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Product versus Process Innovation and the Global Engagement of Firms

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Abstract

Purpose – Although models of innovation and exporting dominate recent studies of relations between innovation and access to foreign markets, relations between innovation and foreign direct investment (FDI) are less explored. This is especially true of relations between types of innovation and FDI. We fill that gap in the literature with empirical evidence that clarifies whether firms enter foreign markets through exports or FDI.

Design/methodology – In order to assess the role of innovation in firms' international engagement strategies, we develop research hypotheses and present new empirical evidence on firms' choice of entry – exports and FDI – based on firm-level data.

Findings – Our empirical results suggest that the impact of product innovation is more significant in transition from being a purely domestic firm to an exporter, while process innovation more significantly affect transition from being an exporter to a multinational enterprise. Our results also support 'self-selection into FDI' rather than 'learning-by-performing FDI' in the relationship between innovation and firms' overseas expansion.

Originality/value – 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. We first analyze how product and process innovations influence firms' choices to initiate exports or FDI.

Keywords: Export Competition Between Korea and China, Export Similarity Index, Korea's Bilateral Exports, Market Sophistication

JEL Classifications: D12, F14, O53

1. Introduction

Innovation is a core business competence, and extensive research analyzes its role in firms' strategy. Most studies classify innovation as process innovation and product innovation. The former entails improving extant and inaugurating new processes. The latter entails improving extant products plus developing and commercializing new products (Zakic, *et al*., 2008). Innovation enhances firms' viability and growth in foreign and domestic markets, where globalization intensifies competition and consumer preferences change rapidly. Castellani and Zanfei (2007), Ito and Lechevalier (2010), Lileeva and Trefler (2010) and Damijan *et al.* (2010) documents this innovation-trade relationship.

Although models of innovation and exporting dominate recent studies of relations between innovation and access to foreign markets, relations between innovation and foreign direct investment (FDI) are less explored. This is especially true of relations between types of

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innovation and FDI. We fill that gap in the literature with empirical evidence that clarifies whether firms enter foreign markets through exports or FDI. We link our empirical results to hypotheses emerging from studies of process and product innovations and international trade with heterogeneous firms (Melitz-type models). We first analyze how product and process innovations influence firms' choices to initiate exports or FDI.

We hypothesize that process innovation influences incumbent exporters to initiate FDI, whereas product innovation is a means of switching from purely domestic production to exporting. We base our hypotheses on firms exploiting increasing returns to scale to innovate processes, but marginal costs of innovation expand with firm size. As sales of incumbent exporters exceed those of domestic producers, incumbents more likely undertake process innovation to initiate FDI.

When domestic producers initially want to export, they must accommodate their product quality to foreign consumers' preferences via product innovation. Having already done so, incumbent exporters find it more important to lower production cost via process innovation to initiate FDI, the next advance in operating abroad. Also, incumbent exporters cannibalize extant products to introduce new products abroad, which discourages product innovation. New entrants do not have that concern.

We test these hypotheses by linking different innovative activities to firms' decisions regarding exports and FDI using data for Korean firms spanning 2006–2012. We employ a random probit model as our baseline and an average treatment effects model to check robustness. Our empirical results support our hypotheses that process innovation influences incumbent exporters' propensity to become multinationals (MNEs), whereas product innovation is more associated with purely domestic firms' decision to export.

The paper proceeds as follows. Section 2 reviews previous studies of firm properties and modes of innovation and proposes hypotheses for empirical testing. Section 3 describes empirical specifications and data. Section 4 reports results from the main regression and robustness check. Section 5 concludes.

2. Literature Review and Hypothesis Formulation

2.1. Firm Size and Mode of Innovation

Previous studies relate firm size to mode of innovation. They indicate larger firms have comparative advantage in process innovation and smaller firms have it in product innovation, although larger firms have absolute advantage in both. Accordingly, studies find a complementary relation between firm size and undertaking process innovation.[1]

Their findings primarily derive from increasing returns to scale in production. Since process innovation is said to reduce marginal production costs, it must be considered it in production cost (Bustos, 2009; Caldera, 2010). That is, the more sweeping process innovation is, the lower is production cost. Since firms with larger sales and/or markets earn greater payoffs by reducing production costs, declining marginal costs from process innovation will benefit them more (Cohen and Klepper, 1996; Plehn-Dujowich, 2009).

Similarly, because highly productive and efficient firms sell more and are large (Melitz, 2003), the same result obtains when considering benefits from process innovation and firm output (Cohen and Klepper, 1996), market share (Scherer, 1983), market size (Guerzoni,

[1] See Link (1982), Mansfield(1981), Scherer (1991), Yin and Zuschovitch (1998), Baldwin and Sabourin (1999), Kaufmann and Tödtling (1999), and Tang (2006).

2010), number of goods produced (Petsas and Giannikos, 2005), labor productivity (Baldwin and Gu, 2004), and efficiency (Plehn-Dujowich, 2009).

In contrast, previous studies of innovation mode show that small firms are more likely to undertake product innovation, especially when entering new markets.[2] They find that production innovation induces increased marginal cost at accelerating rates (Gerschenkron, 1962; Maddison, 1987; Lee and Kang, 2007). Firms with lesser level of product innovation incur lower marginal costs from upgrading product quality because they more easily imitate firms operating at higher levels. However, firms undertaking substantial quality upgrades should create a new type of quality and thus incur higher marginal cost from product innovation. In general, large firms produce high-quality goods and small firms lower-quality products (Hallak and Sivadasan, 2009). Thus, large firms with high product quality encounter higher costs for upgrading product quality, inducing diminishing returns to scale from product innovation. The opposite is so for small firms with lesser-quality products.[3] Gerschenkron (1962) calls this "the advantage of backwardness" and Maddison (1987) a "catching-up bonus."[4]

2.2. Market Competition, Firm Evolution, and Mode of Innovation

Previous studies claim that firms respond to intense competition with innovation determined by a product lifecycle. Firms with products in early stages of the product lifecycle favor product innovation to counter competition. Firms with products in the mature stage of the product lifecycle address intense competition through process innovation.[5]

Birth of a new industry generates uncertainty about consumer preferences and product standards. Start-up companies hope to forestall competition by innovating a distinct product (product differentiation) (Weiss, 2003). Many firms offering variants of the product enter the market, investing in product development (Abernathy and Utterback, 1978) or seeking a market niche (Guerzoni, 2010).

Eventually customers refine their preferences. A dominant product emerges, and returns on product innovation fade (Abernathy and Utterback, 1978). At that point competitive companies refocus product development, investing more in manufacturing efficiencies (Utterback and Abernathy, 1975; Link, 1982). Investing in capital-intensive production methods taxes precedence over developing new products (Abernathy and Utterback, 1978).

This process in industry-level revolution applies at firm level. An incumbent can bring new products to foreign markets by cannibalizing extant products, whereas new entrants cannot. Incumbents are reluctant to innovate new products after entering a market successfully, whereas entrants offer new products in response to competition (Igami, 2017).[6]

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[2] See Scherer (1991), Cohen and Klepper (1996), Yin and Zuschovitch (1998), Baldwin and Sabourin (1999), Petsas and Giannikos (2005), Plehn-Dujowich (2009), and Igami (2017).

[3] In some cases, there may be IRS in undertaking product innovation because innovation development is a sunk cost. We defer that prospect for future studies. However, Igami (2017) show that large firms have less incentive for product innovation despite cost advantages, due to cannibalization.

[4] A narrow conception of product innovation suggests small firms create new products through knowledge spillovers, not innovation. A broader conception argues these new products are not the same as a dominant product. Although firms consult the dominant product to develop their own and cut innovation costs, they invest and have heterogeneous product properties. This is more prominent in monopolistically competitive markets.

[5] See Scherer (1983), Klepper (1996), Weiss (2003), Tang (2006), and Bos and Sanders (2013).

[6] Our theoretical framework in the Appendix supports our arguments in Sections 2.1 and 2.2. and connects firm properties to modes of innovation. Our framework extends Plehn-Dujowich (2009) to heterogeneous firms under monopolistic competition.

2.3. Exports and Mode of Innovation

Previous studies combine firm size and market competition as influences over mode of innovation to suggest why domestic firms invest in product innovation to become exporters.[7] One strand of literature argues that potential exporters have lower productivity (Melitz, 2003) and product quality (Hallak and Sivadasan, 2009). They look like startups to foreign markets, so they innovate products, securing diminishing returns to scale from product innovation and increasing returns to scale from process innovation. This is a supply-driven explanation for the affirmative relation between new exports and product innovation.

Another strand of literature insists firms must introduce a distinct product to make inroads in foreign markets and attract foreign consumers. This is specially so for firms in developing economies and/or small firms. Thus, innovation inclines toward creating variety. This is a demand-driven explanation for the affirmative relation between new exports and product innovation (Becker and Egger, 2013).[8] In contrast, cannibalization makes incumbent exporters reluctant to innovate products for foreign markets (Igami, 2017).

Empirical studies show that product innovation is relatively more important in raising propensity to export among small non-exporters.[9] By that logic, Southern producers export goods of higher quality than they sell at home to attract high-income Northern consumers. That logic is expressed in a model featuring heterogeneous plants and quality differentiation (Verhoogen, 2008; Alvarez and Robertson, 2004).

In sum, previous studies of mode of innovation label product innovation relatively more important in raising propensity to export (extensive margin of exports), but it does not increase subsequent export intensity, which is conditional on entering export markets (intensive margin of exports). This phenomenon seems closely tied to the relation between firm evolution and mode of innovation: to advance into foreign markets, new exporters (or incumbent exporters) should occupy early stages (or mature stages) of their evolution. Lileeva and Trefler (2010) find that Canadian firms undertake more product innovation to become exporters.[10] Damijan *et al.* (2010) show that incumbent exporters improve efficiency by stimulating process innovation.

2.4. Firm Characteristics and Global Engagement

Aside from mode of innovation, we draw upon studies of firm characteristics and global engagement for our research hypotheses. Melitz (2003) built the first theoretical model to consider firm heterogeneity in international trade. He shows that highly productive firms serve domestic and foreign markets (exporters), intermediately productive firms serve only domestic markets (purely domestic firms), and Firms with low productivity exit markets in open economies. If a country liberalizes economically, exporters have more chance to export and profit, whereas domestic firms more likely exit because of competition from foreign firms. In this respect, Melitz (2003) assures intra-sectoral redistribution of firms in response to trade liberalization.

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[7] See Lileeva and Trefler (2010), Damijan *et al.* (2010), and Becker and Egger (2013).

[8] For demand-side effects of product innovation in international trade, see 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).

[9] See Bratti and Felice (2009), Cassiman *et al.* (2010), and Caldera (2010).

[10] Refer also to Becker and Egger (2013), Belderbos et al. (2009), Cassiman et al. (2010), Caldera (2010), Ganotakis and Love (2011), Bocquent and Musso (2011), Higon and Driffield (2011), and Van Beveren and Vandenbussche (2013).

Helpman *et al.* (2004) present Melitz's (2003) argument in a model expanded to include FDI as an aspect of global engagement. They show that highly productive firms initiate FDI, whereas upper middle productive firms export. This ordering comes about because fixed costs of FDI are higher. In contrast, lower middle productive firms serve only domestic markets, and firms with low productivity exit.

Scholars must consider product quality and productivity as elements of firm heterogeneity when analyzing product and process innovations for overseas expansion. We can predict whether firms might become MNEs or exporters to profit by upgrading product quality and/or reducing marginal production cost. Hallak and Sivadasan (2009) expand Melitz's (2003) model to two heterogeneities. First, they define productivity as ability to produce a variety of goods at lower variable costs. Second, product quality represents such characteristics as design, shape, and color. Hallak and Sivadasan (2009) believe that innate levels of productivity and product quality exogenously determine a firm's original position concerning whether to exit markets, serve only a domestic market, to serve both by exporting. Consequently, they recapitulate Melitz (2003) and show that highly productive firms and/or firms with high-quality products become exporters and serve both domestic and foreign markets, whereas intermediately productive firms and/or firms with mediocre-quality products serve only a domestic market. Firms with low productivity and/or product quality exit.

2.5. Contribution and Hypotheses

In this paper, we address the question of how 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 present new theoretical and empirical evidences on firms' choices of entry mode – exports and FDI – from strategies for both types of innovation. To our knowledge, this is the first attempt to analyze the different roles of product and process innovations on firms' choices between exports and FDI.

Combining the arguments of Hallak and Sivadasan (2009) with those of Helpman *et al.* (2004), we add another type of global engagement to a firm's original position in an international trade model featuring two firm heterogeneities—that is, serving both markets by initiating FDI. Fig. 1 depicts relations between heterogeneities of productivity (θ) and product quality (λ)[11]. There, $\bar{\theta}_D$ and $\bar{\lambda}_D$ are thresholds of productivity and product quality, respectively, for serving a domestic market. $\bar{\theta}_X$ and $\bar{\lambda}_X$ are thresholds of productivity and product quality, respectively, for exporting. $\bar{\theta}_I$ and $\bar{\lambda}_I$ are thresholds of productivity and product quality, respectively, for initiating FDI. Firms displaying productivity $\theta < \bar{\theta}_D$ or product quality $\lambda < \bar{\lambda}_D$ will decide not to produce and exit the market, whereas firms with $\theta \geq \bar{\theta}_D$ or $\lambda \geq \bar{\lambda}_D$ will operate. Among survivors, firms with $\bar{\theta}_D \leq \theta < \bar{\theta}_X$ or $\bar{\lambda}_D \leq \lambda < \bar{\lambda}_X$ will serve only a domestic market, and firms with $\theta \geq \bar{\theta}_X$ or $\lambda \geq \bar{\lambda}_X$ will expand abroad. Firms displaying $\bar{\theta}_X \leq \theta < \bar{\theta}_I$ or $\bar{\lambda}_X \leq \lambda < \bar{\lambda}_I$ will export. Firms with $\theta \geq \bar{\theta}_I$ or $\lambda \geq \bar{\lambda}_I$ initiate FDI for inroads overseas.

Fig. 1 ordinates three cut-off levels for firm heterogeneity to confirm relations between productivity or product quality and self-selection into markets. Firms with low productivity and/or product quality exit. Firms with low-middle productivity and/or product quality operate only domestically. Firms with high-middle productivity and/or intermediate-quality products export. Firms with high productivity or product quality initiate FDI.[12]

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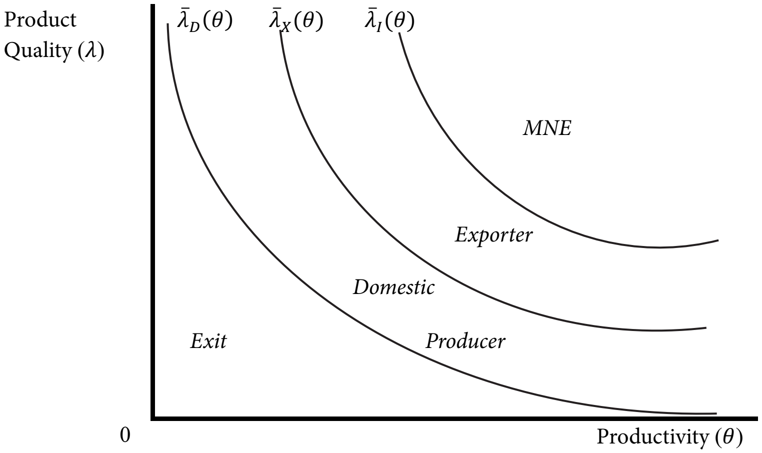
[11] Fig. 1 adds FDI to the original features in Hallak and Sivadasan (2009).

[12] Our firm-level dataset also illustrates this theoretical feature, as represented in detail in Fig. 2.

Fig. 1. Profit and Three Cut-off Levels of Firm Heterogeneity



Source: We add FDI to the original feature in Hallak and Sivadasan (2009).

Helpman *et al.* (2004) show that the highest profits at each level of productivity differ with mode of foreign entry. The most productive firms earn the greatest profit by turning MNE, whereas firms with intermediate productivity by starting exports. Higher profit is feasible if innovation can improve productivity or product quality and the firm can switch status. This rationale incentivizes purely domestic firms to export and exporters to become MNEs. Studies show that causality apparently stems from successfully entering foreign markets after innovating in anticipation of expanding overseas.[13] Processes of internationalizing based on a growing market commitment accord with the Uppsala model described by Johanson and Vahlne (2009).

Given a firm's place among the cut-offs for heterogeneity and the complement between size and process innovation in Section 2.1, we identify two properties of innovation mode and the decision to export or initiate FDI. First, as sales of incumbent exporters surpass those of domestic producers (Melitz, 2003; Helpman *et al.*, 2004), the former, enjoying increasing returns to scale more likely undertakes process innovation to turn MNE. Firms seeking to upgrade quality should create a new type of quality and endure the higher marginal cost of innovation. Since incumbent exporters produce higher-quality products than domestic producers (Hallak and Sivadasan, 2009), they are less inclined toward product innovation to become MNEs. Per Section 2.3, domestic producers are more (or less) likely to become exporters by innovating products (or processes) given decreasing (or increasing) returns to scale.

Second, the stage of evolution (Section 2.2) and standing in productivity and product quality (Fig. 1) encourage domestic firms to accommodate foreign preferences for quality through product innovation as new exporters. Having entered successfully and accommodated foreign preferences, firms do not prioritize changes in product quality. Instead, they cut

[13] For firms that self-select internationalization, see Melitz (2003), Schott (2004), Hallak (2006), Crozet, Head, and Mayer (2009), Hallak and Schott (2011), Baldwin and Ito (2011), Fajgelaum, Grossman and Helpman (2011), and Feenstra and Romalis (2012) for exports. See Helpman et al. (2004) for FDI. Some authors criticized arguments for self-selection by introducing causality from exports to growth—i.e., learning-by-exporting (Cassiman and Golovko, 2011; Gomes *et al.*, 2018).

production costs as an incumbent's strategy in a foreign market. That is, competition shifts to innovations in process efficiency. Incumbent exporters must significantly reduce variable production costs to overcome high fixed costs of overseas production facilities (Helpman *et al.*, 2004; Fasil, 2009). Accordingly, process innovation should tie closely to propensity to initiate FDI.

We propose two hypotheses about mode of innovation and decisions to export and initiate FDI:

Hypothesis 1. *Product innovation is important for purely domestic firms to become exporters (extensive margin of exports).*

Hypothesis 2. *Process innovation is important for exporters to turn MNE (the extensive margin of FDI).*

Our second hypothesis accords with empirical results in Damijan *et al.* (2010), ensuring that firms raise efficiency by stimulating process innovation once they begin exporting.[14] Although Damijan *et al.* (2010) did not consider FDI directly as a global engagement option, we predict exporters will self-select FDI after improving efficiency via process innovation.

3. Empirical Specification

3.1. Main Empirical Model

Following is our empirical strategy to test Hypothesis 1 and 2. Firms will export if profits exceed those from another mode of entry. This similarly applies to initiating FDI (Helpman *et al.* 2004). These conditions can be formalized in a binary choice model of internationalization strategies. We separately model binary decisions to export and initiate FDI. Given incidental parameters and inconsistent estimates of fixed effects[15], we adopt a random effects probit model. Index models to analyze export and FDI decisions can be specified respectively as:

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

$$FDI_{ikt} = \begin{cases} 1\ if\ \beta_1 Product\_Innov_{ikt-1} + \beta_2 Process\_Innov_{ikt-1} + \beta_3 Z_{ikt-1} + \gamma_k + \delta_t + \epsilon_{it} > 0 \\ 0\ otherwise \end{cases} \quad (2)$$

where *i, k,* and *t* respectively represent index firms, industry, and time.

EXP is a dummy that takes 1 if a non-exporting domestic firm in year *t-1* starts exporting in year *t* and 0 otherwise. *FDI* takes 1 if an exporter in year *t-1* initiates FDI in year *t* and 0 otherwise. *Product_Innov* denotes intensity of patent citations. It is a dummy that takes 1 if the firm invested in product innovation and 0 otherwise. *Process_Innov* is a dummy that takes 1 if the firm invested in process innovation and 0 otherwise. *Z* denotes other firm charac-

[14] These studies find that product innovation does not increase subsequent export intensity (intensive margin of exports): Becker and Egger (2013), Belderbos *et al.* (2009), Cassiman *et al.* (2010), Caldera (2010), Ganotakis and Love (2011), Bocquent and Musso (2011), Higon and Driffield (2011), Van Beveren and Vandenbussche (2013).

[15] As there cannot be found sufficient statistics allowing the fixed effects to be conditional out of the likelihood, fixed effects cannot be used for probit model for panel data. Also, estimates of unconditional fixed effects model can be biased.

teristics that can influence export or FDI decisions. We consider firm size, total factor productivity (TFP), and foreign ownership. γ_k and δ_t respectively represent industry and year dummies. ϵ_{it} is an error term.

To estimate how innovation influences initial decisions to export or initiate FDI and to control for potential simultaneity, we eliminated firms that had exported or initiated FDI or culled data only for domestic firms and exporters at time *t-1*:[16]

$$\text{Prob}(EXP_t = 1|Domestic_{t-1} = 1) = \text{f}(Innov_{t-1}) \quad (3)$$

$$\text{Prob}(FDI_t = 1|EXP_{t-1} = 1) = \text{f}(Innov_{t-1}) \quad (4)$$

Equations (3) and (4) define our two-equation probit model. The first equation in the baseline model specifies the probability that domestic firm *i* turns exporter:

$$EXP_{ikt} = \beta_0 + \beta_1 \ln Size_{ikt-1} + \beta_2 \ln TFP_{ikt-1} + \beta_3 Foreign_{ownership_{ikt-1}} + \beta_4 Product\_Innovation_{ikt-1} + \beta_5 Process\_Innovation_{ikt-1} + \gamma_k + \delta_t + \varepsilon_{ikt} \quad (5)$$

The second equation specifies effects of the same group of explanatory variables on the probability a former exporter initiates FDI:

$$FDI_{ikt} = \beta_0 + \beta_1 \ln Size_{ikt-1} + \beta_2 \ln TFP_{ikt-1} + \beta_3 Foreign_{ownership_{ikt-1}} + \beta_4 Product_{Innovation_{ikt-1}} + \beta_5 Process\_Innovation_{ikt-1} + \gamma_k + \delta_t + \varepsilon_{ikt} \quad (6)$$

3.2. Robustness Check

We employ average treatment effects as a robustness check. Although we sample only domestic firms and exporters, endogeneity may persist given difficulty finding appropriate instrumental variables among firm-level data. Most studies support “self-selection into exporting” rather than “learning-by-exporting (LBE),” (Bernard *et al.*, 2011; Bravo-Ortega*, et al.* 2014). Others find that reverse causality between innovation and global activities supports LBE (Van Biesebroeck, 2005; Li, *et. al.*, 2016; Salomon and Shaver, 2005).

To resolve potential endogeneity and confirm empirical results for the impact of innovation on exporting and FDI using probit estimation, we combined propensity score matching (PSM) with average treatment effects. Doing so addressed potential endogeneity absent appropriate instrumental variables (Damijan *et al.*, 2010). We first identified the probability firms will innovate products or processes, which yields a propensity score. Second, we matched innovators and non-innovators and estimated average treatment effects of lagged innovation on exporting. We replicated that procedure to test average treatment effects of previous innovation on FDI.

[16] This restriction is consistent with our hypotheses, which considers only extensive margins of export and FDI. We exclude cases wherein domestic firms initiate FDI without exporting experience, based on logic underlying our hypotheses. MNEs generally begin by exporting to new markets rather than by switching directly from domestic operations to FDI. Nicholas et al. (1994) support this claim, suggesting 69% of sampled firms exported to Australia before FDI. Only 0.8% of our sampled firms initiated FDI as domestic firms and 2.6% of firms conducted FDI before choosing to export.

3.3. Data

We used annual firm-level data spanning 2006–2012 from The Survey on Business Activity by the National Statistical Office (NSO) of Korea. NSO annually surveys Korean enterprises with financial capital exceeding US$300,000 and at least 30 employees. The dataset captures 90% of total sales and 70% of value added in Korea's manufacturing sector. The survey encompasses financial statements, organizational structure, global engagement such as exports and FDI, and innovation-related activities. Initially, it included over 10,000 firms per year. Purging data with unlikely values[17] and measurement errors yielded an unbalanced panel dataset of 8,653 manufacturers and 40,040 observations spanning 2006–2012.

The binary indicator for export or FDI is our dependent variable (Table 1). It measures extensive margins of entry mode on innovative activities.

Table 1. Definition of Key Variables

Variables	Definition
Process Innovation	
ERP(Enterprise Resource	A dummy variable that takes a value of 1 if the firm reports the
Product Innovation	
Patent citation intensity	Number of citation of patents by its own development per labor
Patent citation dummy	A dummy variable that takes the value of 1 when the firm
Other Control Variables	
Size	Natural log of the number of employees
Productivity	Natural log of total factor productivity

Note: While there is possibility that patent citation may not necessarily mean new innovation, an increase (or switch from zero to one in dummy variable) in the number of citation controlled by firm size can largely reflect firms' growing effort adopt innovation.

Measurement of Innovation

The NSO survey asks firms to report innovation. Two indicators measure product innovation: a binary indicator of patents cited and citations per employee. To relate invention to product innovation, we followed Pavitt (1984) in only patents that firms had developed.

To measure process innovation, we used information indicating firms introduced Enterprise Resource Planning (ERP) to their e-business. The NSO survey defines e-business as network-based transfer and exchange of goods, services, information, and knowledge. It excludes simple accounting and human resource software. ERP integrates operational facets, including development, manufacturing, sales, and marketing. It includes modules for product planning, purchasing material, inventory control, distribution, accounting, marketing, finance and human resources. Since facilitating efficient processes is ERP's purpose and advantage, its introduction ties to process innovation. A firm-wide database generated and updated by ERP, for example, gives every employee real-time data, rendering data-mining obsolete and letting them be more innovative and flexible (Davenport 1998, Engelstatter, 2012). Thus, ERP[18] might add knowledge capabilities to process innovation (Srivardhana and Pawlowski, 2007).

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[17] For example, 0 for number of employee is unlikely value for any firm.

[18] Firms using ERP enjoy greater labor productivity than firms that do not (Engelstatter et al., 2008). Firms adopting ERP exhibit significantly higher differential performance than a control group in their second year after adoption (Nicolaou et al., 2003). Matolcsy et al. (2005) show sustained operational efficiencies, improved liquidity, and increased profitability two years after adopting ERP.

Other Variables

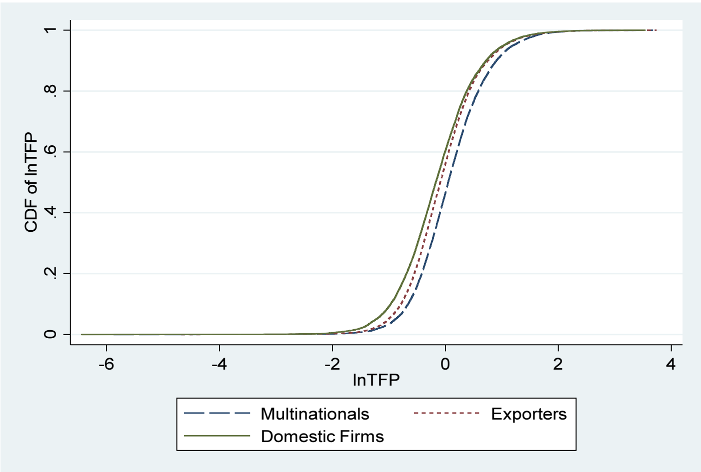
We used firm characteristics from financial statements in the NSO dataset. We constructed controls for number of employees, fixed capital assets, sales, and foreign ownership. Number of employees proxies firm size. It can affect global engagement because larger firms have more resources (e.g., liquid funds, collateral) with which to bear additional fixed costs of entering foreign markets (Wakelin, 1998; Oberhofer and Pfaffermayr, 2012).

TFP is a residual from regressing real output on labor input, real intermediate input, and real capital. We constructed it from the natural log of real total sales (proxy for real output), the log for number of employees (labor inputs), and real tangible assets (fixed capital assets). Intermediate inputs are the sum of sales costs, operating costs, net wages, depreciation, and purchased materials. Fixed capital assets include values of buildings, machinery, and vehicles. We deflated total sales and nominal intermediate inputs by output and intermediate input following two-digit industry-level Korea Standard Industrial Classification in the 2013 Korea Industrial Productivity (KIP) Database. We deflated fixed assets using capital asset formation in NSO data and KIP 2013. One can raise the problem of potential negative correlation between capital stock and probability of exit given TFP measured as residual from OLS estimates, as a firm with a larger capital stock vis-à-vis smaller capital stock is more likely to stay in the market despite the low productivity. To address this issue, value added per labor is employed to alternate TFP as robustness check.

3.4. Features of Firm Heterogeneity

Section 2.3 documents productivity differences across internationalization strategies in recent literature concerning heterogeneous trade models (Melitz, 2003; Helpman *et al*., 2004). Helpman *et al*. (2004) suggest that only the most productive firms can bear higher fixed costs of investing abroad and initiate FDI, whereas less-productive firms export, and least-productive firms operate only domestically. This feature of productivity endorses the logic underlying our hypotheses, and data in Fig. 2 confirm this argument. Graphed cumulative

Fig. 2. Productivity and Firms' Mode of Entry: Cumulative Distribution of Total Factor Productivity



Notes: Kolmogorov-Smirnov test shows that difference in cumulative distribution between domestic firms and exporters is 0.112 and between exporters and multinationals is 0.098 respectively.

distribution functions of productivity as a natural log of TFP situate exporters' TFP to the right of domestic firms and the distribution of MNEs to the right of exporters. This exhibit supports the productivity-centered order of entry suggested in our theory.

Table 2 Panel A compares basic characteristics of product innovators and non-product innovators. Panel B compares those of process innovators and non-process innovators grouped by mode of entry. Both show that MNEs that adopted innovation are largest, and exporters that adopted innovation are larger than domestic firms irrespective of type of innovation. In regard to TFP, process-innovating multinationals are most productive, exporters are less productive, and domestic firms are least productive. Our theoretical model and Helpman et al. (2004) predict that ordering. Within each grouping by entry mode, firms that invested in process innovation are on average more productive than non-innovators. This finding aligns with discussions in Section 2.1 that suggest complementary relation between productivity and process innovation.

However, rankings of product innovation reverse among MNEs. Non-innovators are more productive than innovators. No difference in productivity appears between innovators and non-innovators among exporters and domestic firms. This finding suggests the relation between productivity and product innovation is opaque. Table 3 reports summary statistics for variables in the regression.

Table 2. Firm Characteristics of Each Group of Firms

	Domestic Firms		Exporters		Multinationals	
Panel A.	**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	-0.15	-0.15	-0.06	-0.06	-0.01	0.15
Number of Observations	2293	5353	689	869	640	396
	Domestic Firms		**Exporters**		**Multinationals**	
Panel B.	**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	-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 previous years. Productivity is measured as natural log of total factor productivity.

Sources: NSO and authors' calculations.

Table 3. Summary Statistics

Variable	Observation	Mean	Std. Dev.	Min	Max
Employee (number)	40,040	276.97	1734.631	31	101973
Sales (million KRW)	40,040	184680.9	1829796	28	1.41E+08
Productivity (Natural log of total factor productivity)	40,022	-0.03	0.67	-6.44	3.67
Patent citation intensity	40,040	0.05	0.17	0	7.37
Patent citation dummy	40,040	0.52	0.50	0	1
ERP dummy	40,040	0.59	0.49	0	1

Notes: Patent citation intensity is the number of citation of patents developed by the firm itself per labor. ERP=enterprise resource planning.

4. Empirical Results

4.1. Baseline Model

Table 4 reports the effects of switching to exporting or FDI from baseline specification models in Equations (5) and (6). Columns (1) through (4) present two different variables for product innovation: Columns (1) and (2) patent invention intensity and Columns (3) and (4) patent citations.

Columns (1) and (3) present estimation results for the extensive margin of exports from the baseline model in Equation (5). Controlling for number of employees as a measure of firm size and TFP as a measure of firm productivity, purely domestic firms with higher intensity of patent citations or a patent dummy in t-1 more likely will have exported during the preceding year than firms with less intense product innovation. However, the coefficient of the ERP dummy is statistically insignificant for the extensive margin of exports. These results imply that only product innovation significantly affects it.

Columns (2) and (4) show that among exporters firms exhibiting greater patent intensity or patents cited the previous year had greater tendency to serve foreign markets via FDI the following year. This finding implies that product innovation significantly raises the probability of firms serving foreign markets via FDI.

Similarly, exporters undertaking process innovation via ERP are significantly more likely to become MNEs in year *t* than firms that did not undertake process innovation in year *t-1*. Hence, both types of innovation enhance the extensive margin of FDI. Note that coefficients of the ERP dummy become statistically significant in Columns (2) and (4) and remain statistically insignificant in Columns (1) and (3). In addition, coefficients for the ERP dummy exceed those for patent invention intensity in Column (2) (0.174*** > 0.029***).

These results suggest product innovation enhances exporting and FDI. Process innovation also exhibits a consistent positive impact on FDI, but its effect is not statistically significant for exporting. Thus, we confirm that process innovation becomes important in exporters' decision to switch mode of entry from exporting to FDI, supporting Hypothesis 2.

However, the relative effects of production innovation seem ambiguous for exporting and FDI in Table 4. The ambiguity likely stems from endogeneity attributable to reverse causality between innovation and firms' global strategies. A robustness check resolves this issue in the next section.

Among control variables, effects of firm size on exporting and FDI are positive and statistically significant at 1%. Productivity relates positively to both modes of entering foreign markets. This result accords with our theoretical model and previous literature (Melitz, 2003; Helpman *et al.*, 2004).

Table 4. Baseline Model

VARIABLES	(1) Export	(2) FDI	(3) Export	(4) FDI
Size	0.279***	0.274***	0.273***	0.262***
	(0.0413)	(0.0645)	(0.041)	(0.064)
Productivity	0.152***	0.136**	0.146***	0.116*
	(0.034)	(0.062)	(0.034)	(0.061)
Product Innovation				
Patent invention intensity	0.021***	0.028***		
	(0.003)	(0.006)		
Patent citation dummy			0.279***	0.371***
			(0.047)	(0.091)
Process Innovation				
ERP dummy	0.062	0.174**	0.063	0.181**
	(0.045)	(0.087)	(0.045)	(0.087)
Year Fixed Effect	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes
Rho	0.371	0.484	0.372	0.484
Log Likelihood	-3938.55	-1375.34	-3940.61	-1376.97
Observations	9,528	7,538	9,528	7,528
Number of Firms	3,528	2,986	3,528	2,983

Notes: Random effect probit models are estimated. Standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$ 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.

4.2. Robustness Check

To address potential negative effect of capital stock and probability of exit when TFP is used, we use value added per labor as an alternative measure of productivity. The results are reported in Table A1. The results are largely consistent with those of baseline model in Table 4, though the level of statistical significance of the coefficient for process innovation in FDI decision is 10%.

To control for endogeneity in the baseline model we employed average treatment effects as additional robustness checks. Table 5 reports estimates and standard errors for average treatment of lagged innovation on current exporting or FDI based on PSM. We compared estimates of three types of matching: one-to-one, nearest neighbor, and local linear regression. We estimated standard errors by bootstrapping with 100 repetitions. Table A2 reports probit estimations from PSM, showing that large firms more likely pursue both product and process innovation. For exporting as an outcome of PSM, productivity measured as TFP is either not significant or negative, whereas it is significant and positive for MNEs. Balancing tests in Table A3 validate all specifications for covariates: bias < 5% and t-test not significant for all covariates.

Table 5 shows that matching confirms the link between lagged innovation and probability of exporting in the current year, which vary with the nature of innovation. Lagged product innovation variables exhibit significantly positive impacts on current propensity to export. Process innovation, which correlates positively with exporting, is statistically insignificant in nearest neighbor and local linear regression matching, and significant only at 10% in one-to-one matching. Even in one-to-one matching, the coefficient of product innovation exceeds that of process innovation (0.053***>0.014*), supporting Hypothesis 1.

Process innovators and product innovators are more likely to initiate FDI. Lagged process innovation becomes statistically significant and exhibits a positive impact on the probability firms enter foreign markets through FDI, but it is statistically insignificant for exporting, supporting Hypothesis 2.

Thus, robustness checks confirm our baseline model tests. They support our hypotheses that the positive effect of process innovation presides more for FDI, whereas product innovation presides relatively more for exporting.

Table 5. 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.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

5. Conclusion

Using Korean panel data spanning 2006–2012, we have investigated how product and process innovation influence firms' decision to internationalize by exporting and by FDI. After reviewing the literature, including a Melitz-type model of firm heterogeneity, we hypothesized that process innovation inclines incumbent exporters toward FDI, and product innovation influences purely domestic firms' preference for exporting. Empirical tests support our prediction. Process innovation positively influences incumbent exporters' decision to invest abroad. Purely domestic firms emphasize product innovation to become exporters. No significant and positive association between process innovation and exporting is clear in the data.

Domestic firms should accommodate foreign consumer's preferences for product quality when first entering foreign markets as exporters. Thus, product innovation is more important in raising a firm's propensity to export in its globalization strategies. Once a firm enters a foreign market, successfully accommodates consumer preferences, and become an incumbent exporter, cutting production costs becomes a more important market strategy.

This research provides empirical evidence that governmental R&D policy should focus on different types of innovations, depending on different types of firms' global engagement. That is, our results support self-selection into FDI rather than learning-by-initiating FDI in the relation between innovation and overseas expansion. Korea's global strategy[19] of emphasizing rapid growth in previous decades may bear implications for emerging markets pursuing development through openness.

Our paper has some limitations in the way that some important determinants of FDI in destination countries are excluded. For example, labor cost, import tariff, and demand level in host countries as well as innovations might jointly affect FDI. However, unfortunately our dataset does not contain information on destination countries. Also, it is possible that two types of innovation can be related each other and jointly affect FDI (Tang 2006; Weiss 2003). We do not consider it in the paper because 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. We leave these issues for future studies.

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[19] Decades of rapid growth seemingly yield no consensus about Korea's stage of development. Korea formerly was classified as a developing country by the United Nations and as an emerging market by Morgan Stanley Capital International and Colombia University in 2012, which largely matches our span of study (2006–2012). Korea is a developed economy within the World Trade Organization.

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Appendix A.

A1. Theoretical Framework for relating Firm Heterogeneity and Mode of Innovation

We develop the following supplementary theoretical framework to support qualitative arguments in Section 2.1 and 2.2. It expands Plehn-Dujowich's (2009) model to heterogeneous firms under monopolistic competition. We assume a country has homogeneous consumers and heterogeneous firms. Two firm heterogeneities are exogenously given. First, firm productivity is defined as ability to produce a variety of goods with lower variable costs. Second, product quality represents diverse product characteristics such as design, shape, and color. Product quality is represented as proximity to consumer preferences. Assumptions governing product quality and consumer preferences assure no *ex ante* correlation between firm productivity and its product quality.

The representative consumer has income M and CES preferences across a set of differentiated goods indexed by x,

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

where q is demand, λ is corresponding quality, e is product innovation, X is a set of all potentially available goods, $d > 1$ is a constant, and ρ is elasticity of substitution between any two goods with $0 < \rho < 1$. This specific form of utility function satisfies all conditions with respect to product quality and product innovation:

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

Its conditions assure that demand rises with product quality or product innovation but at a decreasing rate. Conditions also assure that firms with higher innate quality have no *ex ante* comparative advantage in product innovation, controlling for an *ex ante* bias between innate product quality and innovation strategy. From the consumer maximization problem, demand for x is derived as

$$q = p^{-\sigma}P^{\sigma-1}M(\lambda + d\ln e), \tag{2}$$

where $\sigma = \frac{1}{1-\rho} > 1$ and the aggregate price index, $P = \left[\int_{x\in X} (p(\lambda + d\ln e))^{1-\sigma}dx\right]^{\frac{1}{1-\sigma}}$.

Production occurs in a monopolistically competitive market with X firms. Marginal cost (MC) functions for process and product innovations are

$$MC = \frac{1}{\theta} - d\ln z + e^2, \tag{3}$$

where $\theta \geq 1$ is the firm's heterogeneous productivity and z denotes process innovation. This specific form of marginal function satisfies all conditions with respect to innate productivity and process innovation:

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

Its conditions ensure that production cost declines as firm productivity and process innovation rise, but at a decreasing rate. They also assure that highly productive firms have no *ex ante* comparative advantage in process innovation.

Also, the marginal function satisfies all conditions with respect to innate productivity and product innovation:

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

Its conditions assure that MCs increase alongside product innovation at an increasing rate and that highly productive firms have no *ex ante* comparative advantage in product innovation.

Finally, we assume the fixed cost function for process innovation is identical for all firms, considering z and e as respective fixed costs of process and product innovation for simplicity. Hence the corresponding total cost (TC) function is $TC = MCq + f + z + e$. Also, the marginal cost function is satisfied with $\frac{\partial^2 MC}{\partial z \partial e} = \frac{\partial^2 MC}{\partial e \partial z} = 0$, representing that both innovations are not related each other for simplicity.

Given the demand function in (2), the first-order condition (FOC) with respect to price in the profit maximization problem yields:

$$p = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\theta} - d \ln z + e^2\right), \tag{4}$$

where equilibrium price (p) depends on a firm's markup $(\frac{\sigma}{\sigma-1})$ and MC $(\frac{1}{\theta} - d \ln z + e^2)$. FOC with respect to process innovation (z) yields:

$$\frac{dp^{-\sigma}P^{\sigma-1}M(\lambda+d\ln e)}{z} = 1 \tag{5}$$

Substituting (4) into (5) obtains

$$\frac{d\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\theta}-d\ln z+e^2\right)\right)^{-\sigma} P^{\sigma-1}M(\lambda+d\ln e)}{z} = 1 \tag{6}$$

The left of Equation (6) represents the marginal benefits of process innovation (MB_z).

Based on these equations, we propose:

Proposition 1. *Highly productive firms and/or firms with higher product quality are more likely to undertake process innovation.*

Proof. The proof of Proposition 1 is that firms with higher productivity and/or high-quality products enjoy greater marginal benefits through process innovation:

$$\frac{\partial MB_z}{\partial \theta} = \frac{\frac{d\sigma^2 P^{\sigma-1}M(\lambda+d\ln e)}{\theta^2(\sigma-1)}\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\theta}-d\ln z+e^2\right)\right)^{-\sigma-1}}{z} = \frac{d}{z}\frac{\partial q}{\partial \theta} > 0$$

$$\text{and } \frac{\partial MB_z}{\partial \lambda} = \frac{d\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\theta}-d\ln z+e^2\right)\right)^{-\sigma} P^{\sigma-1}M}{z} = \frac{d}{z}\frac{\partial q}{\partial \lambda} > 0.$$

Proposition 1 originates with 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 enjoy payoff from cost reductions.

Proposition 1 addresses increasing returns to scale of process innovation and considers firm productivity and product quality as determinants of firm size. In our firm-level dataset, Table 2 empirically supports this feature of relation between a heterogeneous firm characteristics and process innovation.

Meanwhile, FOC with respect to product innovation (e) is

$$p^{-\sigma}P^{\sigma-1}M\frac{d}{e}\left(p-\frac{\tau}{\theta}+d\ln z-e^2\right)=2ep^{-\sigma}P^{\sigma-1}M(\lambda+d\ln e)+1. \quad (7)$$

Substituting (4) into (7) obtains

$$P^{\sigma-1}M\frac{d}{e}\frac{1}{\sigma}\left(\left(\frac{1}{\sigma-1}\right)\left(\frac{\tau}{\theta}-d\ln z+e^2\right)\right)^{1-\sigma}=2e\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau}{\theta}-d\ln z+e^2\right)\right)^{-\sigma}P^{\sigma-1}M(\lambda+d\ln e)+1 \quad (8)$$

The left of Equation (8) represents the marginal benefits of product innovation (MB_e), and the right represents its MCs (MC_e). Using these equations we raise Proposition 2:

Proposition 2. *Firms with low productivity and/or lesser product quality are more likely to undertake product innovation.*

Proof. The relation between product quality (λ) and product innovation (e) is derived from two facts. First, considering MB_e, we obtain $\frac{\partial MB_e}{\partial \lambda}=0$ as the equilibrium price. It consists of mark-up and MC and is unrelated to λ, implying innate product quality does not affect production cost in our original framework. Considering MC_e, we obtain $\frac{\partial MC_e}{\partial \lambda}=2e\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\theta}-d\ln z+e^2\right)\right)^{-\sigma}P^{\sigma-1}M=\frac{\partial MC}{\partial e}\frac{\partial q}{\partial \lambda}>0$ as $\frac{\partial q}{\partial \lambda}>0$ and $\frac{\partial MC}{\partial e}>0$, respectively.

In other words, if a firm with innately high product quality undertakes product innovation, its MC is relatively high because original demand or production for that product was greater. Hence product innovation entails diminishing returns to scale. As a result, firms with innately high product quality are less likely to undertake product innovation.

With regard to the relation between productivity (θ) and product innovation (e), we first obtain

$$\frac{\partial MB_e}{\partial \theta}=\frac{d}{e}\left(\left(\frac{1}{\sigma-1}\right)\left(\frac{1}{\theta}-d\ln z+e^2\right)\right)^{-\sigma}\frac{1}{\theta^2}P^{\sigma-1}M>0 \text{ as } \sigma>1$$

and $MC=\frac{1}{\theta}-d\ln z+e^2>0$.

The unpinning of this result is that $\frac{\partial MC}{\partial \theta}<0$ and thus $\frac{\partial p}{\partial \theta}<0$.

In other words, even though firms undertake identical product innovation, the firm with innately high productivity enjoys higher marginal benefits because it can charge less for a good of identical quality. Firms with innately high productivity reap greater benefit from product innovation.

We obtain $\frac{\partial MC_e}{\partial \theta} = 2e\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\theta} - d\ln z + e^2\right)\right)^{-\sigma-1}\left(\frac{\sigma^2}{\sigma-1}\right)\frac{1}{\theta^2}P^{\sigma-1}M(\lambda + d\ln e) = \frac{\partial MC}{\partial e}\frac{\partial q}{\partial \theta} > 0$ as $\frac{\partial MC}{\partial e} > 0$, $\frac{\partial p}{\partial \theta} < 0$ and thus $\frac{\partial q}{\partial \theta} > 0$, respectively. That is, firms with innately high productivity incur higher MC through product innovation because their output is greater. Like the effect of innate product quality on MC of product innovation (i.e., $\frac{\partial MC_e}{\partial \lambda}$), innately high productivity entails diminishing returns to scale.

Finally,

$$\frac{\partial MB_e}{\partial \theta} - \frac{\partial MC_e}{\partial \theta} = \frac{1}{\theta^2}P^{\sigma-1}M\frac{d}{e}\frac{\sigma}{\sigma-1}\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\theta} - d\ln z + e^2\right)\right)^{-\sigma-1}\left[\left(\frac{1}{\theta} - d\ln z + e^2\right) - \frac{2e^2\sigma}{d}(\lambda + d\ln e)\right].$$

Therefore, if $MC_l\left(= \frac{1}{\theta} - d\ln z + e^2\right)$ exceeds $\frac{2e^2\sigma}{d}(\lambda + d\ln e)$, then $\frac{\partial MB_e}{\partial \theta} > \frac{\partial MC_e}{\partial \theta}$. As innate firm productivity (θ) is greater, MC is lower and is more likely to exhibit $\frac{\partial MB_e}{\partial \theta} < \frac{\partial MC_e}{\partial \theta}$. Hence, high-productivity firms are less likely to undertake product innovation because its MC is more likely to exceed its marginal benefit.

Our theoretical result addresses that innately high product quality and/or productivity discourage product innovation.

A2. Additional Tables

Table A1. Results using value added per labor as productivity

	Export (1)	FDI (2)	Export (3)	FDI (4)
Size	0.238***	0.228***	0.233***	0.220***
	(0.042)	(0.062)	(0.042)	(0.062)
Value added per labor	0.171***	0.259***	0.167***	0.245***
	(0.035)	(0.066)	(0.035)	(0.065)
Product Innovation				
Patent invention intensity	0.020***	0.028***		
	(0.003)	(0.006)		
Patent citation dummy			0.273***	0.366***
			(0.047)	(0.090)
Process Innovation				
ERP dummy	0.063	0.160*	0.065	0.166*
	(0.045)	(0.085)	(0.045)	(0.085)
Year Fixed Effect	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes
Rho	0.373	0.469	0.374	0.471
Log Likelihood	-3938.6	-1368.8	-3940.5	-1370.7
Observations	9,526	7,522	9,526	7,522
Number of Firms	3,526	2,982	3,526	2,982

Notes: Random effect probit models are estimated. Standard errors are in parentheses. *** 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 A2. Probit Estimation Results of Propensity Score Matching Estimation in Table 5

VARIABLES	(1) Product Innovation	(2) Process Innovation	(3) Product Innovation	(4) Process Innovation
Size	0.245***	0.217***	0.417***	0.283***
	(.026)	(0.022)	(0.026)	(0.023)
Productivity	0.008	-0.180***	0.306***	0.184***
	(.020)	(0.023)	(0.02)	(0.024)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Log Likelihood	-5575.592	-4717.929	-6119.164	-4638.507
Pseudo R-squared	0.0724	0.0813	0.0696	0.0483
Observations	9,529	7,538	9,529	7,538

Notes: Column (1) and (2) report results on probit estimation when outcome of propensity score matching is exporting. Column (3) and (4) report results on probit estimation when outcome of propensity score matching is FDI. *** p<0.01, ** p<0.05, * p<0.1.

Table A3. Balancing Test from Propensity Score Matching Estimation in Table 5

Product Innovation-Exporting						
Variable	Treated Mean	Control Mean	%bias	t	p>t	V(T)/V(C)
Size	4.653	4.647	1.1	0.42	0.671	1.09*
Productivity	-0.146	-0.119	-4.1	-1.60	0.109	0.85*
Product Innovation-FDI						
Variable	Treated Mean	Control Mean	%bias	t	p>t	V(T)/V(C)
Size	4.916	4.903	1.8	0.80	0.424	1.14*
Productivity	-0.046	-0.052	0.9	0.43	0.665	0.81*
Process Innovation-Exporting						
Variable	Treated Mean	Control Mean	%bias	t	p>t	V(T)/V(C)
Size	4.674	4.669	1	0.44	0.663	0.92*
Productivity	-0.042	-0.039	-0.4	-0.19	0.846	0.94*
Process Innovation-FDI						
Variable	Treated Mean	Control Mean	%bias	t	p>t	V(T)/V(C)
Size	4.93	4.918	1.7	0.78	0.438	0.96
Productivity	0.036	0.064	-4.4	-2.1	0.036	0.87*