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Capacity Investment Under Responsive Pricing: Implications of Market Entry Choice*

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ABSTRACT

We consider a manufacturer's new market entry problem when it already has some established facility in its existing market. We consider two common market entry strategies: the export strategy and the foreign direct investment (FDI) strategy. In the export strategy the firm increases the capacity at its existing facility and subsequently allocates the output to the existing and the new market dynamically, depending on realized market conditions. The export strategy is a flexible strategy. In the FDI strategy, the firm invests in a dedicated capacity to serve the new market only. The FDI strategy is a (partially) dedicated strategy. We study these two strategies from a planning perspective, that is, how the firm's strategy choice influences the optimal capacity levels. We find that the firm's strategy choice can significantly impact the optimal capacity investment levels. We prove, for example, that the firm may enter the new market in the export strategy but not in the FDI strategy, even if the capacity investment cost is identical in the existing and the new market. In addition, we prove that the firm may invest a strictly higher capacity level in the export strategy than that in the FDI strategy. We also prove that new market entry in the FDI strategy may strictly decrease the firm's supply to its existing market but this is not so in the export strategy, and hence policy makers should carefully consider the implications of trade regulations on firms' market entry choices.
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INTRODUCTION

Consider a manufacturer's new market entry problem when it already has some established facility in its existing market. The product offered in the new market may require some minor customization but otherwise is similar to the product offered in the existing market. This is a quite common problem facing both established and emerging firms: should the firm serve customers in the new market by expanding its existing facility, or should it invest in a facility that can manufacture locally

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in the new market (Head & Ries, 2004, p. 409)? In the international economics literature, these two choices are often referred to as *export* and *horizontal foreign direct investment (FDI)*, where "horizontal FDI refers to an investment in a foreign production facility that is designed to serve customers in the foreign market" (Helpman, Melitz, & Yeaple, 2004, p. 300).

In this research we adopt the terms export and FDI in a broader sense, regardless of whether or not the new market is indeed a foreign market. From a flexibility point of view, because both the existing and the new markets are served by the existing (and potentially expanded) facility, the export strategy is a flexible strategy. In contrast, because it establishes a dedicated facility in the new market, the FDI strategy is a (partially) dedicated strategy. The FDI strategy is partially dedicated because the firm may still export a fraction of outputs from its existing facility to complement the FDI investment. Hereafter we use the terms export and FDI in this broader sense and hence they can also be interpreted as flexible and dedicated, respectively.

Research Perspective

We study the firm's new market entry problem primarily from a planning perspective. In other words, we are interested in the implications of the optimal capacity levels between the two strategies. Understanding how strategy choices influence the optimal capacity levels is important for operations managers because one can use such information for resource planning purposes (e.g., labor, land, inputs, regulatory conformance, and government incentives).

By understanding the firm's capacity investment problem from an operational and planning perspective, this article offers insights that are important to both practitioners and academicians. For many firms, capacity levels (e.g., market sizes) have been considered as one of the most important drivers beyond financial metrics. Higher capacity levels can be valuable to the firm for many different reasons including, for example, volume advantage (buying power), access to new markets, advertising scale, and access to regulatory reliefs (tax concessions). The Profit Impact of Market Strategy database developed by General Electric suggests that a larger market size brings the benefit of economies of scale, which often leads to higher profitability. Hence, understanding capacity levels in a firm's market entry strategy is no less important than understanding the expected earnings. An important insight we found in this article is that, under certain conditions, capacity investment via export strategy may lead to larger market sizes than that via FDI strategy. This insight is not only valuable for operations managers from a resource planning perspective, it is also important from a policy maker's perspective.

Government regulations (e.g., tariffs and subsidies) often influence a firm's market entry strategies. This article identifies situations when the export strategy strictly benefits the firm's existing market (higher supply and lower market price) compared to the FDI strategy. Policy makers should therefore consider this factor (among others) that may positively influence a firm's market entry strategy. Note that this article is not intended to be a decision support tool; rather, it attempts to identify important capacity implications of the firm's market entry strategies via stylized models. From a research point of view, we hope this article spurs further research in firm's market entry problem by considering more broad factors such as trade barriers, taxation, and price restrictions.

Relation to Relevant Literature

In both the export and the FDI strategies, the capacity decision is set before demand uncertainty is realized, but the firm uses responsive pricing to mitigate the potential mismatch between supply and demand. Hence, this article is closely related to the responsive pricing literature. In particular, Bish and Wang (2004) and Chod and Rudi (2005) study the value of flexible resources under responsive pricing for a given set of dedicated and flexible resources. However, they do not consider the choice of selecting flexible versus dedicated resources, and therefore the capacity consequences of such a strategic choice are not relevant in their research.

Our research is also closely related to the global facility network design literature, but with important differences. Kulkarni, Magazine, and Raturi (2004), Chakravarty (2005), and Lu and Van Mieghem (2009), for example, study the optimal configuration of facility networks under exogenous price and they do not consider the impact of the firm's existing facility in market entry choices. Kazaz, Dada, and Moskowitz (2005) consider responsive pricing but their focus is on the impact of exchange uncertainty on production and allocation hedging for a given facility network. Dong, Kouvelis, and Su (2010) study the optimal configuration of facility networks under responsive pricing. They derive boundary conditions under which a complete network or centralized network is optimal and they explore the impact of exchange rate versus demand uncertainty on the optimal structure of the facility networks. Because both the complete and centralized network configurations in Dong et al. (2010) are essentially flexible strategies, they do not explore the market entry choice between flexible and dedicated strategies when the firm already has an existing facility.

In this article, we find that the optimal capacity investment levels are significantly impacted by the firm's strategy choice. We prove, for example, that under certain conditions the firm will expand into the new market under the export strategy only, even if the capacity investment cost in both markets is identical. We also prove that, even if the firm in both strategies expands to the new market and the capacity cost is identical, the firm using the export strategy may still invest in strictly higher capacity levels than the firm using the FDI strategy. This is somewhat counterintuitive because the export strategy has a demand-risk pooling benefit that tends to reduce the optimal capacity levels. The fact that the firm in the export strategy invests in higher capacity expansions does not suggest that the export strategy is less efficient than the FDI strategy; on the contrary, it suggests that the export strategy becomes more valuable to the firm under responsive pricing.

It is worth pointing out that we are not the first to note that the export (flexible) strategy may invest in higher capacity levels. In the inventory literature, several researchers have investigated the implications of the inventory levels between centralized and dedicated inventory systems. Eppen (1979) implicitly established that the centralized system has a lower (higher) inventory level than the dedicated system if the newsvendor critical fractile is greater (less) than 0.5. Gerchak and Mossman (1992) observed through a numerical example that the inventory level in the centralized system can be higher than that in the dedicated system when demand is exponentially distributed. Recently, Yang and Schrage (2007) systematically studied the conditions under which centralization may lead to increased inventory levels and they found that such an inventory "anomaly" could occur for any right skewed demand distribution. All the above mentioned research considers exogenous pricing only. More importantly, in all of the above mentioned research, the inventory anomaly will disappear if demand in one of the two markets exhibits no uncertainty. In contrast, we prove that with responsive pricing, the firm using export strategy may invest in higher capacity levels even if (i) there is no uncertainty in one of the two markets and (ii) demand is not right skewed.

This article also studies the effect of new market entry on the firm's existing market. We show that after entering into the new market the firm in the FDI strategy may supply strictly less (in expectation) to its existing market, but this is not so in the export strategy. Policy makers may therefore want to examine trade policies that could encourage a firm to engage in export strategy as opposed to the FDI strategy in expanding into the new market. The above observation may not hold, however, if the firm faces stringent price regulations. Price regulation is an important concern for multinational firms. For example, Horst (1971) examined how global trade barriers influenced a multinational firm's pricing strategies and found that the firm's optimal pricing strategy hinged upon whether the firm could price-discriminate between the two markets.

The rest of this article is organized as follows. We describe the model and provide preliminary analysis in the following section. Next, we explore the implications of the optimal capacity investments between the export and the FDI strategy. We then discuss several important limitations and extensions, and we conclude in the final section. All proofs are contained in the Appendix.

MODEL AND PRELIMINARIES

Consider a firm that serves its existing market (market 0) with an existing facility with capacity K_0. We consider two strategies the firm may use to serve a new market (market 1): the export and the FDI strategy. In the export strategy, the firm invests additional capacity K_0^f in market 0, such that after the market demand is realized the combined output from $K_0 + K_0^f$ can be flexibly allocated between market 0 and market 1. Each unit supplied to market 1 may incur an additional per-unit cost δ, which can include additional transportation, tariff, and customization cost associated with the new market. The export strategy is a (flexible) postponement strategy that delays the allocation decision. In contrast, in the FDI strategy, the firm installs a separate facility with capacity K_1^d exclusively for market 1. The firm may, however, complement its FDI investment by flexibly allocating a fraction of the output from its existing capacity to the new market. Hence, the FDI strategy is a partially dedicated strategy with early commitment to the new market. In both the export and the FDI strategy, we ignore fixed capacity setup cost: for the export strategy, capacity adjustments in the existing market is often incremental, whereas for the FDI strategy any fixed capacity cost in the new market only makes the export strategy (all else equal) more attractive.

Market demand is uncertain and sensitive to price. In both export and FDI strategies, the firm makes capacity and production decisions before market uncertainty is resolved, but makes its pricing (and selling quantity) decision after the market uncertainty is resolved. In essence, the firm operates a "push" production process and a "pull" pricing and quantity allocation process. Let $p_i(q_i, \epsilon_i)$ denote the firm's inverse demand function in market i, where q_i is the selling quantity in market i and ϵ_i captures realized market uncertainty. Intuitively, one may regard $\boldsymbol{\epsilon}_i$ as an aggregate indicator of random factors (e.g., uncertain customer preferences) that influence market price. We assume that market uncertainties are independent, and that the distribution function of $\boldsymbol{\epsilon}_i$ exists and is given by $G_i(\cdot)$.

Assumption 1: Demand function $p_i^{-1}(\cdot, \epsilon_i)$ is a (PF_2) Polya frequency function of order 2.

Condition PF_2 is satisfied by many common distributions such as normal, exponential, gamma, and Weibull distributions. All logconcave functions are also PF_2 (Efron, 1965). Define $R_i(q_i, \epsilon_i) = p_i(q_i, \epsilon_i)q_i$ and $\mathrm{MR}_i(q_i, \epsilon_i) = \partial R_i(q_i, \epsilon_i)/\partial q_i$ as the firm's revenue and marginal revenue function, respectively.

Assumption 2: $\partial \mathrm{MR}_i(q_i, \epsilon_i)/\partial \epsilon_i > 0$.

Assumption 2 implies that the firm's marginal revenue increases in ϵ_i, which is quite reasonable.

Summary of Notation

- f, d: Superscripts (subscripts) that denote export (flexible) and FDI (dedicated) strategy.
- K_i: Production capacity in market i, $i = 0, 1$.
- c_0, c_0^f, c_1^d: Unit production (including capacity investment) cost at the firm's existing facility K_0, flexible capacity K_0^f, and dedicated capacity K_1^d, respectively.
- $G_i(\cdot)$: Distribution function of $\boldsymbol{\epsilon}_i$, $i = 0, 1$.
- q_{ij}: Amount of production in market i supplied to market j, $i, j = 0, 1$.
- q_i: Total quantity available in market i, i.e., $q_i = \sum_{j=0,1} q_{ji}$, $i = 0, 1$.
- δ: Unit cost incurred for production supplied from the existing market (market 0) to the new market (market 1). Such costs may include additional transportation cost, tariff, and customization cost. For brevity, hereafter we refer to δ as *exporting cost*.

As a convention, we use $\vec{\boldsymbol{\epsilon}} = (\boldsymbol{\epsilon}_1, \boldsymbol{\epsilon}_2)$ to denote the vector of the random market uncertainty. We are now in a position to formulate the firm's two-stage decision problem.

Export Strategy

The firm's first stage expected profit function is

$$\text{Stage 0: } V_f\left(K_0^f \mid K_0\right) = -c_0 K_0 - c_0^f K_0^f + \mathsf{E}_{\vec{\epsilon}}\, \Pi_f^*\left(K_0^f \mid K_0, \vec{\epsilon}\right), \tag{1}$$

where the second stage optimal revenue function is

$$\text{Stage 1: } \Pi_f^*\big(K_0^f \mid K_0, \vec{\epsilon}\big) = \max_{q_{ij}\geq 0} \; p_0(q_0, \epsilon_0)q_0 + p_1(q_1, \epsilon_1)q_1 - \delta q_{01} \qquad (2)$$

$$\text{subject to:} \quad q_0 = q_{00}, \quad q_1 = q_{01}, \quad q_{00} + q_{01} \leq K_0 + K_0^f. \qquad (3)$$

FDI Strategy

The firm's first stage expected profit function is

$$\text{Stage 0: } V_d\big(K_1^d \mid K_0\big) = -c_0 K_0 - c_1^d K_1^d + \mathrm{E}_{\vec{\epsilon}}\Pi_d^*\big(K_1^d \mid K_0, \vec{\epsilon}\big), \qquad (4)$$

where the second stage optimal revenue function is

$$\text{Stage 1: } \Pi_d^*\big(K_1^d | K_0, \vec{\epsilon}\big) = \max_{q_{ij}\geq 0} \; p_0(q_0, \epsilon_0)q_0 + p_1(q_1, \epsilon_1)q_1 - \delta q_{01} \qquad (5)$$

$$\text{subject to:} \quad q_0 = q_{00}, \quad q_1 = q_{11} + q_{01}, \quad q_{00} + q_{01} \leq K_0, \quad q_{11} \leq K_1^d. \qquad (6)$$

General Properties

In both strategies, the relevant constraints, Equations (3) and (6), each form a convex set. Hence, we can characterize the structure of the first stage objective functions by exploiting the special properties of the mathematical programs of Equations (2) and (5).

Proposition 1: $V_f(K_0^f \mid K_0)$ and $V_d(K_1^d \mid K_0)$ are concave in K_0^f and K_1^d, respectively.

Because constraints (3) and (6) each form a convex set, we can use the Lagrangian approach to characterize the optimal K_0^f and K_1^d more explicitly. The Lagrangian function for the export strategy is

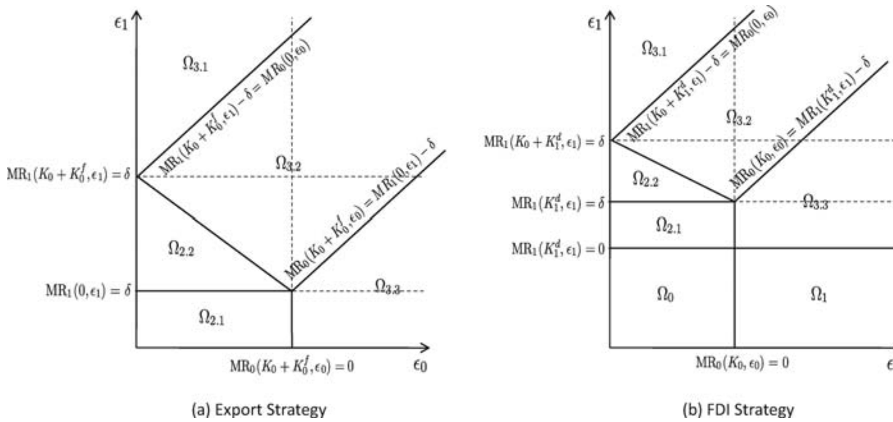
$$L_f\big(K_0^f | K_0, \lambda_f\big) = p_0(q_0, \epsilon_0)q_0 + p_1(q_1, \epsilon_1)q_1 - \delta q_{01} - \lambda_f\big(q_0 + q_1 - K_0 - K_0^f\big), \qquad (7)$$

where λ_f is the Lagrangian multiplier. A direct analysis of Equation (7) partitions the demand space into different regions (Figure 1(a)). The analysis for the FDI strategy is similar and the partitions of the demand space are illustrated in Figure 1(b).

In Figure 1(a), region $\Omega_2 = \Omega_{2.1} \cup \Omega_{2.2}$ represents low demand realizations in both markets such that the export strategy is able to fill demand in both markets; in $\Omega_{2.1}$ it is not profitable to export to the new market (due to transshipment/customization cost), whereas in $\Omega_{2.2}$ it is profitable to do so because the new market is sufficiently large. Region $\Omega_3 = \Omega_{3.1} \cup \Omega_{3.2} \cup \Omega_{3.3}$ represents high demand realizations in at least one market such that the export strategy will need to balance the existing and the new market demand. In particular, the firm exports 100% in $\Omega_{3.1}$, exports nothing in $\Omega_{3.3}$, and serves both existing and new market in $\Omega_{3.2}$.

In Figure 1(b), the demand regions can be similarly interpreted. There are two additional regions Ω_0 and Ω_1 that are unique to the FDI strategy. In both regions

Figure 1: A schematic of demand space partitions for export and FDI strategies.



the firm does not complement its FDI investment with exporting, because in Ω_0 demand in each market can be satisfied by their respective resources, whereas in Ω_1 the demand in the existing market is so high it is not profitable to export. By Lemma 1 and the above analysis in demand space partitions, we have the following proposition.

Proposition 2:

(a)The optimal K_0^f satisfies

$$\sum_{i=1}^{3} \mathsf{E}_{\Omega_{3.i}} \left[\frac{\partial \Pi_f^*(K_0^f | K_0, \vec{\epsilon})}{\partial K_0^f} \right] = c_0^f - \lambda_f, \tag{8}$$

where $\lambda_f \cdot K_0^f = 0$, and

$$\frac{\partial \Pi_f^*\big(K_0^f | K_0, \vec{\epsilon}\big)}{\partial K_0^f} = \begin{cases} \mathrm{MR}_1\big(K_0 + K_0^f, \epsilon_1\big) - \delta, & \Omega_{3.1}; \\ \mathrm{MR}_0\big(K_0 + K_0^f - q_{01}^*, \epsilon_0\big), & \Omega_{3.2}; \\ \mathrm{MR}_0\big(K_0 + K_0^f, \epsilon_0\big), & \Omega_{3.3}. \end{cases}$$

(b)The optimal K_1^d satisfies

$$\sum_{i=2}^{3} \sum_{j=1}^{i} \mathsf{E}_{\Omega_{i.j}} \left[\frac{\partial \Pi_d^*\big(K_1^d | K_0, \vec{\epsilon}\big)}{\partial K_1^d} \right] = c_1^d - \lambda_d, \tag{9}$$

where $\lambda_d \cdot K_1^d = 0$, and

$$\frac{\partial \Pi_d^*\big(K_1^d | K_0, \vec{\epsilon}\big)}{\partial K_1^d} = \begin{cases} \mathrm{MR}_1\big(K_1^d, \epsilon_1\big), & \Omega_{2.1} \cup \Omega_{3.3}; \\ \mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big), & \Omega_{2.2}; \\ \mathrm{MR}_1\big(K_0 + K_1^d, \epsilon_1\big), & \Omega_{3.1}; \\ \mathrm{MR}_0\big(K_0 - q_{01}^*, \epsilon_0\big) + \delta, & \Omega_{3.2}. \end{cases}$$

Proposition 2 characterizes the optimal capacity investment levels under the export and FDI market entry strategies. Notice that the L.H.S. of Equations (8) and (9) are simply the expected marginal revenue of K_0^f and K_1^d, respectively. It is therefore intuitive that at optimality, the (interior) capacity levels are such that the marginal revenue equals marginal cost.

OPTIMAL CAPACITY INVESTMENT IN EXPORT AND FDI STRATEGIES

In this section, we first study how the firm's preference to the export and FDI strategy is influenced by market and demand characteristics, and then contrast the optimal capacity investments between these two market entry strategies.

Strategy Preferences

Because the impact of production cost c_0^f and c_1^d is straightforward (i.e., increasing c_0^f makes FDI strategy more attractive whereas increasing c_1^d makes export strategy more attractive), in what follows we focus on two important market characteristics: the exporting cost δ and the existing capacity K_0.

Intuition suggests that, all else equal, an increase in the exporting cost δ makes the FDI strategy more attractive. One may therefore conjecture that, with a sufficiently high $\overline{\delta}$, the firm would prefer FDI to export for any exporting cost $\delta \geq \overline{\delta}$. This intuition is largely correct, but with some important nuances. Define $V_f^* = V_f(K_0^{f*}|K_0)$ and $V_d^* = V_d(K_1^{d*}|K_0)$.

Proposition 3: (a) If $\delta \leq c_1^d - c_0^f$, then $V_f^* - V_d^* \geq 0$. (b) $\partial(V_f^* - V_d^*)/\partial\delta \leq 0$. (c) It is possible that $V_f^* - V_d^* > 0$ even if $\delta = \infty$.

Proposition 3 confirms one's intuition that the firm always prefers export strategy when the exporting cost δ is sufficiently low (part (a)), and that a higher exporting cost δ increases the attractiveness of the FDI strategy (part (b)). By part (a), if capacity investment cost is identical (i.e., $c_0^f = c_1^d$) and the exporting cost δ equals zero, then the firm always prefers export strategy. As the exporting cost δ increases, the attractiveness of the FDI strategy increases. Part(c) tells us, however, that the firm's preference to export strategy may not switch even at $\delta = \infty$, which is a degenerate case where the firm invests in $K_0^f > 0$ but never exports because $\delta = \infty$. A natural question arises: when will there exist a $\overline{\delta}$ such that the firm prefers export strategy for any $\delta \leq \overline{\delta}$, and prefers FDI for $\delta > \overline{\delta}$? Note that by part (b) of Proposition 3, if such $\overline{\delta}$ exists, it must be unique.

Corollary 1: Define $\Gamma = \{\epsilon_0 : \mathrm{MR}_0(K_0, \epsilon_0) \geq 0\}$ for any given K_0. Let $\overline{K}_0$ be the unique solution to $\mathsf{E}_\Gamma[\mathrm{MR}_0(\overline{K}_0, \epsilon_0)] = c_0$. Similarly, define $\Psi = \{\epsilon_1 : \mathrm{MR}_1(K_1^d, \epsilon_1) \geq 0\}$ for any given K_1^d. If (i) $c_0 = c_0^f = c_1^d$, (ii) $K_0 = \overline{K}_0$, and (iii) $\mathsf{E}_\Psi[\mathrm{MR}_1(0, \epsilon_1)] \geq c_1^d$, then there exists a unique $\overline{\delta} < \infty$ such that $V_f^* \geq V_d^*$ for any $\delta \leq \overline{\delta}$ and $V_f^* < V_d^*$ for any $\delta > \overline{\delta}$.

The above corollary provides a sufficient condition for the existence of a switchover exporting cost $\overline{\delta}$. In particular, if capacity investment costs are similar (condition (i)), the firm has sufficient existing capacity (condition (ii)), and the new market is not too small (condition (iii)), then there exists a unique boundary exporting cost $\overline{\delta}$, such that the firm prefers export strategy for $\delta \leq \overline{\delta}$ and prefers FDI strategy for $\delta > \overline{\delta}$.

We now turn our attention to the effect of the firm's existing capacity K_0 on its strategy preferences. One important question that is of managerial interest is whether or not a larger existing capacity favors export strategy. Intuition offers two contrasting views. On the one hand, a larger existing capacity translates into excess capacity and therefore the firm should favor export strategy. On the other hand, a larger existing capacity renders declining returns for any further investment in K_0^f and hence the firm is better off choosing FDI investment. The following proposition suggests that the effect of the firm's existing capacity K_0 on firm's strategy preference is somewhat more subtle.

Proposition 4: (a) $\partial K_0^{f*}/\partial K_0 \leq 0$. (b) $\partial K_1^{d*}/\partial K_0 \leq 0$. (c) $\partial V_f^*/\partial K_0 = -c_0 + c_0^f$. (d) $\partial V_d^*/\partial K_0 = -c_0 + c_1^d + \rho$, where $\rho = \mathsf{E}_{\Omega_1 \cup \Omega_{3.3}} \mathrm{MR}_0(K_0, \epsilon_0) - \mathsf{E}_{\Omega_{2.1} \cup \Omega_{3.3}} \mathrm{MR}_1(K_1^d, \epsilon_1) - \Pr(\Omega_{2.2} \cup \Omega_{3.1} \cup \Omega_{3.2})\delta$.

Parts (a) and (b) of the above proposition tell us that, as one might expect, the firm's existing capacity is a substitute for new capacity investments, either in the export strategy or the FDI strategy. In other words, higher existing capacity levels result in a lower marginal value of K_0^f and K_1^d, and hence reduce the firm's incentive to invest in new capacities. The effect of existing capacity on the firm's strategy preference, however, is less clear. Part (c) tells us that the effect of K_0 on the optimal expected profit in the export strategy depends *only* on the relative costs of c_0 and c_0^f. In particular, the firm benefits from a larger existing capacity if $c_0 < c_0^f$ but not if $c_0 \geq c_0^f$. In fact, if $c_0 > c_0^f$, the firm is better off having *less* existing capacity, which often is the case when newer technology, for example, affords lower production costs. In contrast, part (d) says that the effect of K_0 on the FDI strategy depends not only on the relative costs of c_0 and c_1^d, but also on the market characteristics summarized by ρ. Because ρ can be either negative or positive, the firm may prefer a higher existing capacity K_0 even if $c_0 > c_1^d$ and vice versa. As a result, the effect of K_0 on the firm's preference toward export or FDI strategy can be ambiguous, even if $c_0 = c_0^f = c_1^d$. Despite this difficulty, the following proposition sheds further insights on the effect of K_0.

Proposition 5: If $c_0 = c_0^f$, there exists a unique $\widetilde{K}_0 > \overline{K}_0$ such that $\partial(V_d^* - V_f^*)/\partial K_0 \geq 0$ for any $K_0 \leq \widetilde{K}_0$, and $\partial(V_d^* - V_f^*)/\partial K_0 < 0$ for any $K_0 > \widetilde{K}_0$.

Note that $\overline{K}_0$ (defined in Corollary 1) is the optimal capacity level if the firm serves its existing market only. Proposition 5 establishes a unique threshold capacity level $\widetilde{K}_0$ such that the FDI strategy becomes more attractive as K_0 increases, but only up to the threshold level $\widetilde{K}_0$. Once the firm's existing capacity exceeds $\widetilde{K}_0$, the FDI strategy becomes less attractive as K_0 continues to increase. The intuition for this nonmonotonic behavior can be partially explained by the interplay of the marginal value of the existing capacity and of the dedicated capacity. This was discussed in the paragraph preceding Proposition 4.

Capacity Implications

Having partially characterized the effect of market characteristics on the firm's strategy preferences, we now focus on the capacity implications of the firm's strategy choice. One might expect that the optimal capacity investment in the export strategy is less than that in the FDI strategy due to the demand-risk pooling benefit embedded in the export strategy. This intuition is correct, for example, when market price is exogenous and the critical newsvendor fractile is greater than 0.5 (Eppen, 1979). With responsive pricing, however, it is unclear whether or not the above intuition will continue to hold. The following proposition proves that a firm may invest in the export strategy a capacity level that is strictly *greater* than that in the FDI strategy.

Proposition 6: Suppose $c_0^f \le c_0$ and $K_0 = \overline{K}_0$. (a) If (i) $\mathsf{E}[\boldsymbol{\epsilon}_1] \le c_1^d$ and (ii) $\exists \overline{\epsilon}_1$, such that $\forall \epsilon_1 > \overline{\epsilon}_1$ $\mathrm{MR}_1(0, \epsilon_1) > \delta$, then all else equal $V_f^* > V_d^*$, $K_0^{f*} > 0$, and $K_1^{d*} = 0$. (b) If $\exists \overline{\epsilon}_1$, such that $\forall \epsilon_1 > \overline{\epsilon}_1$ $\mathrm{MR}_1(0, \epsilon_1) > \delta$, then all else equal there exists some $\overline{c}_1^d > c_1^d$ such that if $c_1^d < \mathsf{E}[\boldsymbol{\epsilon}_1] \le \overline{c}_1^d$ then $K_0^{f*} > K_1^{d*} > 0$.

First focus on part (a) of the above proposition. In part (a), condition (i) guarantees that the firm invests no positive capacity in the new market under the FDI strategy, and condition (ii) guarantees that it is profitable to export a fraction of output to the new market with some positive probability. Note that conditions (i) and (ii) are easily satisfied by any distribution that has support on R^+.

If we loosely interpret $\mathsf{E}[\boldsymbol{\epsilon}_1]$ as a proxy of the expected "maximum willingness to pay" of the new market, part (a) of Proposition 6 suggests that if the willingness to pay in the new market is small but the variability is high, all else equal the firm will expand into this new market via export strategy *only*. What makes this result somewhat surprising is that it holds even when $c_0 = c_0^f = c_1^d$ (so $c_0^f + \delta > {c_1}^d$); in other words, it is more costly to export one unit to the new market than it is when using the FDI strategy.

It is worth pointing out that the opposite may happen if market price is exogenous (e.g., Proposition 13 in the Appendix). As a numerical example, if price is identical at $p_0 = p_1 = 4$, demand for each market is uniformly distributed between 0 and 20, $\delta = 1$, $c_0^f = c_1^d = 2$ and $K_0 = 18$, then $K_1^{d*} = 2.1388 > K_0^{f*} = 0$. The reason for such opposite behavior is fairly straightforward: with identical and exogenous market price, the contribution margin in the FDI strategy is greater than that in the export strategy.

The fact that the export strategy invests a strictly higher capacity than that in the (degenerate) FDI strategy suggests that the value of the export strategy is enhanced by responsive pricing. Note that the term "value" used here and subsequently refers to the fact that the export strategy invests in higher capacity and thus is more valuable to the market place. Part of the intuition is as follows.

With responsive pricing, it is profitable for the firm in the FDI strategy to serve market 1 when ϵ_1 is high but not when ϵ_1 is low. Because $\mathsf{E}[\boldsymbol{\epsilon}_1]$ is relatively low, the upside gain when realized ϵ_1 is high cannot offset the downside loss when realized ϵ_1 is low, with the result that $K_1^{d*} = 0$; this means the firm invests no capacity in market 1 under the FDI strategy. In contrast, the firm in the export strategy can mitigate its downside loss by shifting some of its output to market 0 when realized ϵ_1 is low but ϵ_0 is moderate to high, and vice versa. This limited loss exposure coupled with potential upside gain creates an option value for the firm to make higher capacity investment in the export strategy.

Part (b) of Proposition 6 extends the result in part (a) by telling us that the firm can invest a strictly higher capacity using the export strategy than it would when using the FDI strategy, even if the firm also expands into the new market using the FDI strategy. The intuition is similar to that explained above, with the exception that it is marginally profitable for the firm using the FDI strategy to invest a positive capacity in market 1. The firm, however, continues to invest a strictly higher capacity in the export strategy, because, again, the potential upside gain more than offsets the limited downside loss.

Proposition 6 suggests that the option value created by responsive pricing dominates the demand-risk pooling benefit inherent in the export strategy. Because the demand-risk pooling benefit tends to increase if the potential of the new market grows, one might suspect that the firm may invest *less* capacity in the export strategy than it would for the FDI strategy if ϵ_1 becomes sufficiently large. In what follows, we investigate the effect of market uncertainty ϵ_1 on the firm's capacity investment and strategy preferences.

Effect of New Market Uncertainty

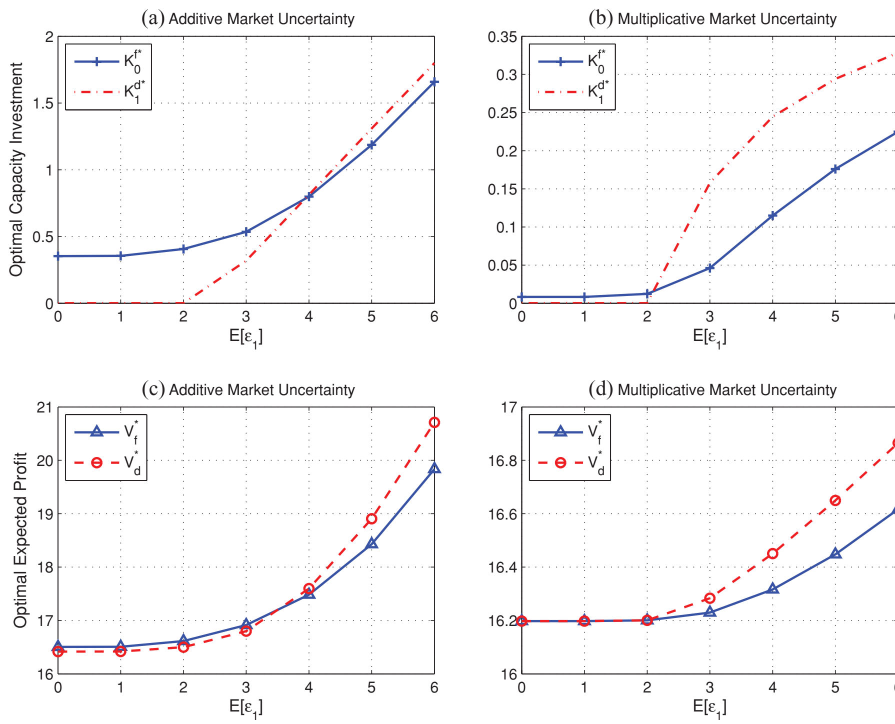
Definition 1: A random variable $\boldsymbol{\epsilon}_1^a$ is stochastically larger than $\boldsymbol{\epsilon}_1^b$, i.e., $\boldsymbol{\epsilon}_1^a \geq_{st} \boldsymbol{\epsilon}_1^b$, if $F_a(x) \leq F_b(x)$ for all x, where $F_a(\cdot)$ and $F_b(\cdot)$ are distribution functions of $\boldsymbol{\epsilon}_1^a$ and $\boldsymbol{\epsilon}_1^b$, respectively.

Using the above definition, then, a stochastically larger $\boldsymbol{\epsilon}_1$ implies a higher $\mathsf{E}[\boldsymbol{\epsilon}_1]$. Recall that the firm's marginal revenue increases in ϵ_1 (Assumption 2); one therefore expects that the firm's optimal expected profit would increase as $\boldsymbol{\epsilon}_1$ becomes stochastically larger. It is unclear, however, whether or not a stochastically larger $\boldsymbol{\epsilon}_1$ makes the FDI strategy or the export strategy more attractive.

Proposition 7: (a) $\boldsymbol{\epsilon}_1^a \geq_{st} \boldsymbol{\epsilon}_1^b \Rightarrow V_f^*(\boldsymbol{\epsilon}_1^a) \geq V_f^*(\boldsymbol{\epsilon}_1^b)$. (b) $\boldsymbol{\epsilon}_1^a \geq_{st} \boldsymbol{\epsilon}_1^b \Rightarrow V_d^*(\boldsymbol{\epsilon}_1^a) \geq V_d^*(\boldsymbol{\epsilon}_1^b)$. (c) If $K_0^{f*} \leq K_1^{d*}$ then $\boldsymbol{\epsilon}_1^a \geq_{st} \boldsymbol{\epsilon}_1^b \Rightarrow V_f^*(\boldsymbol{\epsilon}_1^a) - V_d^*(\boldsymbol{\epsilon}_1^a) \leq V_f^*(\boldsymbol{\epsilon}_1^b) - V_d^*(\boldsymbol{\epsilon}_1^b)$.

The above proposition confirms that the firm benefits from a stochastically larger new market, regardless of whether the firm adopts the export or the FDI strategy. If in addition, the firm's current capacity investment in the FDI strategy is at least as large as what the firm would have invested in the export strategy, then the FDI strategy becomes more attractive as the new market becomes stochastically larger. In other words, if the firm already invests in a higher dedicated capacity in the new market, then any stochastic increase in $\boldsymbol{\epsilon}_1$ makes the FDI strategy

Figure 2: An illustration of stochastically larger $\boldsymbol{\epsilon}_1$ under additive/multiplicative uncertainty.



Note: Figure 2 was obtained by setting $\boldsymbol{\epsilon}_i \sim N(\mu_i, \sigma_i)$, $c_0 = c_0^f = c_1^d = 2$, $K_0 = 4$, and $\delta = 1$. Part (a,c) was obtained by setting $p_i = \epsilon_i - q_i$, where $\mu_0 = 10$, $cv_0 = \sigma_0/\mu_0 = 0.3$, μ_1 varies from 0 to 6, and $cv_1 = 0.5$. Part (b,d) was obtained by setting $p_i = (a_i - q_i)\epsilon_i$, where $a_0 = 10$, $\mu_0 = 1$, $cv_0 = 0.3$, $a_1 = 1$, μ_1 varies from 0 to 6, and $cv_1 = 0.5$.

more attractive. Part of the intuition is as follows. As the new market becomes stochastically larger, the increased exporting cost begins to offset the risk pooling benefit inherent in the export strategy, with a result that the FDI strategy becomes more attractive. We note, however, that the reverse is in general not true; if the firm invests in a lower dedicated capacity in the new market, then a stochastic increase in market uncertainty does not necessarily make the export strategy more attractive. Figure 2(a) illustrates that both K_0^{f*} and K_1^{d*} increase as $\boldsymbol{\epsilon}_1$ becomes stochastically larger. As predicated by Proposition 7(c), the FDI strategy becomes more attractive as K_1^{d*} becomes greater than K_0^{f*} (Figure 2(c)).

Having partially characterized the effect of stochastic larger market uncertainty on the firm's optimal expected profit in Proposition 7, we now turn our attention to its effect on the optimal capacity investment levels.

Proposition 8: (a) $\boldsymbol{\epsilon}_1^a \geq_{st} \boldsymbol{\epsilon}_1^b \Rightarrow K_0^{f*}(\boldsymbol{\epsilon}_1^a) \geq K_0^{f*}(\boldsymbol{\epsilon}_1^b)$. (b) $\boldsymbol{\epsilon}_1^a \geq_{st} \boldsymbol{\epsilon}_1^b \Rightarrow K_1^{d*}(\boldsymbol{\epsilon}_1^a) \geq K_1^{d*}(\boldsymbol{\epsilon}_1^b)$.

The above proposition tells us that, as one might expect, the optimal capacity investment level increases as the new market uncertainty becomes stochastically larger. A stochastic increase in $\boldsymbol{\epsilon}_1$ makes the new market more attractive, and therefore the firm invests in higher capacity levels regardless of whether it adopts an export or FDI strategy. A more interesting question remains: how does stochastic increase in $\boldsymbol{\epsilon}_1$ impact the relative capacity investment levels between the export and FDI strategies? First we distinguish between additive and multiplicative market uncertainties.

Definition 2: (a) The inverse demand function is additive if $p_i(q_i, \epsilon_i) = p_i(q_i) + \epsilon_i, i = 0, 1$. (b) The inverse demand function is multiplicative if $p_i(q_i, \epsilon_i) = p_i(q_i) \cdot \epsilon_i, i = 0, 1$.

In an additive inverse demand function, quantity affects price levels but not variances, whereas in a multiplicative inverse demand function quantity affects price variances but not the coefficient of variations. For notational ease, in what follows we use $\mathrm{MR}_i'(x, \epsilon_i)$ to denote $\partial \mathrm{MR}_i(x, \epsilon_i)/\partial x$. Define

$$\begin{aligned}
\Lambda_f &= \mathsf{E}_{\Omega_{3.1}}\big[\mathrm{MR}_1\big(K_0 + K_0^f, 1\big)\big] + \mathsf{E}_{\Omega_{3.2}}\big[\mathrm{MR}_1\big(q_{01}^*, 1\big) \cdot \eta^f\big],\\
\Lambda_f' &= \mathsf{E}_{\Omega_{3.1}}\big[\mathrm{MR}_1'\big(K_0 + K_0^f, \epsilon_1\big)\big] + \mathsf{E}_{\Omega_{3.2}}\big[\mathrm{MR}_1'(q_{01}^*, \epsilon_1) \cdot \eta^f\big]\\
&\quad + \mathsf{E}_{\Omega_{3.3}}\big[\mathrm{MR}_0'\big(K_0 + K_0^f, \epsilon_0\big)\big],\\
\Lambda_d &= \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\big[\mathrm{MR}_1\big(K_1^d, 1\big)\big] + \mathsf{E}_{\Omega_{3.1}}\big[\mathrm{MR}_1\big(K_0 + K_1^d, 1\big)\big]\\
&\quad + \mathsf{E}_{\Omega_{3.2}}\big[\mathrm{MR}_1\big(K_1^d + q_{01}^*, 1\big) \cdot \eta^d\big],\\
\Lambda_d' &= \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\big[\mathrm{MR}_1'\big(K_1^d, \epsilon_1\big)\big] + \mathsf{E}_{\Omega_{3.1}}\big[\mathrm{MR}_1'\big(K_0 + K_1^d, \epsilon_1\big)\big]\\
&\quad + \mathsf{E}_{\Omega_{3.2}}\big[\mathrm{MR}_1'\big(K_1^d + q_{01}^*, \epsilon_1\big) \cdot \eta^d\big],
\end{aligned}$$

where $\eta^f = 1/[1 + \mathrm{MR}_1'(q_{01}^*, \epsilon_1)/\mathrm{MR}_0'(K_0 + K_0^f - q_{01}^*, \epsilon_0)]$, and $\eta^d = 1/[1 + \mathrm{MR}_1'(K_1^d + q_{01}^*, \epsilon_1)/\mathrm{MR}_0'(K_0 - q_{01}^*, \epsilon_0)]$.

Corollary 2: (a) If the inverse demand function is additive and $\Lambda_f' \le \Lambda_d{}'$, then $\boldsymbol{\epsilon}_1^a \ge_{st} \boldsymbol{\epsilon}_1^b \Rightarrow K_0^{f*}(\boldsymbol{\epsilon}_1^a) - K_1^{d*}(\boldsymbol{\epsilon}_1^a) \le K_0^{f*}(\boldsymbol{\epsilon}_1^b) - K_1^{d*}(\boldsymbol{\epsilon}_1^b)$. (b) If the inverse demand function is multiplicative and $\Lambda_f/\Lambda_f' \ge \Lambda_d/\Lambda_d'$, then $\boldsymbol{\epsilon}_1^a \ge_{st} \boldsymbol{\epsilon}_1^b \Rightarrow K_0^{f*}(\boldsymbol{\epsilon}_1^a) - K_1^{d*}(\boldsymbol{\epsilon}_1^a) \le K_0^{f*}(\boldsymbol{\epsilon}_1^b) - K_1^{d*}(\boldsymbol{\epsilon}_1^b)$.

Depending on whether the market uncertainty is additive or multiplicative, its stochastic effect on the firm's investment levels is somewhat different. In part (a), the firm is more likely to invest in higher capacity in the FDI strategy if $\Lambda_f' \le \Lambda_d{}'$, which is more likely to hold if the firm already invests in a higher capacity level in the FDI strategy than for the export strategy. This is consistent with our earlier observations on the profit implications in Proposition 7, that a stochastic increase in new market uncertainty benefits the FDI strategy more if the firm already invests in higher capacities in the FDI strategy than it does in the export strategy. In part (b), the condition is more nuanced when demand uncertainty is multiplicative. In particular, both Λ_f and the absolute value of Λ_f' decrease as K_0^f increases, and hence the ratio of Λ_f/Λ_f' cannot be directly linked with the magnitude of capacity levels. Nevertheless, our numerical observations suggest that the effect is somewhat similar to that in the additive case; see Figures 2(b) and (d) for an illustration.

While Corollary 2 partially characterizes the relative capacity impact, the conditions defined are not easily interpreted (although numerical evaluation is straightforward). To further improve insights into the capacity implications, the following remark provides an asymptotic characterization of the effect of stochastically larger new market.

Remark 1: As the new market becomes sufficiently large (in the stochastic sense), $\boldsymbol{\epsilon}_1^a \gg_{st} \boldsymbol{\epsilon}_1^b \Rightarrow K_0^{f*}(\boldsymbol{\epsilon}_1^a) - K_1^{d*}(\boldsymbol{\epsilon}_1^a) \leq K_0^{f*}(\boldsymbol{\epsilon}_1^b) - K_1^{d*}(\boldsymbol{\epsilon}_1^b)$ if (a) the inverse demand function is additive and $K_0^{f*} < K_1^{d*}$ in the first place, or (b) the inverse demand function is multiplicative, linear, and $K_0^{f*} > K_1^{d*}$ in the first place.

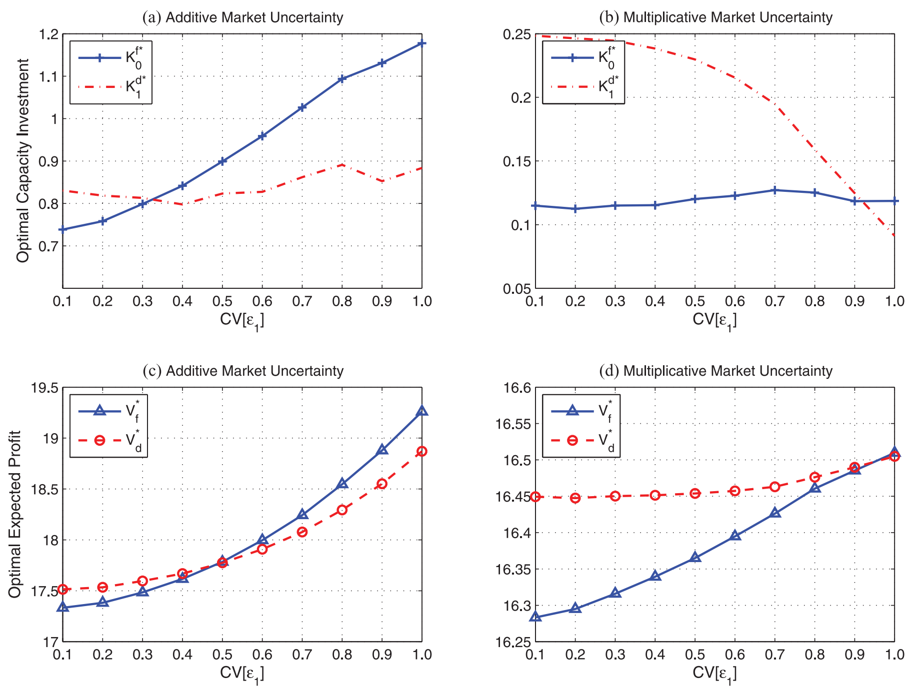
By Remark 1 and Proposition 6, if there exists a finite $\overline{\boldsymbol{\epsilon}}_1$ such that $K_0^{f*} \leq K_1^{d*}$ for $\boldsymbol{\epsilon}_1 \geq_{st} \overline{\boldsymbol{\epsilon}}_1$, then this $\overline{\boldsymbol{\epsilon}}_1$ is unique, and $K_0^{f*} > K_1^{d*}$ for any $\boldsymbol{\epsilon}_1 <_{st} \overline{\boldsymbol{\epsilon}}_1$. In other words, the export strategy invests in higher capacity than the FDI strategy when $\boldsymbol{\epsilon}_1$ is small, and if the optimal capacity investment levels between these two strategies ever cross, they cross only once as $\boldsymbol{\epsilon}_1$ becomes stochastically larger.

In summary, the above analysis tells us that, as $\boldsymbol{\epsilon}_1$ becomes stochastically larger, the firm may indeed invest *less* capacity in the export strategy than it would in the FDI strategy. We note that if the inverse demand function is linear, there is no uncertainty in the existing market, and that if the new market uncertainty is uniformly distributed, then one can completely characterize the unique $\overline{\boldsymbol{\epsilon}}_1$ such that $\boldsymbol{\epsilon}_1 \leq_{st} \overline{\boldsymbol{\epsilon}}_1 \Rightarrow K_0^{f*} \geq K_1^{d*}$ and $\boldsymbol{\epsilon}_1 >_{st} \overline{\boldsymbol{\epsilon}}_1 \Rightarrow K_0^{f*} < K_1^{d*}$. It is somewhat surprising that a demand-risk pooling benefit in the export strategy continues to exist even if one market does not exhibit any demand uncertainty. This phenomenon cannot occur if (i) price is exogenous and (ii) demand in one market does not exhibit uncertainty; in this case the optimal capacity investment would be identical for the export and the FDI strategies. Eppen (1979), for example, establishes that with exogenous price a flexible (centralized) system offers no demand-risk pooling benefit when demand in one market exhibits no uncertainty (Eppen, 1979, p. 500, where substituting $N = 2$ and $\sigma_1 = 0$ into Equation (14) recovers Equation (12)).

Definition 3: A random variable $\boldsymbol{\epsilon}_1^a$ is stochastically more variable than $\boldsymbol{\epsilon}_1^b$, i.e., $\boldsymbol{\epsilon}_1^a \geq_{ssd} \boldsymbol{\epsilon}_1^b$, if $\mathsf{E}[\boldsymbol{\epsilon}_1^a] = \mathsf{E}[\boldsymbol{\epsilon}_1^b]$ and $\int_0^x F_a(y)\, dy \leq \int_0^x F_b(y)\, dy$ for all x, where $F_{\mathrm{a}}(\cdot)$ and $F_b(\cdot)$ are distribution functions of $\boldsymbol{\epsilon}_1^a$ and $\boldsymbol{\epsilon}_1^b$, respectively.

Using the above definition, a stochastically more variable $\boldsymbol{\epsilon}_1$ implies a higher variance (Gerchak & Mossman, 1992; Xu, Chen, & Xu, 2010). It is well known in the classical newsvendor model that increasing market variance may result in higher or lower capacity investments, depending on whether the critical fractile is greater or less than 0.5. With responsive pricing, then, the relation between market variance and capacity investment in general cannot be unambiguously determined. Nevertheless, we can leverage some existing results in the literature to partially characterize the effect of a stochastically more variable $\boldsymbol{\epsilon}_1$.

Figure 3: An illustration of more variable $\boldsymbol{\epsilon}_1$ under additive/multiplicative uncertainty.



Note: Figure 3 was obtained using similar parameters as that in Figure 2, except that we fix $\mu_0 = 10$, $cv_0 = 0.3$, $\mu_1 = 5$, and vary cv_1 as illustrated.

Proposition 9: (a) Suppose $p_i(q_i, \epsilon_i)$ is linear in q_i and additive in ϵ_i. If $\boldsymbol{\epsilon}_1$ has support on R^+ and $\mathsf{E}[\boldsymbol{\epsilon}_1] < c_1^d$, then $\boldsymbol{\epsilon}_1^a \geq_{ssd} \boldsymbol{\epsilon}_1^b \Rightarrow K_0^{f*}(\boldsymbol{\epsilon}_1^a) - K_1^{d*}(\boldsymbol{\epsilon}_1^a) \geq K_0^{f*}(\boldsymbol{\epsilon}_1^b) - K_1^{d*}(\boldsymbol{\epsilon}_1^b)$. (b) [Proposition 6, Dong et al. (2010).] Suppose $p_i(q_i, \epsilon_i)$ is multiplicative in ϵ_i, then $\boldsymbol{\epsilon}_1^a \geq_{ssd} \boldsymbol{\epsilon}_1^b \Rightarrow V_f^*(\boldsymbol{\epsilon}_1^a) \geq V_f^*(\boldsymbol{\epsilon}_1^b)$, $V_d^*(\boldsymbol{\epsilon}_1^a) \geq V_d^*(\boldsymbol{\epsilon}_1^b)$.

In contrast to the stochastically larger $\boldsymbol{\epsilon}_1$, Proposition 9(a) tells us that as the new market becomes stochastically more variable, the firm can in fact invest more in the export strategy than that in the FDI strategy. This suggests that as the new market becomes more uncertain, the export strategy becomes a “safer” investment strategy as compared with the FDI strategy. This is in stark contrast with the case of stochastically larger new market: a stochastically larger new market implies that the new market becomes fundamentally more attractive, whereas a stochastically more variable new market implies that the new market becomes fundamentally more risky. Part (b) of Proposition 9 tells us that the option value embedded in both strategies increases as the new market becomes more variable (Figure 3).

It is worth pointing out that the firm’s optimal FDI investment K_d^* can in fact decrease as the new market becomes stochastically more variable (Figure 3(b)). The fact that K_d^* can decrease does not contradict Lemma 4 in Dong et al. (2010)

because here the FDI strategy is a partially dedicated strategy whereas Lemma 4 pertains to pure dedicated strategy only.

We now turn our attention to a question of practical importance: how does capacity investment for export to the new market (market 1) affect the expected supply to the existing market (market 0)? It is not obvious a priori whether the *expected* supply to the existing market will change after the firm's entry into the new market.

Proposition 10: Suppose $K_0 \leq \overline{K}_0$, where $\overline{K}_0$ is defined in Corollary 1. (a) All else equal the expected supply to the existing market decreases as the firm enters new market via FDI strategy. (b) All else equal the expected supply to the existing market does not decrease as the firm enters a new market via export strategy.

Proposition 10 tells us that expanding to a new stochastic market results in the firm in the FDI strategy supplying *less* (in expectation) to its existing market, but this is not so in the export strategy. This result holds regardless of whether the firm's optimal capacity investment K_1^{f*} is higher or lower than K_0^{d*}. From a policy point of view, then, the FDI strategy can have a negative impact on the firm's existing market (less expected supply and higher expected price), whereas the export strategy does not exhibit such negative characteristics. Hence, trade policies that influence the firm's preference toward export versus FDI strategies should be carefully weighed such that the existing market is not inadvertently impacted by firms' entry into new markets.

EXTENSIONS

In this section, we consider several extensions to our base model: price setting with residual uncertainty, dependent market prices, and multiple periods. We examine each of the extensions separately.

Price Setting with Residual Uncertainty

Let $\boldsymbol{\epsilon}_i = \boldsymbol{\omega}_i + \boldsymbol{z}_i$, where $\boldsymbol{\omega}_i$ is the part of the uncertainty that is resolved before price (and allocation quantity) is set, and $\boldsymbol{z}_i$ is the residual uncertainty after price is set. In addition, let $\sigma_{\epsilon_i}^2$ and $\sigma_{z_i}^2$ denote the variance of $\boldsymbol{\epsilon}_i$ and $\boldsymbol{z}_i$, respectively. Define $\rho_i = \sigma_{z_i}^2 / \sigma_{\epsilon_i}^2$, the fraction of market uncertainty that is resolved before price is set. A lower ρ_i, then, is associated with a lower residual uncertainty.

Let $F_i(z_i)$ denote the distribution of $\boldsymbol{z}_i$. Also, let $d_i(p_i, \epsilon_i)$ denote the demand function in market i. The firm's second-stage optimal revenue function in export strategy can be rewritten as

$$\text{Stage 1: } \Pi_f^*\left(K_0^f | K_0, \vec{\omega}\right) = \max_{q_{ij} \geq 0, p_i \geq 0} \; p_0 \mathsf{E}_{z_0}[s_0] + p_1 \mathsf{E}_{z_1}[s_1] - \delta q_{01} \tag{10}$$

$$\text{subject to:} \qquad q_{00} + q_{01} \leq K_0 + K_0^f, \; q_{11} = 0, \tag{11}$$

where $\mathsf{E}_{z_i}[s_i] = \int_{z_i \leq \bar{z}_i} d_i(p_i, \omega_i + z_i) dF_i(z_i) + d_i(p_i, \omega_i + \bar{z}_i)\overline{F}_i(\bar{z}_i)$, $\bar{z}_0$ satisfies $q_{00} = d_0(p_0, \omega_0 + \bar{z}_0)$, and $\bar{z}_1$ satisfies $q_{01} + q_{11} = d_1(p_1, \omega_1 + \bar{z}_1)$. In

Equation (10) we use s_i to denote the sales in market i, $i = 1, 2$, respectively. Note that the FDI strategy can be similarly analyzed.

The joint pricing and quantity decision described in Equation (10) above is in general not well behaved. Therefore, a direct analytical comparison between the two strategies (export vs FDI) is challenging. If $\rho = 1$, however, then no market uncertainty is resolved before price is set. In this case, all else equal the export strategy offers no additional option value (operational recourse) relative to the FDI strategy. To see this, notice that for $\rho = 1$ the firm's optimal expected profit (Equation (1)) can be rewritten as

$$\begin{aligned} V_f\left(K_0^{f*}|K_0\right) &= \max_{K_0^f \geq 0} \left\{-c_0 K_0 - c_0^f K_0^f + \mathsf{E}_{\vec{\epsilon}} \Pi_f^*\left(K_0^f | K_0, \vec{\epsilon}\right)\right\} \\ &= \max_{K_0^f \geq 0} \left\{-c_0 K_0 - c_0^f K_0^f + \max_{q_{ij} \geq 0, p_i \geq 0} \left\{p_0 \mathsf{E}_{z_0}[s_0]\right.\right. \\ &\quad \left.\left. + p_1 \mathsf{E}_{z_1}[s_1] - \delta q_{01}\right\}\right\} \\ &= \max_{K_0^f \geq 0, q_{ij} \geq 0, p_i \geq 0} \left\{-c_0 K_0 - c_0^f K_0^f + p_0 \mathsf{E}_{z_0}[s_0]\right. \\ &\quad \left. + p_1 \mathsf{E}_{z_1}[s_1] - \delta q_{01}\right\}, \end{aligned}$$

where the last equality follows from the fact that $\boldsymbol{\epsilon}$ remains the same before price (and quantity) is set. The following property ensues.

Remark 2: (a) If $\rho = 1$, then all else equal the optimal capacity expansion in the export and FDI strategy is identical. (b) If $\rho < 1$, then the optimal capacity expansion in the export strategy can differ from that in the FDI strategy.

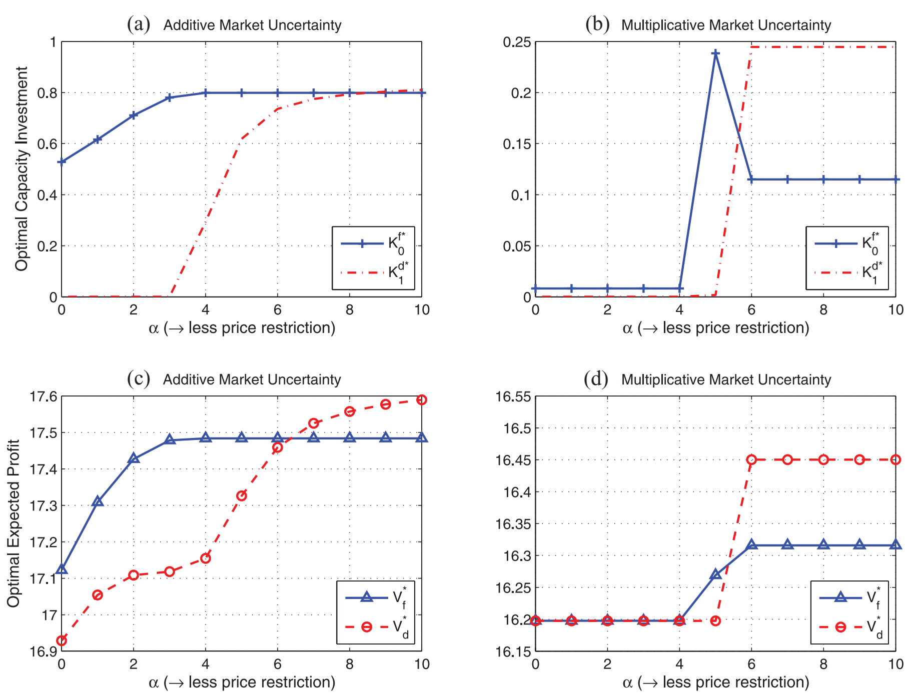
Numerical observations indicate that the firm may in fact still invest in a higher capacity in the export strategy, as long as some amount of demand uncertainty is resolved in the second stage when the firm makes pricing and allocation decisions. In summary, our earlier results (Proposition 6) do not seem to hinge upon the assumption of responsive pricing. As long as some market uncertainty is resolved before price is set, the firm in the export strategy may continue to invest in higher capacity than that in the FDI strategy.

Dependent Market Prices

In our base model, we implicitly assume that market price can be set independently between the existing and the new market. This is reasonable when the two markets are geographically separated, for example, when trade barriers exist between the two markets. Court rulings may also allow for independent market prices; for example, the European Court of Justice's ruling of the Tesco–Levi case expressly endorses Levi's right to charge up to twice the price for a pair of jeans in the EU as it charges in the US (BBC News, 2001).

It is difficult to maintain different market prices in some other situations. The prevalence of parallel trade, for example, often equalizes market prices within a certain range. This is especially true when the court is concerned with antitrust practices and sympathizes with the parallel traders. The European Court of Justice recently ruled that "differences in national price regulations are in themselves not

Figure 4: Impact of price band α on capacity investment.



Note: Figure 4 was obtained by using similar parameter values as that in Figure 2, except that we fix $\mu_0 = 10$, $cv_0 = 0.3$, $\mu_1 = 5$, and $cv_1 = 0.3$.

a sufficient justification [to impede parallel trade]" (EUROPA, 2008). Hence, the European Court of Justice contends that firms have the right to set differential prices, but they cannot maintain that right by impeding parallel trade.

We can incorporate dependent market prices by imposing an additional price constraint on Equation (2) such that $|p_0 - p_1| \leq \alpha$, where $\alpha \geq 0$ is the market *price band*. Setting $\alpha = \infty$ recovers our base model. A decrease in the price band is associated with tighter price restrictions between the existing and the new market. Intuitively, all else equal a decrease in α tends to increase (decrease) the supply to the market with higher (lower) prices, and hence reduces the price differential between the two markets. Note that because of the price restriction brought by α, the firm's decision problem cannot be decoupled. Numerical experiment suggests that the firm's optimal capacity investment is in general not monotonic in α: as α decreases, the optimal capacity may initially increase but then eventually decreases (Figure 4).

Figure 4(a) is an example of the additive market uncertainty case. Note that as α decreases, the firm decreases its capacity investment in both the export and the FDI strategies. Note also that when α drops below 3.0, the FDI strategy abandons new market entry altogether. Because price restriction dampens the value of flexibility, it is not surprising that price band α tends to reduce the level of capacity investment in the export strategy as well. Figure 4(b) illustrates the multiplicative market uncertainty case where it can be optimal for both the export strategy and the FDI strategy to abandon capacity investment in the new market when α becomes very restrictive. The following proposition formalizes this observation.

Proposition 11: All else equal, a firm may abandon market entry when price band α approaches zero.

From a trade regulation perspective, then, price regulation may have a significant impact on the firm's capacity investment decisions. Court opinions on parallel trade, for example, may unwittingly hurt customers in the new market when price pressure hinders the firm's expansion to the new market. It is also clear that our earlier result (Proposition 10) is no longer true in general. That is, with dependent market prices it is possible that capacity investment in the new market may result in a decrease in the firm's expected supply to its existing market.

In summary, if the firm cannot perfectly price-discriminate between the existing and the new market, then the firm in the export strategy may be less likely to engage in capacity investment, and there is no guarantee that capacity investment in export strategy will not decrease the supply to the firm's existing market. From a policy point of view, trade policies that influence a firm's ability to price differentiate between markets can have a significant impact on the firm's capacity investment decisions.

Multiple Periods

We investigate in this section whether or not the results in our base model carry over to a multiperiod setting. Specifically, the firm makes a capacity investment decision at stage 0, and this capacity remains as a production upper bound in all subsequent periods. Production decisions are made at the beginning of each period. Let $\hat{c}_i^f$ ($\hat{c}_i^d$) denote the unit production cost, and hence $c_i^f - \hat{c}_i^f$ ($c_i^d - \hat{c}_i^d$) is the unit capacity investment cost. In each period, let $y \geq x$ denote the inventory after production decision, where x is the amount of inventory at the beginning of each period. Let $0 < \gamma < 1$ denote the one-period discount factor and h denote the per-unit holding cost for leftover inventories. We focus on the export strategy because the FDI strategy can be analogously solved. The expected value function starting at the beginning of period t with a starting inventory of x is

$$V_t\big(K_0^f, x \mid K_0\big) = \max_{y \leq x+K_0+K_0^f} -\hat{c}_0^f(y-x) + \mathsf{E}_{\vec{\epsilon}}\big[\Pi_f^*(y \mid \vec{\epsilon}) + \gamma V_{t+1}\big(K_0^f, y-x|K_0\big)\big], \tag{12}$$

where $\Pi_f^*(y, \vec{\epsilon}) = \max_{q_{00}+q_{01} \leq y} \; p_0(q_{00}, \epsilon_0)q_{00} + p_1(q_{01}, \epsilon_1)q_{01} - \delta q_{01} - h(y - q_{00} - q_{01})$. In the last period, the terminal condition for the expected value function satisfies $V_{T+1}(K_0^f, x|K_0) = \hat{c}_0^f x$. Define $G(K_0^f, y|K_0) = -\hat{c}_0^f y + \mathsf{E}_{\vec{\epsilon}}\Pi_f^*(y|\vec{\epsilon})$. The expected value function can be rewritten as $V_t(K_0^f, y|K_0) = \max_{y \leq K_0+K_0^f+x} G(K_0^f, y|K_0) + \gamma \mathsf{E}_{\vec{\epsilon}} V_{t+1}(K_0^f, y - q_{00} - q_{01}|K_0) + \hat{c}_0^f x$. Notice that $x \geq 0$ for any period because of responsive pricing. The form of the expected value function is similar to that of Van Mieghem and Rudi (2002), hence we leverage Proposition 4 in Van Mieghem and Rudi (2002, p. 329) to prove that a base-stock policy is optimal.

Proposition 12: A base-stock policy with level S^* is optimal, where S^* maximizes the one-period profit function $G(K_0^f, y \mid K_0)$.

Assuming that the firm follows the optimal base-stock policy, the optimal expected profit in each period is stationary, and therefore the capacity investment decision at time 0 can be obtained by solving

$$J^* = \max_{K_0^f} -\left(c_0^f - \hat{c}_0^f\right)K_0^f + V_1\left(K_0^f, 0 \mid K_0\right)$$
$$= \max_{K_0^f} -\left(c_0^f - \hat{c}_0^f\right)K_0^f + \frac{1-\gamma^T}{1-\gamma}G\left(K_0^f, S^* \mid K_0\right), \tag{13}$$

Comparing Equation (13) with the single-period value function of Equation (1) and recognizing that $\gamma < 1$, one can see that the optimal capacity investment in a multiperiod setting is higher than that in a single-period setting. This is somewhat expected because the longer time horizon increases the value of capacity investment. It is challenging to directly compare the optimal capacity investment level between the export and the FDI strategy in the multiperiod setting, but Equation (13) seems to suggest that the optimal capacity expansion decision is not fundamentally altered by the multiperiod setting (because $G(K_0^f, S^* | K_0)$ is exactly the one-period profit function). Nevertheless, we believe that further investigation is merited in future research.

CONCLUSION

In this research we study a firm's capacity investment problem with responsive pricing under two commonly observed market entry strategies, namely, the export strategy and the FDI strategy. A unique feature of this research is that we explicitly consider the firm's existing production capacity, which is often absent in the global facility network design literature. The consideration of the firm's existing capacity is important because, for example, Khanna and Palepu (2010) found that firms typically expand into global markets only after they have already established some existing domestic production capabilities. It is the existence of such production facilities that give rise to strategic questions of exporting versus FDI, which "concerns the extent to which the firm will export or produce locally. It can rely on 100 percent export of finished goods, export of components but localized assembly, 100 percent local production, and so on" (Gupta & Govindarajan, 2000, p. 48).

We found that the firm's existing capacity has a significant, nonmonotonic effect on the firm's strategic preference between export and FDI: a higher existing capacity makes the FDI strategy more attractive, but only up to a certain point, beyond which the export strategy becomes more attractive. In contrast, the effect of exporting cost on the firm's strategic choice is fairly straightforward: the export strategy becomes less attractive as the exporting cost increases. We prove, however, that even if exporting cost approaches infinity, it is possible that the firm may still prefer (the degenerate) export strategy to the FDI strategy.

From a planning perspective, we prove that all else equal, a firm in the export strategy may invest in a higher capacity level than would a firm in the FDI strategy. This result holds even if one of the markets does not exhibit any uncertainty, a result that cannot happen if market price is exogenous. Furthermore, we prove that a firm in the FDI strategy supplies less (in expectation) to its existing market but a firm using export strategy may not. We also show that regulatory price restrictions may dampen the firm's capacity investment in both the existing and the new market; extreme price restriction may result in the firm abandoning the new market altogether. From a trade regulation point of view, therefore, policy makers should carefully consider such potential impacts when setting trade policies.

The class of capacity investment problem with new market entry offers a number of future research opportunities. How would the possibility of supply disruption, for example, influence the firm's capacity investment levels between the export and the FDI strategies? Also, trade barriers (Wang, Gilland, & Tomlin, 2011) and regulations (World Trade Organization, 2011) may create stochastic allocation costs such that δ becomes a random variable. How would such trade barriers influence the firm's market entry decisions? Another aspect worth exploring is the implication of lead times: the firm in the export strategy may encounter longer and oftentimes stochastic lead times to supply the new market. How would such stochastic lead times affect the firm's preference toward export versus FDI strategy? We hope answers to these and other questions will yield further insights into the firm's capacity investment problem under different market entry strategies.

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APPENDIX: PROOFS

Proof of Proposition 1: We first present a more general result using special properties of the class of mathematical programs similar to that in Equations (2) and (5). □

Lemma 1: Let $f : U \rightarrow R$ be a continuous, twice-differentiable function, where U is a convex subset of R^n. Let g_i, $i = 1, \ldots, m$, be convex functions on $U \rightarrow R$. For any $\vec{b} \in R^m$, let $V(\vec{b})$ denote the optimal solution to the following mathematical programming

$$\max f(\vec{x}) \quad \text{s.t.} \quad \vec{x} \in U : g_i(\vec{x}) \leq b_i, \quad i = 1, \ldots, m. \tag{A1}$$

If f is concave, then $V(\vec{b})$ is concave in $\vec{b}$.

Proof: The lemma statement and its proof are similar to Theorem 21.23 (b) in Simon and Blume (1994, p. 533). We briefly present the proof for completeness. Let $\vec{b}^0 = t\vec{b}^1 + (1-t)\vec{b}^2$ for any $0 \leq t \leq 1$. Let $\vec{x}^i$, $i = 0, 1, 2$, denote the respective set of $\vec{x}$ that maximizes f corresponding to $\vec{b}^i$. For $j = 1, \ldots, m$, we have

$$g_j(t\vec{x}^1 + (1-t)\vec{x}^2) \leq tg_j(\vec{x}^1) + (1-t)g_j(\vec{x}^2) \leq tb_j^1 + (1-t)b_j^2 = b_j^0.$$

It follows that any linear combination of $t\vec{x}^1 + (1-t)\vec{x}^2$ is again a feasible solution to Equation (A1) under $\vec{b}^0$. By definition, the optimal solution to Equation (A1) under $\vec{b}^0$ is given by $V(\vec{b}^0) = f(\vec{x}^0)$. Because by assumption f is concave, we have

$$\begin{aligned} V(\vec{b}^0) &= f(\vec{x}^0) \geq f(t\vec{x}^1 + (1-t)\vec{x}^2) \geq tf(\vec{x}^1) + (1-t)f(\vec{x}^2) \\ &= tV(\vec{b}^1) + (1-t)V(\vec{b}^2), \end{aligned}$$

which is the definition of concave functions. □

Hence, the proposition statement is true if $\Pi_f(\vec{q}\,|K_0^f, K_0, \vec{\epsilon})$ and $\Pi_d(\vec{q}\,|K_1^d, K_0, \vec{\epsilon})$ are both concave functions. Consider $\Pi_f(\vec{q}\,|K_0^f, K_0, \vec{\epsilon})$, by Equation (2) we have $\frac{\partial^2 \Pi_f(\vec{q}|K_0^f, K_0, \vec{\epsilon})}{\partial q_i^2} = p_i''(q_i, \epsilon_i)q_i + 2p_i'(q_i, \epsilon_i)$. Define $H_i(\cdot, \epsilon_i) = p_i^{-1}(\cdot, \epsilon_i)$. We have $H_i(p_i(q_i, \epsilon_i), \epsilon_i) = q_i$. For presentational clarity, in what follows we drop the parameter ϵ_i and simply write, for example, $H_i(p_i(q_i)) = q_i$. By chain rule, we have $H_i'(p_i(q_i))p_i'(q_i) = 1 \Rightarrow p_i'(q_i) = 1/H_i'(p_i(q_i)) = 1/h_i(p_i(q_i))$, where we use $h_i(\cdot)$ to denote the derivative of $H_i(\cdot)$. Also note that $p_i''(q_i) = -(1/h_i^2(p_i(q_i)))h_i'(p_i(q_i))p_i'(q_i) = -h_i'(p_i(q_i))/h_i^3(p_i(q_i))$. Substituting $p_i'(q_i)$ and $p_i''(q_i)$ into the expression of $\frac{\partial^2 \Pi_f(\vec{q}|K_0^f, K_0, \vec{\epsilon})}{\partial q_i^2}$, we have

$$\frac{\partial^2 \Pi_f\left(\vec{q}\,|K_0^f, K_0, \vec{\epsilon}\right)}{\partial q_i^2} = \frac{-h_i'(p_i(q_i))H_i(p_i(q_i)) + 2h_i^2(p_i(q_i))}{h_i^3(p_i(q_i))}. \tag{A2}$$

Because $h_i(\cdot) \leq 0$ (demand decrease in price), the R.H.S. of Equation (A2) is nonpositive if and only if $-h_i'(p_i(q_i))H_i(p_i(q_i)) + 2h_i^2(p_i(q_i)) \geq 0$. Because $H_i(\cdot, \epsilon_i) = p_i^{-1}(\cdot, \epsilon_i)$, by Assumption 1, we have $h_i^2(x) \geq H_i(x)h_i'(x) \Rightarrow -h_i'(p_i(q_i))H_i(p_i(q_i)) + 2h_i^2(p_i(q_i)) \geq 0$. Further note that $\frac{\partial^2 \Pi_f(\vec{q}|K_0^f, K_0, \vec{\epsilon})}{\partial q_i \partial q_j} = 0$. It follows that $\Pi_f(\vec{q}\,|K_0^f, K_0, \vec{\epsilon})$ is concave in $\vec{q}$. The proposition statement then follows by applying Lemma 1. The proof for $\Pi_d(\vec{q}|K_1^d, K_0, \vec{\epsilon})$ follows analogously. $\square$

Proof of Proposition 2: The proposition statement follows from Proposition 1, and specific expressions of $\partial\Pi_f^*(K_0^f|K_0, \vec{\epsilon})/\partial K_0^f$ in different demand regions Ω_2 to Ω_3 can be obtained by taking first-order derivatives of Equation (7) with respect to K_0^f. The marginal value of K_1^d in the FDI strategy $\partial\Pi_d^*(K_1^d|K_0, \vec{\epsilon})/\partial K_1^d$ can be similarly obtained. $\square$

Proof of Proposition 3: Part (a). We prove the proposition statement by contradiction. Suppose $\delta \le c_1^d - c_0{}^f$ but $V_f^* < V_d^*$. Let K_0^{f*} and K_1^{d*} denote the corresponding optimal capacities. Because $\delta \le c_1^d - c_0^f \Rightarrow c_0^f + \delta \le c_1^d$, $V_d(K_1^{d*}|K_0) \le V_d(K_1^{d*} - \xi_K|K_0) + V_f(\xi_K|K_0)$ for any $0 \le \xi_K \le K_1^{d*}$. Setting $\xi_K \le K_1^{d*}$, we have $V_d(K_1^{d*}|K_0) \le V_f(K_1^{d*}|K_0) \le V_f(K_0^{f*}|K_0)$, proving the contradiction.

Part (b). By Proposition 2, the unit exporting cost δ is incurred only in regions $\Omega_e = \Omega_{2.2} \cup \Omega_{3.1} \cup \Omega_{3.2}$. Let Ω_e^f and Ω_e^d denote the respective exporting regions for the export and FDI strategy, respectively. Applying the envelope theorem to Equations (1) and (4), we have

$$\frac{\partial V_f^*}{\partial \delta} = \frac{\partial \Pi_f^*\big(K_0^f|K_0\big)}{\partial \delta} = -\mathsf{E}_{\Omega_e^f}\big[q_{01}^*|K_0^f\big],$$
$$\frac{\partial V_d^*}{\partial \delta} = \frac{\partial \Pi_d^*\big(K_1^d|K_0\big)}{\partial \delta} = -\mathsf{E}_{\Omega_e^d}\big[q_{01}^*|K_1^d\big],$$

where the last equalities follow from Proposition 2. First observe that for any given realized market uncertainty $\vec{\epsilon}$, $q_{01}^*|K_0^f \ge q_{01}^*|K_1^d$, because the exporting quantity under the FDI strategy is a relaxation of that in the export strategy. By definition of the demand space partitions, $\Omega_e^f \ge \Omega_e^d$. Combining the above two observations, we have $\mathsf{E}_{\Omega_e^f}[q_{01}^*|K_0^f] \ge \mathsf{E}_{\Omega_e^d}[q_{01}^*|K_1^d] \Rightarrow \partial V_f^*/\partial\delta \le \partial V_d^*/\partial\delta$. The proposition statement then follows directly.

Part (c). We prove the proposition statement by constructing an example. First partition ϵ_0 into two regions Γ_0 and Γ_1, where $\Gamma_1 = \{\epsilon_0 : \mathrm{MR}_0(K_0, \epsilon_0) \ge 0\}$ and Γ_0 is the complement of Γ_1. Let $\overline{K}_0$ be the unique solution to $\mathsf{E}_{\Gamma_1}[\mathrm{MR}_0(\overline{K}_0, \epsilon_0)] = c_0$. In essence, $\overline{K}_0$ is the upper bound on the firm's existing capacity such that if $K_0 \ge \overline{K}_0$, then $K_0^{f*} = 0$ if the firm serves its existing market demand only. Conversely, if $K_0 < \overline{K}_0$, then all else equal, $K_0^{f*} > 0$ even if the firm does not enter the new market (i.e., when $\delta = \infty$). Following similar logic, partition ϵ_1 into two regions Ψ_0 and Ψ_1, where $\Psi_1 = \{\epsilon_1 : \mathrm{MR}_1(K_1^d, \epsilon_1) \ge 0\}$ and Ψ_0 is the complement of Ψ_1. If $\mathsf{E}_{\Psi_1}[\mathrm{MR}_1(\overline{0}, \epsilon_1)] \le c_1^d$, then $K_1^{d*} = 0$. Hence, if $c_0 = c_0^f = c_1^d$, $K_0 < \overline{K}_0$, and $\mathsf{E}_{\Psi_1}[\mathrm{MR}_1(0, \epsilon_1)] \le c_1^d$, we have $K_0^{f*} > 0$, $K_1^{d*} = 0$, and $V_f^* > V_d^*$, where the inequality follows from the fact that $V_f^* > V_f(0|K_0) = V_d(0|K_0) = V_d^*$. This completes the proof for part (c). $\square$

Proof of Corollary 1: We note that condition (ii) guarantees that if $\delta = \infty$ then $K_0^{f*} = 0$ because $\overline{K}_0$ is the optimal capacity investment level for the existing market only. Condition (iii) guarantees that it is optimal to invest in a positive amount of capacity $K_1^{d*} > 0$ if $\delta = \infty$. It follows that when conditions (ii) and (iii) hold, $K_1^{d*} > 0$ and $K_0^{f*} = 0$ when $\delta = \infty$. It follows that $V_f^* < V_d^*$ at $\delta = \infty$. By Proposition 3, $V_f^* > V_d^*$ at $\delta = 0$ when condition (i) holds and $\partial(V_f^* - V_d^*)/\partial\delta$ monotonically decreases. By the interior point theorem, there exists a unique $\overline{\delta}$ such that $V_f^* \geq V_d^*$ for any $\delta \leq \overline{\delta}$ and $V_f^* < V_d^*$ for $\delta > \overline{\delta}$. □

Proof of Proposition 4: Part (a). Applying implicit function theorem to Equation (8), we have $\frac{\partial K_0^{f*}}{\partial K_0} = -\frac{\partial v/\partial K_0}{\partial v/\partial K_0^{f*}}$, where $v = -c_0^f + \sum_{i=1}^3 \mathsf{E}_{\Omega_{3.i}}[\frac{\partial \Pi_f^*(K_0^f|K_0,\vec{\epsilon})}{\partial K_0^f}]$. By Proposition 1, we have $\partial v/\partial K_0^{f*} < 0$. Note that $\frac{\partial v}{\partial K_0} = \mathsf{E}_{\Omega_{3.1}}[\frac{\partial \text{MR}_1(K_0+K_0^f,\epsilon_1)}{\partial K_0}] + \mathsf{E}_{\Omega_{3.2}}[\frac{\partial \text{MR}_0(K_0+K_0^f-q_{01}^*,\epsilon_0)}{\partial K_0}] + \mathsf{E}_{\Omega_{3.3}}[\frac{\partial \text{MR}_0(K_0+K_0^f,\epsilon_0)}{\partial K_0}]$. Because for any given $\vec{\epsilon}$, $\partial MR_i(x, \epsilon_i)/\partial x \leq 0$, it follows that $\partial v/\partial K_0 \leq 0$ and hence the proposition statement follows directly. Part (b) can be analogously proved.

Part (c).

$$
\begin{aligned}
\frac{\partial V_f^*}{\partial K_0} &= -c_0 + \frac{\partial \mathsf{E}_{\vec{\epsilon}}\Pi_f^*\big(K_0^{f*}|K_0,\vec{\epsilon}\big)}{\partial K_0} = -c_0 + \mathsf{E}\left[\sum_{i=1}^3 \Omega_{3.i}\frac{\partial \Pi_f^*\big(K_0^{f*}|K_0,\vec{\epsilon}\big)}{\partial K_0}\right] \\
&= -c_0 + \mathsf{E}_{\Omega_{3.1}}\big[\text{MR}_1\big(K_0 + K_0^{f*}, \epsilon_1\big) - \delta\big] + \mathsf{E}_{\Omega_{3.2}}\big[\text{MR}_0\big(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\big)\big] \\
&\quad + \mathsf{E}_{\Omega_{3.3}}\big[\text{MR}_0\big(K_0 + K_0^{f*}, \epsilon_0\big)\big] \\
&= -c_0 + \mathsf{E}\left[\sum_{i=1}^3 \Omega_{3.i}\frac{\partial \Pi_f^*\big(K_0^{f*}|K_0,\vec{\epsilon}\big)}{\partial K_0^f}\right] = -c_0 + c_0^f.
\end{aligned}
$$

Part (d).

$$
\begin{aligned}
\frac{\partial V_d^*}{\partial K_0} &= -c_0 + \frac{\partial \mathsf{E}_{\vec{\epsilon}}\Pi_d^*\big(K_1^{d*}|K_0,\vec{\epsilon}\big)}{\partial K_0} = -c_0 + \mathsf{E}\left[\sum_i \Omega_i\frac{\partial \Pi_d^*\big(K_1^{d*}|K_0,\vec{\epsilon}\big)}{\partial K_0}\right] \\
&= -c_0 + \mathsf{E}_{\Omega_1}\left[\text{MR}_0(K_0, \epsilon_0)\right] + \mathsf{E}_{\Omega_{3.1}}\big[\text{MR}_1\big(K_0 + K_1^{d*}, \epsilon_1\big) - \delta\big] \\
&\quad + \mathsf{E}_{\Omega_{3.2}}\big[\text{MR}_0\big(K_0 - q_{01}^*, \epsilon_0\big)\big] + \mathsf{E}_{\Omega_{3.3}}\left[\text{MR}_0(K_0, \epsilon_0)\right] \\
&= -c_0 + \mathsf{E}\left[\sum_i \Omega_i\frac{\partial \Pi_d^*\big(K_1^{d*}|K_0,\vec{\epsilon}\big)}{\partial K_1^d}\right] + \mathsf{E}_{\Omega_1}\left[\text{MR}_0(K_0, \epsilon_0)\right] \\
&\quad - \mathsf{E}_{\Omega_{2.2}}\big[\text{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)\big] \\
&\quad - \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\big[\text{MR}_1\big(K_1^d, \epsilon_1\big)\big] + \mathsf{E}_{\Omega_{3.3}}[\text{MR}_0(K_0, \epsilon_0)] - \Pr(\Omega_{3.1} \cup \Omega_{3.2})\delta \\
&= -c_0 + c_1^d + \mathsf{E}_{\Omega_1\cup\Omega_{3.3}}[\text{MR}_0(K_0, \epsilon_0)] - \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\big[\text{MR}_1\big(K_1^d, \epsilon_1\big)\big] \\
&\quad - \Pr(\Omega_{2.2} \cup \Omega_{3.1} \cup \Omega_{3.2})\delta.
\end{aligned}
$$

□

Proof of Proposition 5: By part (c) of Proposition 4, $\partial V_f^*/\partial K_0 = 0$ when $c_0 = c_0^f$. Hence, the sign of $\partial(V_d^* - V_f^*)/\partial K_0$ depends on $\partial V_d^*/\partial K_0$ only. Although a direct analysis of $\partial V_d^*/\partial K_0$ yields ambiguous sign (part (d) of Proposition 4), we can construct a boundary capacity level $\widetilde{K}_0$ such that the sign of $\partial V_d^*/\partial K_0$ can be unambiguously signed. Consider the case where the firm can invest in $\widetilde{K}_0^f$ and $\widetilde{K}_1^d$ simultaneously and let $\widetilde{K}_0 = K_0 + \widetilde{K}_0^{f*}$, where $\widetilde{K}_0^{f*}$ is the optimal capacity investment level in the existing market assuming the firm can also optimally invest $\widetilde{K}_1^{d*}$ in the new market. Let $\widetilde{V}^*$ denote the corresponding optimal expected profit. Because the FDI strategy is a constrained version of the above described scenario, it is clear that $V_d^* \leq \widetilde{V}^*$. Leveraging Proposition 1, it is straightforward to show that $\widetilde{V}$ is jointly concave in $\widetilde{K}_0^f$ and $\widetilde{K}_1^d$. It follows that $\partial V_d^*/\partial K_0 > 0$ for $K_0 < \widetilde{K}_0$ and $\partial V_d^*/\partial K_0 < 0$ for $K_0 > \widetilde{K}_0$. The uniqueness of $\widetilde{K}_0$ follows the fact that $\widetilde{V}$ is jointly concave in $\widetilde{K}_0^f$ and $\widetilde{K}_1^d$. Finally, $\widetilde{K}_0 > \overline{K}_0$ because $\overline{K}_0$ is a constrained capacity investment decision when the firm serves the existing market only. □

Proof of Proposition 6: Part (a). By part (b) of Proposition 2, $\mathsf{E}[\boldsymbol{\epsilon}_1] \leq c_1^d \Rightarrow K_1^{d*} = 0$, in other words, the firm in the FDI strategy does not invest any dedicated capacity in the new market. In the export strategy, if $\text{MR}_1(0, \epsilon_1) > \delta$ then by part (a) of Proposition 2 the optimal (interior) K_0^{f*} satisfies $c_0^f = \sum_{i=1}^{3} \mathsf{E}_{\Omega_{3.i}}[\frac{\partial \Pi_f^*(K_0^f|K_0,\vec{\epsilon})}{\partial K_0^f}] = \mathsf{E}_{\Omega_{3.1}}[\text{MR}_1(K_0 + K_0^f, \epsilon_1) - \delta] + \mathsf{E}_{\Omega_{3.2}}[\text{MR}_1(K_0 + K_0^f - q_{01}^*, \epsilon_1)] + \mathsf{E}_{\Omega_{3.3}}[\text{MR}_0(K_0 + K_0^f, \epsilon_0)] > \mathsf{E}_{\Gamma_1}[\text{MR}_0(\overline{K}_0, \epsilon_0)]$, where Γ_1 is defined in the proof of part (c) of Proposition 3. Note that in the above expression the region $\Omega_{3.1}$ is nonempty because by assumption (ii) there exists $\epsilon_1 > \overline{\epsilon}_1$. Note that $\overline{K}_0$ exactly satisfies $c_0 = \mathsf{E}_{\Gamma_1}[\text{MR}_0(\overline{K}_0, \epsilon_0)]$, combining this with the fact that $c_0^f \leq c_0$, it follows directly that $K_0^{f*} > 0$.

Part (b). By the above analysis, if $\mathsf{E}[\boldsymbol{\epsilon}_1] > c_1^d$ then $K_1^d \geq 0$. Define $\Delta K = K_0^{f*} - K_1^{d*}$, then $\Delta K > 0$ when $\mathsf{E}[\boldsymbol{\epsilon}_1] = c_1^d$. Because $V_d(K_1^d|K_0)$ is continuous, concave in K_1^d (Proposition 1), and $\text{MR}_1(x, \epsilon_1)$ is increasing in x for any x, K_1^{d*} is monotonically increasing in ϵ_1. Hence, by the intermediate value theorem, there exists a $\overline{c}_1^d$ such that for all $\mathsf{E}[\boldsymbol{\epsilon}_1] \leq \overline{c}_1^d$, $\Delta_K > 0 \Rightarrow K_1^{d*} < K_0^{f*}$. □

Proof of Proposition 7: Part (a). It suffices to prove that $\partial V_f^*/\partial \epsilon_1 \geq 0$. Applying the envelope theorem to Equation (1), we have $\frac{\partial V_f^*}{\partial \epsilon_1} = \frac{\partial \mathsf{E}_{\vec{\epsilon}} \Pi_f^*(K_0^{f*}|K_0,\vec{\epsilon})}{\partial \epsilon_1} = \mathsf{E}_{\Omega_{2.2}}[\frac{\partial R_1(q_{01}^*,\epsilon_1)}{\partial \epsilon_1}] + \mathsf{E}_{\Omega_{3.1}}[\frac{\partial R_1(K_0+K_0^{f*},\epsilon_1)}{\partial \epsilon_1}] + \mathsf{E}_{\Omega_{3.2}}[\frac{\partial R_1(q_{01}^*,\epsilon_1)}{\partial \epsilon_1}] > 0$, where the inequality follows from Assumption 2 and the fact that $\frac{\partial \text{MR}_1(\cdot,\epsilon_1)}{\partial \epsilon_1} > 0 \Rightarrow \frac{\partial \int \text{MR}_1(x,\epsilon_1)}{\partial \epsilon_1} dx > 0 \Rightarrow \frac{\partial R_1(\cdot,\epsilon_1)}{\partial \epsilon_1} > 0$.

Part (b). Following analogously from part (a), we have $\frac{\partial V_d^*}{\partial \epsilon_1} = \frac{\partial \mathsf{E}_{\vec{\epsilon}} \Pi_d^*(K_1^{d*}|K_0,\vec{\epsilon})}{\partial \epsilon_1} = \mathsf{E}_{\Omega_0 \cup \Omega_1}[\frac{\partial R_1(q_{11}^*,\epsilon_1)}{\partial \epsilon_1}] + \mathsf{E}_{\Omega_{2.1}}[\frac{\partial R_1(K_1^{d*},\epsilon_1)}{\partial \epsilon_1}] + \mathsf{E}_{\Omega_{2.2}}[\frac{\partial R_1(K_1^{d*}+q_{01}^*,\epsilon_1)}{\partial \epsilon_1}] + \mathsf{E}_{\Omega_{3.1}}[\frac{\partial R_1(K_0+K_1^{d*},\epsilon_1)}{\partial \epsilon_1}] + \mathsf{E}_{\Omega_{3.2}}[\frac{\partial R_1(K_1^{d*}+q_{01}^*,\epsilon_1)}{\partial \epsilon_1}] + \mathsf{E}_{\Omega_{3.3}}[\frac{\partial R_1(K_1^{d*},\epsilon_1)}{\partial \epsilon_1}] > 0$.

Part (c). The proposition statement is true if $\partial(V_f^* - V_d^*)/\partial \epsilon_1 \leq 0$. By parts (a) and (b), for any given $\vec{\epsilon}$ (i.e., in any Ω regions) the optimal output allocated to market 1 in FDI strategy is greater than that in export strategy (i.e., $q_1^{d*} = q_{11}^{d*} + q_{01}^{d*} > q_{01}^{f*} = q_1^{f*}$) if $K_1^{d*} \geq K_0^{f*}$. Because $R_1(q, \epsilon_1)$ is concave in q, it follows that $R_1^d(\cdot, \epsilon_1) \geq R_1^f(\cdot, \epsilon_1)$ for any given $\vec{\epsilon}$. It is straightforward to show that $\partial R_1(q,$

$\epsilon_1)/\partial\epsilon_1$ is nondecreasing in q, we therefore have $\partial(V_f^* - V_d^*)/\partial\epsilon_1 \leq 0$. Note that if $K_1^{d*} < K_0^{f*}$, however, the reverse is not necessarily true. In other words, $K_1^{d*} < K_0^{f*}$ $\not\Rightarrow \partial(V_f^* - V_d^*)/\partial\epsilon_1 > 0$. □

Proof of Proposition 8: Part (a). By Proposition 2, the optimal (interior) K_0^{f*} satisfies

$$-c_0^f + \mathsf{E}_{\Omega_{3.1}}\big[\mathrm{MR}_1\big(K_0 + K_0^f, \epsilon_1\big) - \delta\big] + \mathsf{E}_{\Omega_{3.2}}\big[\mathrm{MR}_0\big(K_0 + K_0^f - q_{01}^*, \epsilon_0\big)\big] + \mathsf{E}_{\Omega_{3.3}}\big[\mathrm{MR}_0(K_0 + K_0^f, \epsilon_0)\big] = 0. \tag{A3}$$

Let H denote the L.H.S. of Equation (A3), we have $\frac{\partial K_0^{f*}}{\partial\epsilon_1} = -\frac{\partial H/\partial\epsilon_1}{\partial H/\partial K_0^{f*}}$. By Equation (A3), we have

$$\frac{\partial H}{\partial\epsilon_1} = \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial\mathrm{MR}_1\big(K_0 + K_0^f, \epsilon_1\big)}{\partial\epsilon_1}\right] + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial\mathrm{MR}_0\big(K_0 + K_0^f - q_{01}^*, \epsilon_0\big)}{\partial q_{01}^*}\cdot\frac{\partial q_{01}^*}{\partial\epsilon_1}\right]. \tag{A4}$$

Note that in $\Omega_{3.2}$, the optimal q_{01}^* satisfies

$$\mathrm{MR}_1(q_{01}^*, \epsilon_1) - \delta - \mathrm{MR}_0\big(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\big) = 0. \tag{A5}$$

Let I denote the L.H.S. of Equation (A5), we have $\frac{\partial q_{01}^*}{\partial\epsilon_1} = -\frac{\partial I/\partial\epsilon_1}{\partial I/\partial q_{01}^*}$. By Equation (A5), we have

$$\frac{\partial q_{01}^*}{\partial\epsilon_1} = -\frac{\dfrac{\partial I}{\partial\epsilon_1}}{\dfrac{\partial I}{\partial q_{01}^*}} = -\frac{\dfrac{\partial\mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial\epsilon_1}}{\dfrac{\partial\mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial q_{01}^*} - \dfrac{\partial\mathrm{MR}_0\big(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\big)}{\partial q_{01}^*}}. \tag{A6}$$

Substituting Equation (A6) into Equation (A4), we have

$$\begin{aligned}\frac{\partial H}{\partial\epsilon_1} &= \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial\mathrm{MR}_1\big(K_0 + K_0^f, \epsilon_1\big)}{\partial\epsilon_1}\right] \\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[-\frac{\dfrac{\partial\mathrm{MR}_0\big(K_0 + K_0^f - q_{01}^*, \epsilon_0\big)}{\partial q_{01}^*}\cdot\dfrac{\partial\mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial\epsilon_1}}{\dfrac{\partial\mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial q_{01}^*} - \dfrac{\partial\mathrm{MR}_0\big(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\big)}{\partial q_{01}^*}}\right] \\ &= \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial\mathrm{MR}_1\big(K_0 + K_0^f, \epsilon_1\big)}{\partial\epsilon_1}\right] + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial\mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial\epsilon_1}\cdot\eta^f\right],\end{aligned} \tag{A7}$$

where

$$\eta^f = \frac{1}{1 - \frac{\frac{\partial \mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial q_{01}^*}}{\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\right)}{\partial q_{01}^*}}} = \frac{1}{1 + \frac{\mathrm{MR}_1'(q_{01}^*, \epsilon_1)}{\mathrm{MR}_0'\left(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\right)}} > 0, \tag{A8}$$

where for notational ease we use $\mathrm{MR}_i'(x, \epsilon_i) = \partial \mathrm{MR}_i'(x, \epsilon_i)/\partial x$ to denote the partial derivative of marginal revenue function with respective to its first argument. By Equation (A7) and Assumption 2, we conclude that $\partial H/\partial \epsilon_1 > 0$. Now consider $\partial H/\partial K_0^{f*}$, we have

$$\begin{aligned}\frac{\partial H}{\partial K_0^{f*}} &= \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial \mathrm{MR}_1\left(K_0 + K_0^f, \epsilon_1\right)}{\partial K_0^f}\right] + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f - q_{01}^*, \epsilon_0\right)}{\partial K_0^f}\right] \\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f - q_{01}^*, \epsilon_0\right)}{\partial q_{01}^*} \cdot \frac{\partial q_{01}^*}{\partial K_0^f}\right] \\ &\quad + \mathsf{E}_{\Omega_{3.3}}\left[\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f, \epsilon_0\right)}{\partial K_0^f}\right].\end{aligned} \tag{A9}$$

Using a similar approach as in calculating $\partial q_{01}^*/\partial \epsilon_1$, we have

$$\frac{\partial q_{01}^*}{\partial k_0^f} = -\frac{\frac{\partial I}{\partial K_0^f}}{\frac{\partial I}{\partial q_{01}^*}} = -\frac{\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f - q_{01}^*, \epsilon_0\right)}{\partial K_0^f}}{\frac{\partial \mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial q_{01}^*} - \frac{\partial \mathrm{MR}_0\left(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\right)}{\partial q_{01}^*}}. \tag{A10}$$

Substituting Equation (A10) into Equation (A9), we have

$$\begin{aligned}\frac{\partial H}{\partial K_0^{f*}} &= \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial \mathrm{MR}_1\left(K_0 + K_0^f, \epsilon_1\right)}{\partial K_0^f}\right] + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f - q_{01}^*, \epsilon_0\right)}{\partial K_0^f}\right] \\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[-\frac{\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f - q_{01}^*, \epsilon_0\right)}{\partial q_{01}^*} \cdot \frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f - q_{01}^*, \epsilon_0\right)}{\partial K_0^f}}{\frac{\partial \mathrm{MR}_1(q_{01}^*, \epsilon_1)}{\partial q_{01}^*} - \frac{\partial \mathrm{MR}_0\left(K_0 + K_0^{f*} - q_{01}^*, \epsilon_0\right)}{\partial q_{01}^*}}\right] \\ &\quad + \mathsf{E}_{\Omega_{3.3}}\left[\frac{\partial \mathrm{MR}_0\left(K_0 + K_0^f, \epsilon_0\right)}{\partial K_0^f}\right] \\ &= \mathsf{E}_{\Omega_{3.1}}\left[\mathrm{MR}_1'\left(K_0 + K_0^f, \epsilon_1\right)\right] + \mathsf{E}_{\Omega_{3.2}}\left[\mathrm{MR}_1'(q_{01}^*, \epsilon_1) \cdot \eta^f\right] \\ &\quad + \mathsf{E}_{\Omega_{3.3}}\left[\mathrm{MR}_0'\left(K_0 + K_0^f, \epsilon_0\right)\right],\end{aligned} \tag{A11}$$

where η^f is defined in Equation (A8). By Proposition 1 $\mathrm{MR}_i'(\cdot, \epsilon_i) < 0$. Combining with the fact that $\eta^f > 0$, we conclude that $\partial H/\partial K_0^{f*} < 0$. The proposition statement then follows directly.

Part (b). By Proposition 2, the optimal (interior) K_1^{d*} satisfies

$$-c_1^d + \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\big[\mathrm{MR}_1\big(K_1^d, \epsilon_1\big)\big] + \mathsf{E}_{\Omega_{2.2}}\big[\mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)\big] + \mathsf{E}_{\Omega_{3.1}}\big[\mathrm{MR}_1\big(K_0 + K_1^d, \epsilon_1\big)\big] + \mathsf{E}_{\Omega_{3.2}}\big[\mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)\big] = 0. \tag{A12}$$

Let H denote the L.H.S. of Equation (A12), we have $\frac{\partial K_1^{d*}}{\partial \epsilon_1} = -\frac{\partial H/\partial \epsilon_1}{\partial H/\partial K_1^{d*}}$. By Equation (A12), we have

$$\begin{aligned}\frac{\partial H}{\partial \epsilon_1} = {} & \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d, \epsilon_1\big)}{\partial \epsilon_1}\right] \\ & + \mathsf{E}_{\Omega_{2.2}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)}{\partial \epsilon_1} + \frac{\partial \mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)}{\partial q_{01}^*}\cdot\frac{\partial q_{01}^*}{\partial \epsilon_1}\right] \\ & + \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial \mathrm{MR}_1\big(K_0 + K_1^d, \epsilon_1\big)}{\partial \epsilon_1}\right] \\ & + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)}{\partial \epsilon_1} + \frac{\partial \mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)}{\partial q_{01}^*}\cdot\frac{\partial q_{01}^*}{\partial \epsilon_1}\right],\end{aligned} \tag{A13}$$

where we note that the optimal q_{01}^* in $\Omega_{2.2}$ and $\Omega_{3.2}$ satisfy different conditions. In particular, in $\Omega_{2.2}$, the optimal q_{01}^* satisfies $\mathrm{MR}_1(K_1^d + q_{01}^*, \epsilon_1) - \delta = 0$. Applying the implicit function theorem, we have $\frac{\partial q_{01}^*}{\partial \epsilon_1} = -\frac{\partial \mathrm{MR}_1(K_1^d + q_{01}^*, \epsilon_1)}{\partial \epsilon_1} / \frac{\partial \mathrm{MR}_1(K_1^d + q_{01}^*, \epsilon_1)}{\partial q_{01}^*}$. Substituting $\frac{\partial q_{01}^*}{\partial \epsilon_1}$ into Equation (A13), we have $\mathsf{E}_{\Omega_{2.2}}[\frac{\partial \mathrm{MR}_1(K_1^d + q_{01}^*, \epsilon_1)}{\partial \epsilon_1} + \frac{\partial \mathrm{MR}_1(K_1^d + q_{01}^*, \epsilon_1)}{\partial q_{01}^*}\cdot\frac{\partial q_{01}^*}{\partial \epsilon_1}] = 0$. Now consider $\Omega_{3.2}$. The optimal q_{01}^* satisfies

$$\mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big) - \delta - \mathrm{MR}_0(K_0 - q_{01}^*, \epsilon_0) = 0. \tag{A14}$$

Let I denote the L.H.S. of Equation (A14), we have $\frac{\partial q_{01}^*}{\partial \epsilon_1} = -\frac{\partial I/\partial \epsilon_1}{\partial I/\partial q_{01}^*}$. By Equation (A14), we have

$$\frac{\partial q_{01}^*}{\partial \epsilon_1} = -\frac{\dfrac{\partial I}{\partial \epsilon_1}}{\dfrac{\partial I}{\partial q_{01}^*}} = -\frac{\dfrac{\partial \mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)}{\partial \epsilon_1}}{\dfrac{\partial \mathrm{MR}_1\big(K_1^d + q_{01}^*, \epsilon_1\big)}{\partial q_{01}^*} - \dfrac{\partial \mathrm{MR}_0(K_0 - q_{01}^*, \epsilon_0)}{\partial q_{01}^*}}. \tag{A15}$$

Substituting Equation (A15) into Equation (A13), we have

$$\begin{aligned}\frac{\partial H}{\partial \epsilon_1} &= \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d,\epsilon_1\big)}{\partial \epsilon_1}\right] + \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial \mathrm{MR}_1\big(K_0+K_1^d,\epsilon_1\big)}{\partial \epsilon_1}\right]\\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[-\frac{\dfrac{\partial \mathrm{MR}_0(K_0-q_{01}^*,\epsilon_0)}{\partial q_{01}^*}\cdot\dfrac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial \epsilon_1}}{\dfrac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial q_{01}^*}-\dfrac{\partial \mathrm{MR}_0\big(K_0-q_{01}^*,\epsilon_0\big)}{\partial q_{01}^*}}\right]\\ &= \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d,\epsilon_1\big)}{\partial \epsilon_1}\right] + \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial \mathrm{MR}_1\big(K_0+K_1^d,\epsilon_1\big)}{\partial \epsilon_1}\right]\\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial \epsilon_1}\cdot\eta^d\right], \qquad \text{(A16)}\end{aligned}$$

where

$$\eta^d = \frac{1}{1-\dfrac{\dfrac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial q_{01}^*}}{\dfrac{\partial \mathrm{MR}_0(K_0-q_{01}^*,\epsilon_0)}{\partial q_{01}^*}}} = \frac{1}{1+\dfrac{\mathrm{MR}_1'\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\mathrm{MR}_0'(K_0-q_{01}^*,\epsilon_0)}} > 0. \qquad \text{(A17)}$$

By Equation (A16) and Assumption 2, we conclude that $\partial H/\partial\epsilon_1 > 0$. Now consider $\partial H/\partial K_1^{d*}$, we have

$$\begin{aligned}\frac{\partial H}{\partial K_1^d} &= \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d,\epsilon_1\big)}{\partial K_1^d}\right]\\ &\quad + \mathsf{E}_{\Omega_{2.2}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial K_1^d}+\frac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial q_{01}^*}\cdot\frac{\partial q_{01}^*}{\partial K_1^d}\right]\\ &\quad + \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial \mathrm{MR}_1\big(K_0+K_1^d,\epsilon_1\big)}{\partial K_1^d}\right]\\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[\frac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial K_1^d}+\frac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial q_{01}^*}\cdot\frac{\partial q_{01}^*}{\partial K_1^d}\right]. \qquad \text{(A18)}\end{aligned}$$

In $\Omega_{2.2}$, we have $\frac{\partial q_{01}^*}{\partial K_1^d} = -\frac{\partial \mathrm{MR}_1(K_1^d+q_{01}^*,\epsilon_1)}{\partial K_1^d}\Big/\frac{\partial \mathrm{MR}_1(K_1^d+q_{01}^*,\epsilon_1)}{\partial q_{01}^*}$. Substituting $\frac{\partial q_{01}^*}{\partial \epsilon_1}$ into Equation (A18), we have $\mathsf{E}_{\Omega_{2.2}}[\frac{\partial \mathrm{MR}_1(K_1^d+q_{01}^*,\epsilon_1)}{\partial K_1^d}+\frac{\partial \mathrm{MR}_1(K_1^d+q_{01}^*,\epsilon_1)}{\partial q_{01}^*}\cdot\frac{\partial q_{01}^*}{\partial K_1^d}] = 0$. Now consider $\Omega_{3.2}$, we have

$$\frac{\partial q_{01}^*}{\partial k_1^d} = -\frac{\dfrac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial K_1^d}}{\dfrac{\partial \mathrm{MR}_1\big(K_1^d+q_{01}^*,\epsilon_1\big)}{\partial q_{01}^*}-\dfrac{\partial \mathrm{MR}_0(K_0-q_{01}^*,\epsilon_0)}{\partial q_{01}^*}}. \qquad \text{(A19)}$$

Substituting Equation (A19) into Equation (A18), we have

$$\begin{aligned}\frac{\partial H}{\partial K_1^d} &= \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\left[\frac{\partial \mathrm{MR}_1\left(K_1^d,\epsilon_1\right)}{\partial K_1^d}\right] + \mathsf{E}_{\Omega_{3.1}}\left[\frac{\partial \mathrm{MR}_1\left(K_0+K_1^d,\epsilon_1\right)}{\partial K_1^d}\right] \\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[-\frac{\dfrac{\partial \mathrm{MR}_0(K_0-q_{01}^*,\epsilon_0)}{\partial q_{01}^*}\cdot\dfrac{\partial \mathrm{MR}_1\left(K_1^d+q_{01}^*,\epsilon_0\right)}{\partial K_1^d}}{\dfrac{\partial \mathrm{MR}_1\left(K_1^d+q_{01}^*,\epsilon_1\right)}{\partial q_{01}^*}-\dfrac{\partial \mathrm{MR}_0(K_0-q_{01}^*,\epsilon_0)}{\partial q_{01}^*}}\right] \\ &= \mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\left[\mathrm{MR}_1'\left(K_1^d,\epsilon_1\right)\right] + \mathsf{E}_{\Omega_{3.1}}\left[\mathrm{MR}_1'\left(K_0+K_1^d,\epsilon_1\right)\right] \\ &\quad + \mathsf{E}_{\Omega_{3.2}}\left[\mathrm{MR}_1'\left(K_1^d+q_{01}^*,\epsilon_1\right)\cdot\eta^d\right], \qquad \text{(A20)}\end{aligned}$$

where η^d is defined in Equation (A17). By Proposition 1, $\mathrm{MR}_i'(\cdot,\epsilon_i) < 0$. Combining with the fact that $\eta^d > 0$, we conclude that $\partial H/\partial K_1^{d*} < 0$. The proposition statement then follows directly. □

Proof of Corollary 2: By the proof of Proposition 8, we have

$$\frac{\partial K_0^{f*}}{\partial \epsilon_1} = -\frac{\mathsf{E}_{\Omega_{3.1}}\left[\dfrac{\partial \mathrm{MR}_1\left(K_0+K_0^f,\epsilon_1\right)}{\partial \epsilon_1}\right] + \mathsf{E}_{\Omega_{3.2}}\left[\dfrac{\partial \mathrm{MR}_1(q_{01}^*,\epsilon_1)}{\partial \epsilon_1}\cdot\eta^f\right]}{\Lambda_f'},$$

$$\frac{\partial K_1^{d*}}{\partial \epsilon_1} = -\frac{\mathsf{E}_{\Omega_{2.1}\cup\Omega_{3.3}}\left[\dfrac{\partial \mathrm{MR}_1\left(K_1^d,\epsilon_1\right)}{\partial \epsilon_1}\right] + \mathsf{E}_{\Omega_{3.1}}\left[\dfrac{\partial \mathrm{MR}_1\left(K_0+K_1^d,\epsilon_1\right)}{\partial \epsilon_1}\right] + \mathsf{E}_{\Omega_{3.2}}\left[\dfrac{\partial \mathrm{MR}_1\left(K_1^d+q_{01}^*,\epsilon_1\right)}{\partial \epsilon_1}\cdot\eta^d\right]}{\Lambda_d'},$$

where Λ_f' and Λ_d' are defined before Corollary 2, and η^f and η^d are defined in Equations (A8) and (A17), respectively.

Part (a). If the inverse demand function is additive, then $R_i(x,\epsilon_i) = p_i(q_i,\epsilon_i)q_i = (p_i(q_i)+\epsilon_i)q_i \Rightarrow \mathrm{MR}_i(x,\epsilon_i) = \mathrm{MR}_i(x)+\epsilon_i \Rightarrow \frac{\partial \mathrm{MR}_i(x,\epsilon_i)}{\partial \epsilon_i} = 1$. It follows that $\frac{\partial(K_0^{f*}-K_1^{d*})}{\partial \epsilon_1} = \frac{-1}{\Lambda_f'} - \frac{-1}{\Lambda_d'} \Rightarrow \frac{\partial(K_0^{f*}-K_1^{d*})}{\partial \epsilon_1} \le 0$ if $\frac{-1}{\Lambda_f'} - \frac{-1}{\Lambda_d'} \le 0 \Leftrightarrow \frac{1}{\Lambda_d'} \le \frac{1}{\Lambda_f'} \Leftrightarrow \Lambda_f' \le \Lambda_d'$.

Part (b). If the inverse demand function is multiplicative, then $R_i(x,\epsilon_i) = p_i(q_i,\epsilon_i)q_i = p_i(q_i)q_i\epsilon_i \Rightarrow \mathrm{MR}_i(x,\epsilon_i) = \mathrm{MR}_i(x)\cdot\epsilon_i \Rightarrow \frac{\partial \mathrm{MR}_i(x,\epsilon_i)}{\partial \epsilon_i} = \mathrm{MR}_i(x) = \mathrm{MR}_i(x,1)$. It follows that $\frac{\partial(K_0^{f*}-K_1^{d*})}{\partial \epsilon_1} = -\frac{\Lambda_f}{\Lambda_f'} + \frac{\Lambda_d}{\Lambda_d'} \Rightarrow \frac{\partial(K_0^{f*}-K_1^{d*})}{\partial \epsilon_1} \le 0$ if $-\frac{\Lambda_f}{\Lambda_f'} + \frac{\Lambda_d}{\Lambda_d'} \le 0 \Leftrightarrow \frac{\Lambda_f}{\Lambda_f'} \ge \frac{\Lambda_d}{\Lambda_d'}$. □

Proof of Remark 1: By Corollary 2, as $\boldsymbol{\epsilon}_1$ becomes sufficiently large (in the stochastic sense), the derivative $\frac{\partial K_0^{f*}}{\partial \epsilon_1}$ is dominated by the region $\Omega_{3.1}$, i.e., $\frac{\partial K_0^{f*}}{\partial \epsilon_1} \approx -\frac{\mathsf{E}_{\Omega_{3.1}}[\frac{\partial \mathrm{MR}_1(K_0+K_0^f,\epsilon_1)}{\partial \epsilon_1}]}{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1'(K_0+K_0^f,\epsilon_1)]}$, and similarly $\frac{\partial K_1^{d*}}{\partial \epsilon_1} \approx -\frac{\mathsf{E}_{\Omega_{3.1}}[\frac{\partial \mathrm{MR}_1(K_0+K_1^d,\epsilon_1)}{\partial \epsilon_1}]}{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1'(K_0+K_1^d,\epsilon_1)]}$. If the inverse demand function is additive, then the above expression can be simplified to $\frac{\partial K_0^{f*}}{\partial \epsilon_1} \approx -\frac{\Pr(\Omega_{3.1})}{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1'(K_0+K_0^f,\epsilon_1)]}$ and $\frac{\partial K_1^{d*}}{\partial \epsilon_1} \approx -\frac{\Pr(\Omega_{3.1})}{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1'(K_0+K_1^d,\epsilon_1)]}$. It follows that when $\Pr(\Omega_{3.1})$ is approximately similar in the export and the FDI strategy (because $\boldsymbol{\epsilon}_1$ is sufficiently large stochastically), $\frac{\partial(K_0^{f*}-K_1^{d*})}{\partial \epsilon_1} \leq 0$ when $K_0^f \leq K_1^d$. If the inverse demand function is multiplicative, then the above expression can be simplified to $\frac{\partial K_0^{f*}}{\partial \epsilon_1} \approx -\frac{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1(K_0+K_0^f,1)]}{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1'(K_0+K_0^f,\epsilon_1)]}$, and similarly $\frac{\partial K_1^{d*}}{\partial \epsilon_1} \approx -\frac{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1(K_0+K_1^d,1)]}{\mathsf{E}_{\Omega_{3.1}}[\mathrm{MR}_1'(K_0+K_1^d,\epsilon_1)]}$. Let the inverse demand function be in the form of $p_i(q_i,\ \epsilon_i) = (a_i - b_i q_i)\epsilon_i$. We have $\frac{\partial K_0^{f*}}{\partial \epsilon_1} \approx -\frac{\mathsf{E}_{\Omega_{3.1}}[a_1-2b_1(K_0+K_0^f)]}{\mathsf{E}_{\Omega_{3.1}}[2b_1\epsilon_1)]} = \mathsf{E}_{\Omega_{3.1}}[\frac{a_1-2b_1(K_0+K_0^f)}{2b_1\epsilon_1}]$, and similarly $\frac{\partial K_1^{d*}}{\partial \epsilon_1} \approx -\frac{\mathsf{E}_{\Omega_{3.1}}[a_1-2b_1(K_0+K_1^d)]}{\mathsf{E}_{\Omega_{3.1}}[2b_1\epsilon_1)]} = \mathsf{E}_{\Omega_{3.1}}[\frac{a_1-2b_1(K_0+K_1^d)}{2b_1\epsilon_1}]$. The corollary statement then follows directly. □

Proof of Proposition 9: Part (a). By Proposition 6, we have $K_0^{f*} > 0$ and $K_1^{d*} = 0$ when the condition in part (a) holds. In addition, by Lemma 4 in Dong et al. (2010), we have $\boldsymbol{\epsilon}_1^a \geq_{ssd} \boldsymbol{\epsilon}_1^b \Rightarrow K_0^{f*}(\boldsymbol{\epsilon}_1^a) \geq K_0^{f*}(\boldsymbol{\epsilon}_1^b)$. Combine the above together, we have $\boldsymbol{\epsilon}_1^a \geq_{ssd} \boldsymbol{\epsilon}_1^b \Rightarrow K_0^{f*}(\boldsymbol{\epsilon}_1^a) - K_1^{d*}(\boldsymbol{\epsilon}_1^a) \geq K_0^{f*}(\boldsymbol{\epsilon}_1^b) - K_1^{d*}(\boldsymbol{\epsilon}_1^b)$.

Part (b) follows from Proposition 6 in Dong et al. (2010). □

Proof of Proposition 10: Part (a). Using part (b) of Proposition 2, there exists positive realizations of ϵ_1 such that $q_{01}^* > 0$. Because in the FDI strategy the capacity investment in the existing market remains the same at K_0, the expected supply available to the existing market decreases from K_0 to $K_0 - E_{\vec{\epsilon}}[q_{01}^*] < K_0$. By the proof of Proposition 2 it is straightforward to see that $\partial q_{00}^*/\partial K_0 \geq 0$, it follows that the expected allocation q_{00}^* decreases as $E_{\vec{\epsilon}}[q_{01}^*]$ increases.

Part (b). First note that $K_0 < \overline{K}_0 \Rightarrow K_0^{f*} > 0$ even if $\epsilon_1 = 0$. Because $E_{\vec{\epsilon}}[q_{00}^*]$ increases in $K_0 + K_0^f$, it follows that the expected supply to the existing market strictly increases. Now consider the case $K_0 = \overline{K}_0$, where any additional capacity investment in K_0^{f*} is strictly triggered by new market demand. We prove this case by contradiction. Suppose the expected supply to the existing market is reduced by $\delta_q > 0$, and this δ_q generated an additional expected profit in the new market for an amount of δ_v^d at the expense of lost revenue in the existing market for an amount of δ_v^f. It follows that $\delta_v^d - \delta_v^f > 0$, suggesting that the marginal benefit of K_0^{f*} is greater than that of K_0, but because $c_0^f = c_0$, it is optimal to further increase K_0^{f*}, contradicting the fact that K_0^{f*} is optimal capacity investment level. □

Proof of Proposition 11: Let $\Pi_f(K_0^f|K_0,\vec{\epsilon};\alpha)$ denote the firm's second stage profit function with price band α. Because the price band α can be viewed as an additional constraint on $\Pi_f(K_0^f|K_0,\vec{\epsilon})$ (Equation (2)), we have $\partial\Pi(K_0^f|K_0,\vec{\epsilon};\alpha)/\partial\alpha \geq 0$. Let $\Pi(K_i|\epsilon_i)$ denote the second stage profit when only market i is served. If $\Pi_f^*(K_0^f|K_0,\vec{\epsilon};\alpha=0) < \max_i \Pi(K_i|\epsilon_i)$, then there exists a unique $\bar{\alpha}$ such that the firm only serves a single market when $\alpha < \bar{\alpha}$. Note that the proposition statement can also be proved by characterizing the firm's optimal allocation decisions contingent on the realizations of market uncertainty. The details are tedious (because α introduces nonlinear demand regions) and is not very insightful and therefore is omitted here. □

Proof of Remark 2: Part (a). The statement follows from the fact that, regardless of the variance of market uncertainty $\boldsymbol{\epsilon}_i$, $i = 0, 1$, the optimal allocation quantity (q_{00}, q_{01}) and (q_{00}, q_{11}) for any given K is identical between the export and the FDI strategies.

Part (b). When $\rho < 1$, the allocation (q_{00}, q_{01}) in the export strategy depends on the partial realizations of market uncertainty ω_i, but the allocation (q_{00}, q_{11}) in the FDI strategy does not. Hence, the optimal allocation, and therefore the capacity investment, can differ between the two strategies. □

Proof of Proposition 12: The proof is identical to the proof of Proposition 4 in (Van Mieghem & Rudi, 2002, p. 333), with the only exception that we do not have the shortage penalty cost term (which is linear in y, the inventory level after production). The expected value function $V_t(K_0^f, x|K_0)$ is therefore also structured (i.e., $V_t(K_0^f, x|K_0)$ is concave in K_0^f and linear in the starting inventory level x). The optimality of the base-stock policy follows from backward induction on time period t. □

Proposition 13: Let $F_0(\cdot)$ and $F_1(\cdot)$ denote the distribution of random demand in the existing and the new market, respectively. Suppose market prices are identical such that $p_0 = p_1 = p$. If $c_1^d - \delta F_0(K_0) \le (p-\delta)\int_0^{K_0} \overline{F}_1(K_0 - x)\, dF_0(x) \le c_0^f - p\overline{F}_0(K_0)$ then $K_1^{d*} \ge K_0^{f*}$.

Proof of Proposition 13: With exogenous price, let $\boldsymbol{\epsilon}_0$ and $\boldsymbol{\epsilon}_1$ denote demand for the existing and the new market, respectively. In addition, let $F_0(\cdot)$ and $F_1(\cdot)$ denote the distribution for $\boldsymbol{\epsilon}_0$ and $\boldsymbol{\epsilon}_1$, respectively. For export strategy, partition the demand space into the following three regions. $\Upsilon_1 = \{\vec{\epsilon} : \epsilon_0 \le K_0 + K_0^f \cap \epsilon_1 \le K_0 + K_0^f - \epsilon_0\}$, $\Upsilon_2 = \{\vec{\epsilon} : \epsilon_0 \le K_0 + K_0^f \cap \epsilon_1 > K_0 + K_0^f - \epsilon_0\}$, and $\Upsilon_3 = \{\vec{\epsilon} : \epsilon_0 > K_0 + K_0^f\}$. Adapting Equations (1) and (2) to the exogenous price case, we have $\mathsf{E}_{\vec{\epsilon}}\Pi_f^*(K_0^f|K_0, \vec{\epsilon}) = \mathsf{E}_{\Upsilon_1}[p\epsilon_0 + (p-\delta)\epsilon_1] + \mathsf{E}_{\Upsilon_2}[\delta\epsilon_0 + (p-\delta)(K_0 + K_0^f)] + \mathsf{E}_{\Upsilon_2}[p(K_0 + K_0^f)]$. It follows that

$$\frac{\partial \mathsf{E}_{\vec{\epsilon}}\Pi_f^*\left(K_0^f|K_0, \vec{\epsilon}\right)}{\partial K_0^f} = \int_0^{K_0+K_0^f} (p-\delta)\overline{F}_1\left(K_0 + K_0^f - \epsilon_0\right) dF_0(\epsilon_0) + p\overline{F}_0\left(K_0 + K_0^f\right).$$

It is straightforward that $\partial^2 \mathsf{E}_{\vec{\epsilon}}\Pi_f^*(K_0^f|K_0, \vec{\epsilon})/\partial K_0^{f^2} \le 0$ and therefore the optimal K_0^{f*} can be obtained by setting

$$-c_0^f + (p-\delta)\int_0^{K_0+K_0^f} \overline{F}_1\left(K_0 + K_0^f - \epsilon_0\right) dF_0(\epsilon_0) + p\overline{F}_0\left(K_0 + K_0^f\right) = 0. \tag{A21}$$

For FDI strategy, partition the demand space into the following five regions. $\hat{\Upsilon}_1 = \{\vec{\epsilon} : \epsilon_0 \le K_0 \cap \epsilon_1 \le K_1^d\}$, $\hat{\Upsilon}_{2.1} = \{\vec{\epsilon} : \epsilon_0 \le K_0 \cap \epsilon_1 \le K_0 + K_1^d - \epsilon_0\}$, $\hat{\Upsilon}_{2.2} = \{\vec{\epsilon} : \epsilon_0 \le K_0 \cap \epsilon_1 > K_0 + K_1^d - \epsilon_0\}$, $\hat{\Upsilon}_3 = \{\vec{\epsilon} : \epsilon_0 > K_0 \cap \epsilon_1 \le K_1^d\}$, and $\hat{\Upsilon}_4 = \{\vec{\epsilon} : \epsilon_0 > K_0 \cap \epsilon_1 > K_1^d\}$. Adapting Equations (4) and (5) to the exogenous price case, we have $\mathsf{E}_{\vec{\epsilon}}\Pi_d^*(K_1^d|K_0, \vec{\epsilon}) = \mathsf{E}_{\hat{\Upsilon}_1}[p\epsilon_0 + p\epsilon_1] + \mathsf{E}_{\hat{\Upsilon}_{2.1}}[p\epsilon_0 + pK_1^d + (p - \delta)(\epsilon_1 - K_1^d)] + \mathsf{E}_{\hat{\Upsilon}_{2.2}}[p\epsilon_0 + pK_1^d + (p-\delta)(K_0 - \epsilon_0)] + \mathsf{E}_{\hat{\Upsilon}_3}[pK_0 + p\epsilon_1)] + \mathsf{E}_{\hat{\Upsilon}_4}$ $[pK_0 + pK_1^d]$. It follows that

$$\frac{\partial \mathsf{E}_{\vec{\epsilon}}\Pi_d^*\big(K_1^d|K_0, \vec{\epsilon}\big)}{\partial K_1^d} = \int_0^{K_0} \big[\delta(F_1\big(K_0 + K_1^d - \epsilon_0\big) - F_1(K_1^d)) + p\overline{F}_1\big(K_0 + K_1^d - \epsilon_0\big)\big]\, dF_0(\epsilon_0).$$

It is straightforward that $\partial^2 \mathsf{E}_{\vec{\epsilon}}\Pi_d^*(K_1^d|K_0, \vec{\epsilon})/\partial {K_1^d}^2 \le 0$ and therefore the optimal K_1^{d*} can be obtained by setting

$$-c_1^d + \int_0^{K_0} [\delta(F_1\big(K_0 + K_1^d - \epsilon_0\big) - F_1(K_1^d)) + p\overline{F}_1\big(K_0 + K_1^d - \epsilon_0\big)]\, dF_0(\epsilon_0) = 0. \tag{A22}$$

The proposition statement then follows by setting Equation (A21) less than zero for $K_0^f = 0$ and by setting Equation (A22) greater than zero for $K_1^d = 0$. □

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