However, with the condition of \( 0 < \bar{\theta}_D < \bar{\theta}_X < \bar{\theta}_I < \bar{\theta}_{prod} \), then it is indifferent to perform product innovation between firm 1 and firm C.

In case 4, the productivity of firm 1 is greater than that of firm D, i.e. \( \theta_1 > \theta_D \); however the former’s product quality is lower than the latter’s, i.e. \( \lambda_1 < \lambda_D \). In case 5, the productivity of firm 1 is lower than that of firm E, i.e. \( \theta_1 < \theta_E \), but the former’s product quality is higher than the latter’s, i.e. \( \lambda_1 > \lambda_E \). Both cases 4 and 5 are, however, generally unusual situations because previous literature show that exporters have relatively higher TFP, and simultaneously produce higher quality products, than domestic producers\(^{14}\). Also, our firm-level dataset shows that multinationals have higher performance than exporters and domestic producers, while exporters outperform domestic producers (see Figure 3 and Table 2). Insert [Figure 2]

As s result, we only consider cases 1-3 and exclude case 4 and 5 for the sake of normality, and build up the following corollary based on the argument in Figure 2 above:

**Corollary 2.** In general,

(i) an exporter who wants to start performing FDI is more likely to perform process innovation than a domestic producer who wants to start exporting; however,

\(^{14}\) For evidence of these exporters’ characteristics, see Bekkers (2008), Verhoogen (2008), and Bastos and Silva (2010). In particular, Bastos and Silva (2010) show that these exporter’s characteristics are more pronounced when exporting to high income countries.
(ii) both exporters and domestic producers perform product innovation indifferently in order to obtain better status.

Under the certain condition with the intermediate level of firm productivity threshold for product innovation\textsuperscript{15},

(iii) a domestic producer who wants to start exporting is more likely to perform product innovation than an exporter who wants to start performing FDI.

The sources of the results in (i) and (ii) are not only the increasing return to scale in order to perform both process and product innovations, but also the increasing marginal cost of performing product innovation. However, the increasing return to scale is greater than the increasing marginal cost in performing product innovation for domestic producer under the certain situation in (iii)

In conclusion, we build up the following Proposition 3 to determine the impact of innovation mode on firm’s decisions to export and perform FDI:

**Proposition 3.** In general,

(i) process innovation becomes more important in the extensive margin of FDI than in that of export because firm size grows after it becomes an exporter and the firm can take advantage of the increasing return to scale in process innovation; and

(ii) product innovation is constantly important, irrespective of the extensive margins of FDI and export.

Proposition 3 is the main objective of our empirical test in the next section. In Proposition 3, we predict that process innovation is more significant for a firm’s propensity to perform FDI due to increasing returns to scale, although it was relatively less significant in determining the firm’s propensity to export. However, in general we cannot theoretically determine how product innovation is relatively important to a firm’s propensity to perform FDI and to export. Under the special condition with the intermediate level of firm productivity threshold for the implementation of production innovation, (i.e., $0 < \tilde{\theta}_D \leq \tilde{\theta}_{Prod} \leq \tilde{\theta}_X \leq \tilde{\theta}_I$ or $0 < \tilde{\theta}_D < \tilde{\theta}_{Prod} < \tilde{\theta}_I$.

\textsuperscript{15} The corresponding condition is $0 < \tilde{\theta}_D < \tilde{\theta}_{Prod} < \tilde{\theta}_X < \tilde{\theta}_I$ or $0 < \tilde{\theta}_D < \tilde{\theta}_X < \tilde{\theta}_{Prod} < \tilde{\theta}_I$. 

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$\tilde{\theta}_X < \tilde{\theta}_{\text{prod}} < \tilde{\theta}_I$), product innovation is more important in raising a firm’s propensity to export than that to perform FDI in its globalization strategies. Hence we should identify the effect of product innovation on a firm’s global engagement empirically.

In general, these predictions appear consistent with the general findings of previous related studies. First, with respect to firm size, some studies demonstrate a positive relationship between process innovation and firm size (Mansfield, 1981; Scherer, 1991; Cohen and Klepper, 1996; Yin & Zuschovitch, 1998; Baldwin & Sabourin, 1999; Kaufmann and Tödtling, 1999; Baldwin and Gu, 2004; Petsas and Giannikos, 2005; Tang, 2006; Plehn-Dujowich, 2009). 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. In addition, our hypothesis 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 conjecture 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 production 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 on production costs for an incumbent’s market strategy in a foreign market. Specifically, it is very important for an exporter seeking to become a multinational to significantly reduce their 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 its involvement in export.

3. Empirical Specification

3.1 Empirical Model

In this section we build an empirical strategy to test the proposition 3 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. The index models used to analyze decisions to export and perform FDI can be specified respectively as:

\[
\begin{align*}
EXP_{it} &= \begin{cases} 
1 & \text{if } \alpha_1 \text{Product}_i\text{n}ov_{it-1} + \alpha_2 \text{Process}_i\text{n}ov_{it-1} + \alpha_3 Z_{it-1} + \gamma_k + \delta_t + \epsilon_{it} > 0 \\
0 & \text{otherwise} 
\end{cases}
\end{align*}
\]

(7)

\[
\begin{align*}
FDI_{it} &= \begin{cases} 
1 & \text{if } \beta_1 \text{Product}_i\text{n}ov_{it-1} + \beta_2 \text{Process}_i\text{n}ov_{it-1} + \beta_3 Z_{it-1} + \mu_k + \theta_t + \omega_{it} > 0 \\
0 & \text{otherwise} 
\end{cases}
\end{align*}
\]

(8)

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.\(^{16}\) \text{Product}_i\text{n}ov is a dummy variable that takes the value of 1 if the firm invested in product innovation, and otherwise

---

\(^{16}\) Based on our theoretical model, we exclude the case in which a domestic firm directly performs FDI without prior exporting experience.
takes the value of 0. \textit{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 and exporting firms at time \( t-1 \), as in the following equation:\footnote{Also, this restriction is consistent with our theoretical model, which considers only the extensive margins of export and FDI.}

\[
\begin{align*}
\text{Prob}(\text{EXP}_{t} = 1|\text{Domestic}_{t-1} = 1) &= f(\text{Innov}_{t-1}) \quad (9) \\
\text{Prob}(\text{FDI}_{t} = 1|\text{EXP}_{t-1} = 1) &= f(\text{Innov}_{t-1}) \quad (10)
\end{align*}
\]

Following equations (9) and (10), 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:

\[
\begin{align*}
\text{EXP}_{ikt} &= \beta_0 + \beta_1 \ln \text{Size}_{ikt-1} + \beta_2 \ln \text{TFP}_{ikt-1} + \beta_3 \text{Foreign\_ownership}_{ikt-1} \\
&\quad + \beta_4 \text{Product\_Innovation}_{ikt-1} + \beta_5 \text{Process\_Innovation}_{ikt-1} \\
&\quad + \sum \beta_{5+k} \text{Industry\_dummy}_k + \varepsilon_{ikt} 
\end{align*}
\]

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:
\[ FDI_{ikt} = \beta_0 + \beta_1 \ln Size_{ikt-1} + \beta_2 \ln TFP_{ikt-1} + \beta_3 Foreign\_ownership_{ikt-1} \]
\[ + \beta_4 Product\_Innovation_{ikt-1} + \beta_5 Process\_Innovation_{ikt-1} \]
\[ + \sum \beta_{5+k} Industry\_dummy_k + \epsilon_{ikt} \]  

(12)

3.1.2 Robustness Check

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 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 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\textsuperscript{18} 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]

\textit{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 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. 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).

\textsuperscript{18} The number of observation in our dataset is 40,101.
**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 Figure 3 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 3]

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 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. In terms of average number of patent inventions per labor, firms exposed to foreign markets have a higher intensity of patent invention than purely domestic firms. 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 dummy. Additionally, when the cost of investment in R&D per sales is 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 (11) and (12). Columns (1) through (8) 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, the total factor productivity as a measure of firm productivity, and the dummy variable of foreign ownership, purely domestic firms that conducted patent citation in year $t-1$ are more likely to export in the preceding year than firms that did not engage in product innovation to start exporting. Column (2) also shows that among exporters, firms that cited 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 decisions, 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) through (8) demonstrate that product innovation measured as patent intensity, R&D dummy and R&D intensity significantly raises the probability of firms participating in exports and serving foreign markets via FDI. The likelihood ratio test of $\rho$ rejects the model of no correlation in the error terms, that is, it approves the correlation between the error terms of equations (11) and (12). These results suggest that product innovation positively affects both export and FDI. Process innovation also consistently has a positive impact on export decisions, but the effect is statistically not significant. Thus, in terms of the impact of the type of innovation on firms’ mode of entry, the impact of product innovation on export is significantly stronger than that of process innovation, while both types of innovative activities are positively associated with exporters’ decisions to initiate FDI. Thus, our empirical results support our theoretical prediction (i.e., Proposition 3) that process innovation becomes more important in the decision of FDI than that of export while product innovation is constantly important, irrespective of the mode of entry to foreign markets.

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). The dummy variable of foreign ownership is positively related to firms’ exporting decisions, suggesting that foreign-owned firms may be more likely to serve foreign markets by using international production networks through exporting. Foreign ownership, however, is negatively related
4.2 Robustness Check

To confirm the baseline results using the bivariate probit model, we employed average treatment effects as our 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 important in both FDI and exporting.

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, while product innovation equally affects both FDI and export. This theoretical prediction is supported by empirical tests, in that both innovative activities positively affect firms’ decisions 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 important for the incumbent’s market strategy.

References


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17-29.
The original feature of Figure 1 is found in Hallak and Sivadasan (2009). The difference between Figure 1 and the work of Hallak and Sivadasan (2009), however, is that we consider $\lambda$ to be an exogenous variable and locate it on the y-axis in Figure 1, while they instead consider the firm’s ability to reduce product quality (“caliber”) cost.
[Table 1] Definition of Key Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Innovation</td>
<td></td>
</tr>
<tr>
<td>ERP(Enterprise Resource</td>
<td>A dummy variable that takes a value of 1 if the firm reports the introduction of ERP, and 0 otherwise</td>
</tr>
<tr>
<td>Planning) dummy</td>
<td></td>
</tr>
<tr>
<td>Product Innovation</td>
<td></td>
</tr>
<tr>
<td>R&amp;D dummy</td>
<td>A dummy variable that takes a value of 1 if the firm reports conducting R&amp;D, and 0 otherwise</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td>Expenditure on R&amp;D per Sale</td>
</tr>
<tr>
<td>Patent citation dummy</td>
<td>A dummy variable that takes the value of 1 when the firm reports citing a patent, and 0 otherwise</td>
</tr>
<tr>
<td>Patent invention intensity</td>
<td>Number of patents invented per sales</td>
</tr>
<tr>
<td>Other Control Variables</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>Natural log of the number of employees</td>
</tr>
<tr>
<td>Productivity</td>
<td>Natural log of total factor productivity</td>
</tr>
<tr>
<td>Foreign ownership</td>
<td>A dummy variable that takes a value of 1 when foreign ownership is more than 10%, and 0 otherwise</td>
</tr>
<tr>
<td>Panel A.</td>
<td>Domestic Firms</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>Size(Number of Employees)</td>
<td>127.21</td>
</tr>
<tr>
<td>Size(Sales, million won)</td>
<td>42403.41</td>
</tr>
<tr>
<td>Productivity(Natural log of total factor productivity)</td>
<td>-0.15</td>
</tr>
<tr>
<td>Foreign ownership(share)</td>
<td>2.14</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>2293</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B.</th>
<th>Domestic Firms</th>
<th>Exporters</th>
<th>Multinationals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Process Innovator</td>
<td>Non-process innovator</td>
<td>Process Innovator</td>
</tr>
<tr>
<td>Size(Number of Employees)</td>
<td>127.87</td>
<td>102.50</td>
<td>152.17</td>
</tr>
<tr>
<td>Size(Sales, million won)</td>
<td>51304.17</td>
<td>28754.77</td>
<td>67554.79</td>
</tr>
<tr>
<td>Productivity(Natural log of total factor productivity)</td>
<td>-0.03</td>
<td>-0.24</td>
<td>0.02</td>
</tr>
<tr>
<td>Foreign ownership(share)</td>
<td>3.52</td>
<td>1.69</td>
<td>9.27</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>3394</td>
<td>4252</td>
<td>830</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Year 2006</th>
<th>Year 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Firms</td>
<td>Exporters</td>
</tr>
<tr>
<td>(N=2120)</td>
<td>(N=1536)</td>
</tr>
<tr>
<td>Patent citation dummy</td>
<td>0.263</td>
</tr>
<tr>
<td>Patent invention</td>
<td>0.016</td>
</tr>
<tr>
<td>R&amp;D dummy</td>
<td>0.443</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td>0.018</td>
</tr>
<tr>
<td>ERP dummy</td>
<td>0.312</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Export&lt;sub&gt;i&lt;/sub&gt;</th>
<th>FDI&lt;sub&gt;i&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Product&lt;sub&gt;i&lt;/sub&gt;</td>
<td>0</td>
<td>5564(86.5)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2412(77.8)</td>
</tr>
<tr>
<td>Process&lt;sub&gt;i&lt;/sub&gt;</td>
<td>0</td>
<td>4402(85.8)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3574(81.2)</td>
</tr>
</tbody>
</table>

Notes: For each cell, 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

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td>0.200***</td>
<td>0.362***</td>
<td>0.207***</td>
<td>0.371***</td>
<td>0.199***</td>
<td>0.368***</td>
<td>0.201***</td>
<td>0.371***</td>
</tr>
<tr>
<td>FDI</td>
<td>0.0429</td>
<td>0.0681</td>
<td>0.0428</td>
<td>0.0685</td>
<td>0.0429</td>
<td>0.0679</td>
<td>0.0428</td>
<td>0.0678</td>
</tr>
<tr>
<td>Productivity</td>
<td>0.0888***</td>
<td>0.205***</td>
<td>0.0952***</td>
<td>0.220***</td>
<td>0.083**</td>
<td>0.200***</td>
<td>0.087***</td>
<td>0.207***</td>
</tr>
<tr>
<td>Foreign ownership</td>
<td>0.00714***</td>
<td>-0.0126***</td>
<td>0.0071***</td>
<td>-0.0126***</td>
<td>0.0069***</td>
<td>-0.012***</td>
<td>0.006***</td>
<td>-0.012***</td>
</tr>
<tr>
<td>Product Innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patent citation dummy</td>
<td>0.298***</td>
<td>0.295***</td>
<td>0.00119</td>
<td>0.0216</td>
<td>0.001</td>
<td>0.0216</td>
<td>0.00119</td>
<td>0.0216</td>
</tr>
<tr>
<td>Patent invention intensity</td>
<td></td>
<td></td>
<td>0.0220***</td>
<td>0.0231***</td>
<td>0.00331</td>
<td>0.00631</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D dummy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.275***</td>
<td>0.208**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0450</td>
<td>0.0995</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-1.975***</td>
<td>-3.768***</td>
<td>-1.513***</td>
<td>-3.308***</td>
<td>-1.917***</td>
<td>-3.735***</td>
<td>-1.55***</td>
<td>-3.474***</td>
</tr>
<tr>
<td>ERP dummy</td>
<td>0.0630</td>
<td>0.189**</td>
<td>0.0609</td>
<td>0.183**</td>
<td>0.0612</td>
<td>0.195**</td>
<td>0.058</td>
<td>0.192**</td>
</tr>
<tr>
<td>(0.0453)</td>
<td>(0.0845)</td>
<td>(0.0453)</td>
<td>(0.0845)</td>
<td>(0.0453)</td>
<td>(0.0837)</td>
<td>(0.0453)</td>
<td>(0.0837)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-3.411</td>
<td>-3.768***</td>
<td>-1.513***</td>
<td>-3.308***</td>
<td>-1.917***</td>
<td>-3.735***</td>
<td>-1.55***</td>
<td>-3.474***</td>
</tr>
<tr>
<td>(0.341)</td>
<td>(0.537)</td>
<td>(0.347)</td>
<td>(0.520)</td>
<td>(0.342)</td>
<td>(0.528)</td>
<td>(0.345)</td>
<td>(0.524)</td>
<td></td>
</tr>
<tr>
<td>Rho</td>
<td>0.359</td>
<td>0.44</td>
<td>0.358</td>
<td>0.44</td>
<td>0.36</td>
<td>0.431</td>
<td>0.358</td>
<td>0.431</td>
</tr>
<tr>
<td>(0.032)</td>
<td>(0.099)</td>
<td>(0.032)</td>
<td>(0.099)</td>
<td>(0.032)</td>
<td>(0.099)</td>
<td>(0.032)</td>
<td>(0.099)</td>
<td></td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-3928.98</td>
<td>-1345.43</td>
<td>-3926.83</td>
<td>-1345.43</td>
<td>-3930.39</td>
<td>-1344.03</td>
<td>-3927.02</td>
<td>-1349.51</td>
</tr>
<tr>
<td>Observations</td>
<td>9,529</td>
<td>7,538</td>
<td>9,529</td>
<td>7,538</td>
<td>9,529</td>
<td>7,538</td>
<td>9,529</td>
<td>7,538</td>
</tr>
<tr>
<td>Number of firms</td>
<td>3,529</td>
<td>2,986</td>
<td>3,529</td>
<td>2,986</td>
<td>3,529</td>
<td>2,986</td>
<td>3,529</td>
<td>2,986</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Method</th>
<th>Probability of Exporting</th>
<th>Probability of FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ATT</td>
<td>SE</td>
</tr>
<tr>
<td>One-to-One Matching</td>
<td>0.053*</td>
<td>0.011</td>
</tr>
<tr>
<td>Nearest Neighbor Matching</td>
<td>0.053*</td>
<td>0.0103</td>
</tr>
<tr>
<td>Local Linear Regression</td>
<td>0.059*</td>
<td>0.008</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Probability of Exporting</th>
<th>Probability of FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ATT</td>
<td>SE</td>
</tr>
<tr>
<td>One-to-One Matching</td>
<td>0.014*</td>
<td>0.008</td>
</tr>
<tr>
<td>Nearest Neighbor Matching</td>
<td>0.012</td>
<td>0.009</td>
</tr>
<tr>
<td>Local Linear Regression</td>
<td>0.011</td>
<td>0.007</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Topic</th>
<th>Study</th>
<th>Findings</th>
</tr>
</thead>
</table>
- 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. |
- 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., \( \frac{\partial MB_x}{\partial \theta} = \frac{d \sigma \tau (\sigma - 1)}{z} \left( \left( \frac{\sigma}{\sigma - 1} \right) \left( \frac{\tau}{\sigma} + e^2 \right) \right)^{\sigma - 1} = d \frac{\partial q_1}{z \partial \theta} > 0 \) and \( \frac{\partial MB_x}{\partial \lambda} = \frac{d \sigma \tau (\sigma - 1)}{z} \left( \left( \frac{\sigma}{\sigma - 1} \right) \left( \frac{\tau}{\sigma} + e^2 \right) \right)^{\sigma - 1} M = d \frac{\partial q_1}{z \partial \lambda} > 0 \).

Note that the underlying source of Proposition 1 comes from economies of scale 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. \( \square \)

Proposition 2. Proof.

The relationship between product quality and product innovation 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 \( \lambda \), implying the innate product quality does not affect the production cost in our original framework. Meanwhile, considering \( MC_e \), we obtain \( \frac{\partial MC_e}{\partial \lambda} = 2 e \left( \left( \frac{\sigma}{\sigma - 1} \right) \left( \frac{\tau}{\sigma} + e^2 \right) \right)^{\sigma - 1} P^{\sigma - 1} M = 2 e \frac{\partial q}{\partial \lambda} > 0 \) as \( \frac{\partial q}{\partial \lambda} > 0 \) in (6). 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.

On the other hand, with regard to the relationship between firm productivity and product innovation, first we obtain \( \frac{\partial MB_e}{\partial \theta} = (\sigma - 1) \left( \left( \frac{\sigma}{\sigma - 1} \right) \left( \frac{\tau}{\sigma} + e^2 \right) \right)^{\sigma - 1} P^{\sigma - 1} M d \frac{\tau}{\sigma^2} > 0 \) as \( \sigma > 1 \). The underlying source for this result comes from the fact that \( \frac{\partial p}{\partial \theta} < 0 \) in (7). Hence firms with high innate productivity reap the greater benefit from product innovation. Meanwhile, we also obtain \( \frac{\partial MC_e}{\partial \theta} = (\sigma - 1) \left( \left( \frac{\sigma}{\sigma - 1} \right) \left( \frac{\tau}{\sigma} + e^2 \right) \right)^{\sigma - 1} P^{\sigma - 1} M \frac{\tau}{\sigma^2} (d \frac{\tau}{\sigma} + \left( \frac{\tau}{\sigma} + e^2 \right)^{-1}) (\lambda + \ldots) \).
$d \ln e) > 0$. The underlying source for this result comes from two facts that $\frac{\partial p}{\partial \theta} < 0$ and $\frac{\partial q}{\partial \theta} > 0$ in (7). 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 product innovation. In this respect, we can conclude that the relationship between firm productivity and the implementation of product innovation is ambiguous as the effects of firm productivity on $MB_e$ and $MC_e$ are positive and their relative values are undetermined. □

**Corollary 1. Proof.**

From the process in the proof of Proposition 2, we obtain $\frac{\partial MC_e}{\partial \theta} / \frac{\partial MB_e}{\partial \theta} = \frac{d}{e} + \frac{\theta(\lambda + d \ln e)}{\tau + e^2 \theta}$. Hence there exists the threshold of firm productivity, $\bar{\theta}_{prod}$, such that $\frac{\partial MC_e}{\partial \theta} = \frac{\partial MB_e}{\partial \theta}$; that is $\bar{\theta}_{prod} = \frac{(e-d)\tau}{e(de+\lambda+d\ln e-e^2)}$, where the equilibrium $e$ consists of exogenous variables and can be explicitly obtained from (9). As a result, if $\theta > \bar{\theta}_{prod}$, then the firm is less likely to perform product innovation because $\frac{\partial MC_e}{\partial \theta} > \frac{\partial MB_e}{\partial \theta}$, implying that the effect of the decreasing return to scale in performing product innovation is relatively greater. Similarly, the firm is more likely to perform product innovation if its innate productivity is less than $\bar{\theta}_{prod}$, ensuring $\frac{\partial MC_e}{\partial \theta} < \frac{\partial MB_e}{\partial \theta}$. □