Strategic Foreign Direct Investment in Developing Countries under Demand Uncertainty: Commitment vs. Flexibility

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March 1, 2012

Abstract

The paper analyzes the effect of expected future demand on the investment decisions of multinational enterprises. In particular, I explore the issue of the timing of switching between exporting and FDI in the host developing country and explicitly incorporate the firm's attitude toward risk in the model. The model demonstrates that the optimal time for switching to FDI depends on the expected future demand and the degree of its uncertainty.

Keywords: Foreign Direct Investment, Developing countries, Uncertainty, Switching time, Commitment, Flexibility

JEL Classification: F23, D22

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1. Introduction

In the presence of uncertainty about the future prosperity of an economy, timing of investment arises as a main issue for potential new entrants into the market. Particularly when the information on market demand is incomplete, firms have incentive to delay the investment until the uncertainty is resolved. This situation is more often observed among foreign multinational enterprises than domestic firms because, in general, MNEs have less experience and knowledge in predicting the future profitability of a new market. To gain a better idea on the demand of a host country, MNEs tend to begin by exporting to a new market rather than foreign direct investment. Case studies support this idea that export leads FDI. Survey results suggest that 69 % of the firms in their sample exported to Australia before serving the market via FDI. (Nicholas et al., 1994)

In general, when transportation and other transaction costs of trade are significant, export usually incurs a higher marginal cost of supply than production resulting from FDI. Particularly when transaction occurs between the North and the South, variable costs (major components are labor costs in many cases) of production in high-income source country will exceed those in low-income countries. On the other hand, to serve the foreign market through FDI, the MNE may have to bear the higher fixed cost (most of them are irreversible sunk cost) of investment than export though some fixed cost of exporting will be incurred in establishing a distribution network in the host country. (Buckley and Casson, 1981) Thus, a firm in a foreign market has to choose the mode of entry based on this trade-off. Export is chosen as a means to reduce the risk of investment regarding high sunk costs and potential loss from low demand. As market grows rapidly, however, there comes time when market demand reaches a sufficiently high level to make incurring sunk cost worthwhile, and a MNE has an incentive to build a plant in the foreign country instead of exporting.

Deciding when to switch to FDI could be affected by the uncertainty of demand and market structure as well as the level of demand. The presence of sufficiently large uncertainty generates an option value of waiting. Firms will hesitate to switch to FDI even when they expect demand to hit the threshold level for investment. On the other hand, for a small uncertainty, MNEs have incentive to move first to preempt the market. Firms face a trade-off between commitment by FDI first and flexibility by a wait-and-see strategy.

The purpose of this paper is to propose an explanation of the strategic behavior of MNEs headquartered in developed country with respect to the switching time from exporting to FDI under demand uncertainty in a host developing country. Our model accounts for how the timing and mode of entry strategically chosen[1] by identical firms can persist as equilibrium by reference to key variables without assumption on exogenous heterogeneity across MNEs.[2]

Various sources of uncertainty can affect the investment decision-uncertain cost of production, unexpected political regime change, or factors associated with the goal of FDI. Dunning (1993) suggested that motivation of FDI can fall into four categories: market-seeking, resource-seeking, efficiency-seeking and strategic asset-seeking FDI. Among these, we pay attention to the market-seeking FDI, and assume that the uncertainty originates from the unpredictability of demand side rather than cost side.[3]

This paper contributes to the literature in several ways. First, it demonstrates that the uncertainty plays a crucial role for the occurrence of endogenous sequential FDI. Only a few articles deal with strategic FDI under demand uncertainty. Most of the related literature does not consider uncertainty (Horstmann and Markusen, 1987, Buckley et.al, 1981), FDI (Maggi, 1996, Pacheco-de-Almeida and Zemsky, 2003, Sadanand and Sadanand, 1996) or strategy between multiple firms (Das, 1983, Saggi, 1996, Itagaki, 1991, Ziacik, 2001, Yu, Chang and Fan, 2007). Second, the firm's attitude toward risk is explicitly incorporated in the model. Although the uncertainty may have more negative effects on investment decisions when firms are risk averse than risk neutral, the importance of this rationale is hardly discussed in the related literature. In this paper, firms pursue maximizing CARA (constant absolute risk aversion) utility function. The result suggests that the strategic behavior of duopoly depends

[1] Rob and Vettas (2003) explore entry into a foreign market with uncertain demand growth, but strategic behavior is not considered in the model.

[2] Helpman et al. (2004) show that heterogeneity across firms such as productivity and firm size significantly influence the tendency of firms to substitute FDI for export. In our model, we assume higher productivity of MNEs over domestic firms as initial condition while MNEs within industry are homogeneous. This assumption allows different approach from the argument that within-sector heterogeneity may be an important determinant in organization of the firm.

[3] This assumption is necessary for analysis in our partial equilibrium framework. In a general equilibrium model, both demand shock and supply shock can be analyzed regardless of the goal of FDI. However, Aizenman and Marion (2004) shows that demand shock discourages both vertical and horizontal FDI, while productivity shock adversely affects vertical FDI but promotes horizontal FDI. According to their argument, our assumption of demand uncertainty is more appropriate for analysis of MNE in general case than the alternative assumption of supply uncertainty.

on demand and the joint role of uncertainty and risk aversion[4].

The remainder of the paper is organized as follows. Section 2 discusses the related literature. In section 3, we explore the firm's behavior in a monopoly case as a benchmark case. Section 4 sets up the model and analyzes the equilibrium of duopoly switching time game. Section 5 draws out the implications of the model and concludes.

2. Literature Review

This section relates this paper to existing literature. First, the basic set up of our model borrows the idea of trade-off between exporting and FDI from Buckley and Casson (1981). They analyze optimal timing of switching from exporting to FDI based on NPV (net present value) method, incorporating the costs of servicing the foreign market. As market size increases, the firm that begins by exporting will finally switch to FDI at some point. Here, set-up cost (the cost of transferring technology to the foreign subsidiary) plays a crucial role in postponing time to switch, but not permanently. Their model is one of a few pioneers that attempted to study timing of the switch from exporting to FDI. Their simple assumptions of one firm and no uncertainty are relaxed in this paper.

Horstmann and Markusen (1987) provide conditions on cost structure and technology of multinationals to result in the situation where MNE-domestic production or solely domestic production arises as equilibrium. MNE will emerge in industries in which firm-specific costs and trade costs are large relative to plant-specific costs. High plant-level fixed costs discourage the incentive for centralized production and serving the host country via exporting. Firm-specific activities include organizational activities, advertising expenditures, research facilities and marketing that give a MNE a cost advantage over domestic producers. The firm-specific costs may arise from headquarters services and R&D. (Markusen and Venables, 2000) In our model we use this concept to set the basic assumption that MNEs from a developed source country have firm-specific advantage over domestically owned firms in a developing host country. But the relative magnitude of firm-specific costs to plant-specific costs is not one of main interests in our model, since firms must have already incurred firm-level fixed costs when they built headquarters in the source country before starting export. It

[4] Our model contrasts to R&D competition model in industrial organization literature. In general, cost saving R&D competition model assumes risk-neutral firms, thus strategic behavior is not affected by firms' attitude toward risk, while it is altered by risk aversion in our model. Also in R&D competition model cooperative joint investment can be equilibrium due to externality of knowledge spillovers, while investment is non-cooperative in our model because firms do not have incentive to cooperate in our model setting.

may be more applicable for the case with the firm in its initial stage of organization that cost structure is an important factor in decision making.

Second, the implication of our model can be compared to the industrial organization literature addressing timing issues in investment under uncertainty, despite the different approaches. Maggi (1996) emphasizes the role of uncertainty as a source of asymmetric equilibria when two firms are in the market. If the profitability of a market is uncertain, asymmetric outcome can arise even if firms are *ex ante* identical and have symmetric entry opportunities, provided that irreversible investment has preemptive value, and if and only if capital levels are strategic substitutes. Maggi's model builds on the similar implication of our model in that investment timing could be endogenously determined without using other exogenous conditions such as heterogeneous firm size and technologies. This suggests that introducing uncertainty can yield the implication contrary to the folk theorem which implies that oligopolies are best modeled by Cournot equilibria under the assumption that firms are of equal size, and by Stackelberg equilibria in the presence of different firm size. But this paper contrasts to Maggi's paper in that it extends the case of domestic firms to MNEs involved in international trade. Here, exporting substitutes for the wait-and-see strategy often used in other existing literature, but in fact, exporting gives a more powerful option value than delaying-strategy. By remaining an exporter, firms in our model do not have to invest after the uncertainty is resolved, allowing many possible ways in which entry strategy can evolve; this does not arise in Maggi's model in which export is absent.

Pacheco-de-Almeida and Zemsky (2003) develop a theory of investment under uncertainty when a clear lag exists between investment and production. Allowing time- to-build creates the equilibrium in which the follower invests in both periods. Their benchmark model setting and the implication of the equilibrium is approximately close to our model. If the uncertainty is sufficiently large, the unique equilibrium is both delaying investment, while it is leader-follower equilibrium for small uncertainty. However, Pacheco-de-Almeida and Zemsky do not deal with tradable goods produced by MNEs and their equilibrium is mainly affected by time-to-build, which is not a major issue in this paper.

In Sadanand and Sadanand (1996), both uncertainty and relative firm sizes play crucial role in determining equilibrium. Instead of investment decision as modeled in other literature, they study the timing of irreversible output decisions, where the first-mover advantage is due to the early output decision made by a committed firm in the first period while the other firm defers its output decision and choose its quantity in period 2. Their model suggests that with moderate uncertainty in demand, the larger the disparity in sizes between two firms, the more likely it is that larger firms become Stackelberg leaders and smaller firms are followers. For sufficiently small uncertainty, the Nash equilibrium consists of leader-follower equilibrium even under the assumption of identical firm size. But if the uncertainty is large, this asymmetric equilibrium is replaced by a symmetric Cournot equilibrium where both firms enter the market at the same time. Specifically, Sadanand and Sadanand propose the same idea in explaining identical firms' behavior under small uncertainty with the model of this paper. As in Maggi's paper, however, trade is not modeled in their paper, while it is one of distinctive features in our model. In section 4, we compare the characteristics of equilibrium of our model to theirs.

The third strand of papers deals with FDI decision in the face of uncertainty, but strategies among multiple firms are absent. In his article, Saggi (1998) analyzes a two period model of one firm in the face of switching from exporting to FDI under demand uncertainty. He argues that FDI can occur only when learning from exporting reveals that the market is large enough to support FDI. If the sunk cost as a fraction of fixed cost is not too high, the firm could switch back to exporting in case of low demand. From the role of exporting as a learning process, even a small fixed cost can easily deter FDI as a natural consequence of his model's assumption. In our model, firms are involved in exporting before they face change of market demand, but demand uncertainty is resolved by nature. In addition, the concept of uncertainty differs between two models. In Saggi's model, the uncertainty about demand is represented as the probability that the true value of demand parameter turns out to be either a low value or a high value without reflecting the variability of demand. To the contrary, in our model, the unpredictability associated with attitude toward risk, independently of the level of demand, plays a crucial role in explaining firms' behavior.

Using a different approach and model set-up, Itagaki (1991) develops the model of MNE; FDI is not endogenously chosen, but is initially done by the firm and exporting is an option in the second period. The basic assumption is that a multinational firm maximizes the expected utility of total global profit over domestic output and host country output, and international trade occurs only between MNE's parent firm and foreign subsidiaries. The main results suggest that efficient allocation of capital is still achieved under demand uncertainty in the presence of an MNE, but a risk-averse MNE may invest less and produce less total output than a risk-neutral MNE. The effect of firm's risk-averse nature on resource allocation introduced in Itagaki's article is applied to our model. In his paper, however, timing is not explicitly modeled and international trade does not refer to trade as a substitute for FDI; it is only arm's length transaction in his model.

The main issue addressed in this paper can be compared to Smets' (1993) model. The major implication of duopoly case has a discrepancy between two models, whereas it is quite similar for monopoly case. The main motivation of FDI in his paper is relatively low wage of production in the East (low-income host country) compared to the West (high-income source country). Using optimal stopping time model approach, Smets argues that the presence of uncertainty creates an option value of waiting for the follower, allowing the leader to preempt the market. This idea is also proposed by our model in which sequential leader-follower equilibrium develops endogenously due to the uncertainty about demand. In Smet's model, however, higher uncertainty will make asymmetric equilibrium more likely. Moreover, the sequential FDI occurs only if demand is sufficiently low compared to investment cost. The intuition behind this argument is that if demand is sufficiently high, both firms will be involved in FDI and first-mover advantage will disappear, and vice versa. This implication is a contrast to our model. In our model, asymmetric FDI equilibrium occurs only for sufficiently low level of uncertainty and sufficiently large demand. The presence of uncertainty matters because it causes the sequential movement game, but the magnitudes should be small in order for the leader to invest earlier. The difference may be due to the assumption of his model that firms can collude on the timing decision though not on output decision. In this paper, except the assumption of Cournot leadership game, the possibility of cooperative outcome is excluded, which prevents simultaneous FDI equilibrium in the first period.

3. Benchmark Case: Monopoly

Initially, we consider the case with a monopoly as our benchmark model. The entire market share of a foreign country is assumed to be dominated by one multinational enterprise. In the presence of uncertain demand, there are four periods: t=1 through t=4. The first period is the time to make an investment decision. Before t=1, the firm is an exporter. At the beginning, the firm faces decision on whether to switch to FDI or to wait based on its belief on demand parameter. $\hat{\theta}$ denotes a true demand parameter, and is assumed to be constant during period 1 through 4, though it may be changed from period 0 to 1. Under uncertainty, $\hat{\theta}$ is unknown to the firm at the first stage (t=1). The uncertainty is resolved during t =2 and is observed by the firm. In the third period (t=3), the firm decides whether to invest, if it did not invest at t=1, or to keep exporting. At t=4, the firm will produce output via FDI or exporting. Note that the duration of each period may vary across periods. For example, delay in making an FDI decision may be only temporary if the second period is very short: if $\hat{\theta}$ is revealed shortly. The inverse demand function is

$$p = \mathrm{D}(\hat{\theta}\,; x) = \hat{\theta} - x$$

where p is the price of the good, $\hat{\theta}$ is an intercept term, x is an output produced by monopolist at t=4. $\hat{\theta} = \theta + \varepsilon$, where θ is an expected demand parameter and ε is a disturbance term, where the variance σ^2 represents the uncertainty about demand. Given the assumed distribution of ε, $\hat{\theta}$ is normally distributed-$\hat{\theta} \sim N(\theta, \sigma^2)$. FDI incurs initial fixed cost F and marginal cost is assumed to be zero, while exporting incurs marginal cost of production, c. Focusing on the determinant of the investment decision, we assume that the goal of the firm is to maximize its expected value, not its profit. The key assumption in this section is that the monopolist is risk averse. Although the uncertainty about demand may not directly lower the firm's expected profit, it will ultimately discourage the investment decision because a firm wants to avoid uncertainty of incurring potential loss in relation with sunk cost. To reflect the firm's concern about the negative effect of uncertain demand, the objective value function includes the variance of profit multiplied by risk aversion as an additional term. The firm's expected value EV is expressed as[5]

$$EV^F = R(x^F, \theta) - F - \gamma\sigma^2 (x^F)^2, \quad \text{when the firm decides to switch to FDI}$$

$$EV^e = R(x^e, \theta) - cx^e - \gamma\sigma^2 (x^e)^2, \quad \text{when the firm decides to keep exporting}$$

where R denotes an expected revenue function, γ is a parameter for risk aversion. The superscripts F and e of x indicate that x is a product of FDI and exporter respectively. The firm's objective function throughout all periods is

$$EV = \max(EV^e, EV_t^F)$$

Naturally, we assume that the expected demand parameter is greater than costs; otherwise, both exporting and FDI will never be profitable. In the sections that follow, we will start from the simple case of perfect foresight and will further analyze the case of uncertain demand.

[5] See Appendix 1 for derivation of the monopolist's expected value function.

3.1.Perfect Foresight

We assume that at the time of investment decision, the monopolist has full information about future demand. In the absence of uncertainty, there is no role for multiple stages because waiting does not have option value; there is no difference between payoffs across different periods under a monopoly. Thus, the firm's choice is whether or not it will switch to FDI. The firm will choose the quantity of output that will maximize its expected *ex ante* payoff of FDI or exporting. The firm will invest if its expected payoff of FDI exceeds that of exporting, and it occurs when the demand parameter exceeds a certain level. Taking expectation[6], $\hat{\theta}=\theta$

$$EV^F > EV^e \quad \text{when} \quad \theta > \frac{c}{2}+\frac{2F}{c} \qquad (1)$$

3.2. Uncertain Demand

With uncertainty about demand, contrary to the previous section, there is a possibility that investing is more costly in period 1 rather than period 3 because of irreversible sunk cost and risk aversion of the firm. Thus, there exists an option value of waiting and the role for multiple stages. If we assume that there is no potential entrant to the host market in any stage, there is no strategic preemptive value from investing earlier before the true demand parameter is observed. The incumbent firm does not have incentive to switch to FDI in period 1 unless the expected demand is large enough to satisfy

$$\theta > \frac{c}{2}+\frac{2F}{c}(1+\gamma\sigma^2) \qquad (2)$$

The proof of above inequality is as follows. In the presence of uncertainty, the monopolist's expected value from exporting $EV^e = R(x,\theta)-cx-\gamma\sigma^2x^2$ is maximized when $x=\frac{\theta-c}{2(1+\gamma\sigma^2)}$ and $EV^e = \frac{(\theta-c)^2}{4(1+\gamma\sigma^2)}$, while the output and the expected value from FDI are $x=\frac{\theta}{2(1+\gamma\sigma^2)}$ and $EV^f = \frac{\theta^2}{4(1+\gamma\sigma^2)}-F$. Solving the inequality condition for decision making, $EV^F > EV^e \Leftrightarrow \frac{\theta^2}{4(1+\gamma\sigma^2)}-F > \frac{(\theta-c)^2}{4(1+\gamma\sigma^2)}$, it is straightforward to obtain $\theta>\frac{c}{2}+\frac{2F(1+\gamma\sigma^2)}{c}$. The condition (2) holds for $\sigma^2>0$ and the equation (1) can hold for the case of perfect foresight where $\sigma^2=0$.

[6] See the proof in section 3.2. The inequality (1) is the special case of (2) where $\sigma^2=0$.

As with the case of certain demand, (2) holds for uncertain demand; if demand hits the threshold level of demand to switch to FDI, the firm will invest in period 3. If the uncertainty is high, however, it will be more difficult to expect that demand will be above the threshold level demand and the firm is more likely to choose to wait in period 1 and make a decision on entry mode at the third stage, depending on the level of revealed true demand. (Note that production is not assumed to take place until t=3.) To sum up, compared to the case with perfect foresight, the uncertainty may delay monopolist's investment process.

4. Model: Duopoly

Under a duopoly, firms are engaged in strategic decision making. As in the benchmark case, we will analyze a firms' choice first under certain demand and later under uncertain demand.

4.1.Perfect Foresight

When perfect foresight is assumed, firms are engaged in game under no uncertainty about demand parameter.

4.1.1. Assumptions

1) Two firms are identical MNEs: homogeneous in technology, cost function, location of headquarter and plants, productivity and size. Firms are assumed to be equally risk averse. They are multinational enterprises that have experience of FDI in other countries, but they have been only exporting to the specific host country in our model. We do not consider the possibility of taking the host country as FDI-platform for re-exporting to the third country[7]. FDI in this paper refers to the circumstance where MNE builds the branch plant in the host country to produce and sell the same product as they exported to the host country consumers.

2) We do not consider domestic firm as a potential entrant in the model. MNEs are assumed to take entire market share of an industry of a specific good x which can be produced only by MNE's own superior technology and firm-specific activities. (Horstmann and Markusen, 1987) The MNEs' firm-specific advantage is often identified as entry barriers to domestic firms[8].

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[7] The relationship between FDI and exporting may be either substitution or complementarity. Head and Ries (2004) suggest that empirical evidences supporting the complementarity from vertical linkages between upstream export and downstream FDI do not contradict the theoretical prediction of substitution at product level.

[8] For example, the Canadian beer multinational Hiram Walker could maintain market share and successfully restrict entry of competitors to U.S. beer market by establishing extensive networks of distributors using their internationally recognized brand names. (Rugman, 1996)

3) The inverse demand function is assumed to be

$$p = \mathrm{D}(\hat{\theta}\,; X) = \hat{\theta} - X, \qquad X = x_i + x_j$$

where p is the price of the good, $\hat{\theta}$ is an intercept, x_i is an output produced by firm i, and x_j is output of firm j.

4.1.2. Game

Both firms are involved in pure strategy game: the probability of choosing strategy is one or zero. Each firm is maximizing its expected value EV which is expressed[9] as

Max $EV_i^F = R(x_i^F, \hat{\theta}) - F - \gamma\sigma^2 (x_i^F)^2$, when the firm i decides to switch to FDI

Max $EV_i^e = R(x_i^e, \hat{\theta}) - cx_i^e - \gamma\sigma^2 (x_i^e)^2$, when the firm i decides to keep exporting

where R denotes an expected revenue function, γ is a parameter for risk aversion. The superscripts F and e of x_i indicate that x_i is firm i's output from FDI and exporting respectively. As there is no uncertainty about demand, expected value of a firm can be derived using $\hat{\theta} = \theta$ and $\sigma^2 = 0$. Without further assumption that one firm is to be a leader while the other a follower in FDI, there is no role for multiple stages. Their entry modes are either switching to FDI or exporting in the same period. Thus, the game is a simultaneous move game and firm i decides on the mode of entry based on its belief about firm j's choice on entry mode.

Equilibrium

In the duopoly model, the strategy pair (k_h^*, k_{-h}^*) is a Nash equilibrium if, for each player *h*,

$$EV_h^{k_h^*}(x_h^*, x_{-h}^*) \geq EV_h^{k_h}(x_h, x_{-h}^*)$$

where k_h = switch to FDI, or export by player $h\,(= i \text{ or}, j)$ and x_h is an expected output produced by firm h. Given FDI by firm j, firm i's strategy is to choose entry mode that can satisfy $\max\{EV_i^F(x_i^F, x_j^F), EV_i^e(x_i^e, x_j^F)\}$ with respect to x_i given parameter values. From the assumption about the identical firms, this occurs to firm j's strategy symmetrically. Likewise, given no FDI by firm j, firm i's choice is to switch to FDI or keep exporting according to $\max\{EV_i^F(x_i^F, x_j^e), EV_i^e(x_i^e, x_j^e)\}$ with respect to x_i. This strategy is also applied to firm j.

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[9] See Appendix 1 for derivation of expected value function.

Depending on firm's strategies, three different scenarios are plausible.[10]

1) Both firms switch to FDI.

$$EV_i^F = EV_j^F = \frac{\theta^2}{9} - F$$

2) At t=1, one firm is engaged in FDI while the other firm remains an exporter.

$$EV_i^F = \frac{(\theta+c)^2}{9} - F$$

$$EV_j^e = \frac{(\theta-2c)^2}{9}$$

3) Both firms keep exporting.

$$EV_i^e = EV_j^e = \frac{(\theta-c)^2}{9}$$

In the simultaneous duopoly game with no uncertainty of demand, let parameter $\bar{\theta}$ be determined as a solution to equation (3) when firm j is expected to invest.

$$EV_i^F = \frac{\theta^2}{9} - F = \frac{(\theta-2c)^2}{9} = EV_i^e \tag{3}$$

Also, let parameter $\tilde{\iota}$ be determined as a solution to equation (4) when firm j is expected to export.

$$EV_i^F = \frac{(\theta+c)^2}{9} - F = \frac{(\theta-c)^2}{9} = EV_i^e \tag{4}$$

Then, it is straightforward to show that $\bar{\theta} = c + \frac{9F}{4c} > \frac{9F}{4c} = \tilde{\iota}$.

Proposition 1

1) For $\theta > \bar{\theta}$ in the simultaneous duopolistic game, there is a unique Cournot-Nash equilibrium in which both firms invest.
2) For $\tilde{\iota}$ . . . $\bar{\vartheta}$, there exist two Nash equilibria; one firm switches to FDI and the other firm remains an exporter.
3) For $\theta < \tilde{\iota}$, there is a unique Nash equilibrium, in which both firms choose to keep exporting.

See Appendix 3 for proof.

[10] See Appendix 2 for derivation of expected values.

4.2. Uncertain Demand

This section explores the strategic choices between two MNEs on optimal timing to switch to FDI. In contrast to the benchmark model of a monopoly, where a firm does not invest in period 1 under uncertainty, for small uncertainty, each firm in the duopoly model has an incentive to invest earlier than its rival to preempt the other firm.

4.2.1. Assumptions

1) The assumptions on the nature of two MNEs are same to section 4.1.1. Two firms are identical MNEs: homogeneous technology, cost function, location of headquarters and plants, productivity, and size. Firms are assumed to be equally risk averse. The possibility of taking the host country as FDI-platform for re-exporting to the third country is excluded.

2) We do not consider domestic firm as a potential entrant in the model. MNEs are assumed to take the entire market share of an industry of a specific good x which can be produced only by MNE's own superior technology and firm-specific activities.

3) The inverse demand function is assumed to be

$$p = \mathrm{D}(\hat{\theta}\,; X) = \hat{\theta} - X, \qquad X = x_i + x_j$$

where p is the price of the good, $\hat{\theta}$ is an intercept, x_i is an output produced by firm i, x_j is an output of firm j. Contrary to the assumption of extensive literature on investment timing (Sadanand and Sadanand, 1996, Pal, 1991, Mailath, 1993, Maggi, 1996, and Daughety and Reinganum, 1994) that investments are immediately productive, we assume that production lags the investment decision period. As often described in typical examples of the Stackelberg leadership model, a leader has a first-mover advantage over the follower by limiting the follower's output relative to what it would have been in a simultaneous Cournot equilibrium. Temporal asymmetry from a sequential move game results in a larger profitability for the leader. With this assumption, under high demand, early investment will lead to more profit for a leader than that for a follower. When there is a sufficient amount of uncertainty, however, it is possible that a risk-averse follower's expected payoff is greater than that of the leader, distinguishing the result of our model from the conventional Stackelberg model in which the leader's payoff is always higher than the follower's. For simplicity, we assume that all fixed costs are sunk.

4) As before, $\hat{\theta} = \theta + \varepsilon$ represents demand parameter for the firm's product.

5) Timing of players: We assume that the game has four periods; t=1 through t=4. The true

$\hat{\theta}$ is constant over t=1 through t=4. It is assumed that at t=0, both firms have been exporting. At t=1, each firm faces the decision whether to switch to FDI or take a wait-and-see strategy based on its belief about the expected value of the demand parameter as a function of belief about the other player's expected payoff. The decision to invest incurs sunk cost. By assumption, $\hat{\theta}$ is uncertain at t=1. The uncertainty is resolved at t=2, when $\hat{\theta}$ is observed and becomes common knowledge. At t=3, firms make the choice whether to invest or remain as exporters, provided they did not switch to FDI during the first period. In this period, firms that committed to FDI start producing. In the fourth period, firms that made late decision on entry mode produce output. The amount of production depends on the firms' decision in the earlier periods. The firm that switched to FDI first is assumed to be able to produce output before the follower produces. Thus, leader-follower relationship in investment holds for the relationship between two firms in producing output.

6) The expected value functions[11] of firm h are defined as

$$EV_h^{ks} = \max E[-e^{-r\hat{\pi}_h}]$$

where $h=\{i,j\}$, $-h = rival\ of\ h$, $k=\{F,e\}$ where F is FDI and e stands for export, and $s=\{l,f\}$ where l denotes the leader and f denotes the follower.

The firm's profit $\hat{\pi}_h$ is expressed as

$\hat{\pi}_h^F = R(x_h^F, \hat{\theta}) - F$, when the firm h decides to switch to FDI

$\hat{\pi}_h^e = R(x_h^e, \hat{\theta}) - c\,x_h$, when the firm h decides to keep exporting

where R denotes an expected revenue function. The superscripts F and e of x_h indicate that x_h is a product of FDI and exporter respectively.

4.2.2. Game

<u>Period 1: Decision on early FDI</u>

As with the case for perfect foresight, the firms are engaged in pure strategy game. If a firm switches to FDI based on its expectation on higher demand, it has to incur a sunk cost at t=1. Since the sunk cost is assumed to be irreversible, it has two effects. On the one hand, as is demonstrated by Dixit (1979), the commitment to irreversible investment generates a first-

[11] See Appendix 4 for more detailed derivation of expected value function.

mover advantage; a preemptive value, since the leader's sunk cost is a signal of commitment to FDI in the future, the follower takes its rival's output as given and the resulting profit of the leader will outweigh that of the follower by taking larger market share. Thus, the preemptive value urges firms to invest earlier than their rivals. In our model, however, firms are not assigned to be a leader or a follower at the beginning because they are identical by construction. When leadership equilibrium is the equilibrium, one firm happens to be a leader, while the other firm is a follower. Firms can opt for three types of behavior. One firm either chooses FDI in period 1, waits and invests, or waits and exports at t=3. On the other hand, combined with the irreversible sunk cost, uncertainty creates an option (flexibility) value of waiting for FDI. In the case of switching to FDI in period 1, the firm may lose the opportunity to invest in the foreign market later at second period under possibly a more favorable environment: if actual $\hat{\theta}$ turns out to be high, at t=3, the firm can decide to switch to FDI or to keep exporting otherwise. Thus, the high uncertainty of demand in the host country will make waiting option more attractive: the higher the uncertainty, the higher the option value of waiting. When a firm chooses FDI in the first period, to compensate for the loss of option value, the expected demand should be sufficiently high as the uncertainty increases.

Period 2 and 3: Choice of Nature and the late decision on entry mode

At t=2, the uncertainty about demand is resolved. Based on the realization of $\hat{\theta}$, the leader at t=3 makes decision on output and produce and the follower in t=3 can choose either to invest or continue to export. In case of sequential entry, the output of the first mover is set after it observes the realized demand parameter. Since it is already committed to FDI in the first period, it will still act as a leader even if the true demand parameter turns out to be lower than expected. Taking this leader's output as given, the follower will make output decision. If both firms do not invest in period 1, their choice at t=3 is either to switch to FDI simultaneously or keep exporting depending on the level of $\hat{\theta}$, and each firm will set their output taking its rival's output as given.

Period 4: Production period

At t=4, a follower in FDI or export starts producing and the profit is realized.

4.2.3. Equilibrium

In this section, we describe the Nash equilibrium of subgame and subgame perfect Nash equilibrium (SPNE) of the full game by backward induction. Conditional on FDI decision on the output committed to by the firm which chose to invest, and on the realized value of $\hat{\theta}$, a Nash equilibrium of a subgame is defined. Denote by $X_h(x_{-h}, \hat{\theta})$, the subgame reaction function of firm h to its rival's strategy. A Nash equilibrium of a subgame starting at t=3 is a combination of the firms' strategies that generate a pair of outputs (x_h^*, x_{-h}^*) that is determined by the intersection of the two subgame reaction functions. If there is no FDI by both firms in the first period, there can exist three different equilibria of the subgame. Provided that firm j waits and invests, firm i's best-response function of FDI is then $X_i^{Ff}(x_j^{Ff}) = \arg\max_x (\hat{\theta} - x_i^{Ff} - x_j^{Ff}) x_i^{Ff} - F$ taking firm j's output as given. The reaction function of firm j is the same provided firm j believes that firm i will wait in t=1 and invest at t=3. For linear demand, there is a unique intersection of these reaction functions by each firm at Cournot output in this case. Thus, the equilibrium output of the subgame is determined at $(\frac{\hat{\theta}}{3}, \frac{\hat{\theta}}{3})$. If firm i expects firm j to export at t=3, firm i's reaction function of exporting is $X_i^{ef}(x_j^{ef}) = \arg\max_x (\hat{\theta} - x_i^{ef} - x_j^{ef} - c) x_i^{ef}$ and this is true to firm j. There is a unique intersection of these reaction functions at the outcome $(\frac{\hat{\theta}-c}{3}, \frac{\hat{\theta}-c}{3})$, the standard Cournot equilibrium of the subgame. If firm i expects firm j to export at t=3, while it chooses to produce by FDI, firm i's reaction function at t=3 is $X_i^{Ff}(x_j^{ef}) = \arg\max_x (\hat{\theta} - x_i^{Ff} - x_j^{ef}) x_i^{Ff} - F$ and firm j's reaction function in t=3 becomes $X_j^{ef}(x_i^{Ff}) = \arg\max_x (\hat{\theta} - x_j^{ef} - x_i^{Ff} - c) x_j^{ef}$ yielding equilibrium output $(\frac{\hat{\theta}+c}{3}, \frac{\hat{\theta}-2c}{3})$. Now consider FDI by either firm at t=1. In this situation, the first mover becomes a leader and the other follower. Given firm i (leader) switches to FDI while firm j (follower) waits at t=1 and chooses to invest at t=3, firm j's best response function given firm i's output is $X_j^{Ff}(x_i^{Fl}) = \arg\max_x (\hat{\theta} - x_i^{Fl} - x_j^{Ff}) x_j^{Ff} - F$. Firm i will take into account firm j's reaction function in determining it's own output at t=3, i.e., firm i solves $X_i^{Fl}(X_j^{Ff})$ = $\arg\max_x (\hat{\theta} - x_i^{Fl} - X_j^{Ff}(x_i^{Fl})) x_i^{Fl} - F$. The intersection between two reaction functions produce asymmetric leader-follower outcome $(\frac{\hat{\theta}}{2}, \frac{\hat{\theta}}{4})$. If firm i invests at t=1 and firm j waits and chooses to export, firm j's best response function given firm i's output is $X_j^{ef}(x_i^{Fl}) = \arg\max_x(\hat{\theta} - x_i^{Fl} - x_j^{ef} - c)x_j^{ef}$ Then, firm i's output will solve $X_i^{Fl}(X_j^{ef}) = \arg\max_x(\hat{\theta} - x_i^{Fl} - X_j^{ef}(x_i^{Fl}))x_i^{Fl} - F$. The equilibrium outcome of the subgame will be $(\frac{\hat{\theta}+c}{2}, \frac{\hat{\theta}-3c}{4})$.

Definition 1: In our model set up, the investment strategies available to each firms are the different modes of entry that it will choose at time t=1 or at t=3. The investment strategies are determined based on the expected value[12] of future profit. In the duopoly switching time model, the strategy pair (k_h^*, k_{-h}^*) is a subgame perfect Nash equilibrium (SPNE) if, for each player h and for each subgame,

$$EV_h^{k_h^*}(\hat{\pi}_h^*, \hat{\pi}_{-h}^*) \geq EV_h^{k_h}(\hat{\pi}_h, \hat{\pi}_{-h}^*)$$

where k_h = FDI at t=1, FDI at t=3, or export by player $h(=i\ or,\ j)$ and $\hat{\pi}_h$ is a random profit that will be realized after the true demand parameter is revealed.

Given no FDI by firm j at t=1, firm i's strategy is to choose entry mode and timing of action that can satisfy $\max\{EV_i^{Fl}(\hat{\pi}_j^f), EV_i^{ef}(\hat{\pi}_j^f), EV_i^{Ff}(\hat{\pi}_j^f)\}$ according to parameter values.[13] From the assumption about the identical firms, this occurs to firm j's strategy symmetrically. Likewise, given *ex ante* FDI by firm j, firm i's choice is to switch to FDI at t=1, t=3 or keep exporting according to $\max\{EV_i^{Fl}(\hat{\pi}_j^{Fl}), EV_i^{Ff}(\hat{\pi}_j^{Fl}), EV_i^{ef}(\hat{\pi}_j^{Fl})\}$. This strategy is also applied to firm j. Below, we define two types of *ex ante* FDI by the timing of entry via FDI.

Definition 2: We say firm i *commits* if it invests at t=1 and it *delays* investment if it waits at t=1 and switches to FDI at t=3.

In a Commit-commit equilibrium, both firms switch to FDI in the first period. In a Commit-delay equilibrium, one of the firms commits, while the other firm delays FDI. In a Commit-export equilibrium, one of the firms commits, while the other waits and exports in the third period. In a Delay equilibrium, both firms delay investments until t=3. In an Export equilibrium, both firms wait and export at t=3, and in a Delay-export equilibrium, one firm waits and invest and the other firm waits and exports at t=3.

Expected payoff, $EV_h^{k_h}(\hat{\pi}_h)$ of each firm can be determined in the context of six possible

[12] See Appendix 4 for derivation of the expected value function.

[13] Here, we need condition that $\hat{\theta} > c$. Otherwise, $P = \hat{\theta} - X = 0$ for $\hat{\theta} \leq c$, neither firm will produce $x_h > c$.

scenarios.[14]

1) Firm i switches to FDI in the first period and firm j invests at t=3.

$$EV_i^{Fl} = \frac{\theta^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}$$

$$EV_j^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}$$

2) Assuming Cournot-type leadership, both firms switch to FDI in the first period.

$$EV_i^{Fl} = EV_j^{Fl} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}$$

3) Firm i switches to FDI in the first period and firm j remains an exporter in period 3.

$$EV_i^{Fl} = \frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}$$

$$EV_j^{ef} = \frac{(\theta-3c)^2}{16+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}$$

4) Both firms wait in the first period and switch to FDI in period 3 yielding Cournot-Nash output.

$$EV_i^{Ff} = EV_j^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$$

5) Both firms wait in the first period and one firm invests and the other firm keeps exporting in the third period.

$$EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$$

$$EV_j^{e} = \frac{(\theta-2c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}$$

6) Both firms wait in the first period and remain exporters.

$$EV_i^{e} = EV_j^{e} = \frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}$$

Define $\gamma_1\sigma_1^2$ so that it solves

$$\frac{\theta^2}{8+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) = \frac{\theta^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}),$$

$\gamma_2\sigma_2^2$ satisfies

[14] See Appendix 4 for derivation of profit and expected value for scenario 1), leader-follower game.

$$\frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) = \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}),$$

$\gamma_3\sigma_3^2$ satisfies

$$\frac{(\theta+c)^2}{8+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})=\frac{(\theta+c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}),$$

$\gamma_4\sigma_4^2$ so that it solves

$$\frac{(\theta+c)^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})=\frac{(\theta-c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$$

$\gamma_5\sigma_5^2$ that solves

$$\frac{\theta^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = \frac{\theta^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$$

Simple algebra will show that $\gamma_1\sigma_1^2 < \gamma_3\sigma_3^2$ and $\gamma_2\sigma_2^2 < \gamma_4\sigma_4^2$.

Define θ' such that it solves equation

$$\frac{\theta^2}{16+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = \frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) \qquad (5)$$

θ'' is determined as a solution to equation

$$\frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) \qquad (6)$$

θ''' is determined as a solution to equation

$$\frac{(\theta+c)^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = \frac{(\theta-c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) \qquad (7)$$

Then, it is straightforward to show that $\theta'=\frac{3c}{2}+\frac{(16+\gamma\sigma^2)F}{6c}$, $\theta'' = c+\frac{(9+\gamma\sigma^2)F}{4c}$, $\theta'''=\frac{(9+\gamma\sigma^2)F}{4c}$. Thus, the inequality $\theta'''<\theta''<\theta'$ holds.

Proposition 2

1) For $\theta > \theta'$ and $\gamma\sigma^2 < \gamma_1\sigma_1^2$ in the duopolistic switching time game, there are two pure strategy equilibria (Commit-delay equilibrium); one firm commits, the other firm delays FDI until the third period.

2) For $\theta > \theta'$ and $\gamma\sigma^2 < \gamma_5\sigma_5^2$ in the duopolistic switching time game under the assumption of Cournot type leadership, a Cournot-Nash equilibrium can occur; both firms commit to FDI at t=1.

3) For $\theta > \theta'$ and $\gamma\sigma^2 > \gamma_1\sigma_1^2$, there is a unique Cournot-Nash equilibrium. Both firms

wait and switch to FDI in period 3 simultaneously, i.e., Delay-delay equilibrium.

4) For $\theta'' < \theta < \theta'$ and $\gamma\sigma^2 < \gamma_1\sigma_1^2$, one firm invests in the first period and the other firm chooses to wait and keep exporting in the second period, i.e., Commit-export equilibrium.

5) For $\theta'' < \theta < \theta'$ and $\gamma\sigma^2 > \gamma_1\sigma_1^2$, both firms wait and invest at the third stage, i.e., Delay-delay equilibrium.

6) For $\theta''' < \theta < \theta''$ and $\gamma\sigma^2 < \gamma_3\sigma_3^2$, one firm invests in the first period and the other firm chooses to wait and keep exporting in the third period, i.e., Commit-export equilibrium.

7) For $\theta''' < \theta < \theta''$ and $\gamma\sigma^2 > \gamma_3\sigma_3^2$, one firm waits and invests in the third period and the other firm chooses to wait and keep exporting in the third period, i.e., Delay-export equilibrium.

8) For $\theta < \theta'''$ and $\gamma\sigma^2 < \gamma_4\sigma_4^2$, one firm invests in the first period and the other firm chooses to wait and keep exporting in the third period, i.e., Commit-export equilibrium.

9) For $\theta < \theta'''$ and $\gamma\sigma^2 > \gamma_4\sigma_4^2$, both firms wait and export in the second period, i.e., Export equilibrium.

See Appendix 5 for proof.

Interesting features are worth noting in the analysis of equilibrium. All sequential move equilibria (Commit-Delay or Commit-export equilibrium) occur for small amounts of joint value of uncertainty and risk aversion. In particular, Commit-Delay is an equilibrium strategy for sufficiently large demand and small uncertainty. Commit-export equilibrium is SPNE for $\theta < \theta'$ as long as the uncertainty and coefficient of risk-aversion is small. In contrast, except Commit-Commit equilibrium, all simultaneous move equilibria (Delay equilibrium, Delay-export equilibrium, or Export equilibrium) exist under sufficiently large uncertainty. This implies that the choice of the timing of action is mainly affected by the effects of uncertainty about demand and the firms' attitude toward risk. Note that the effects are joint effects of two factors; the amounts of value may be due to the level of uncertainty, the level of risk-aversion, or both.

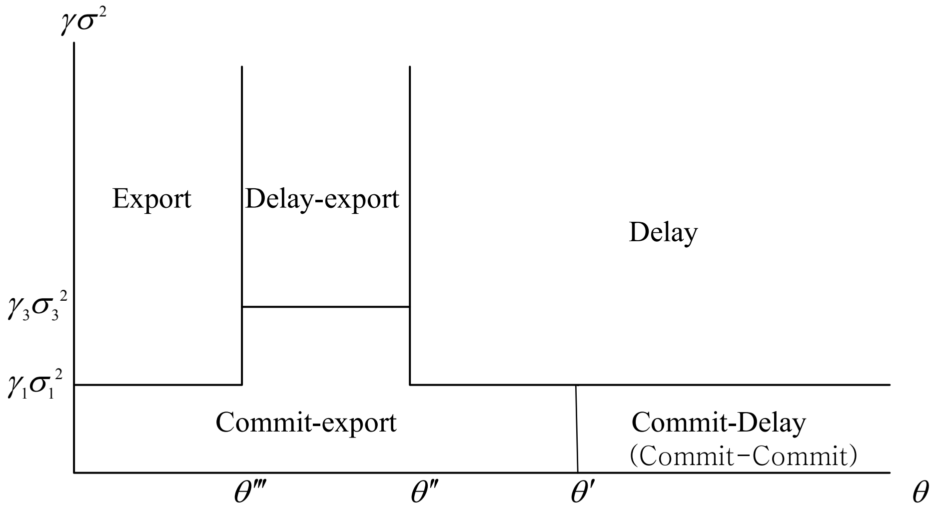
Regarding the choice on the mode of entry, besides timing, the result of this section can be compared to the benchmark case of monopoly. As a natural consequence of trade-offs between higher marginal cost of exporting and the irreversible plant-level fixed costs of FDI, a monopolist will switch to FDI only when demand is sufficiently large, remaining an exporter otherwise. For a duopoly game, however, a firm can choose commitment to FDI even under smaller demand parameter conditions than are required in the monopoly case, given the uncertainty is small and the other player is believed to keep exporting as a follower. (See *proposition 2*. case (9)) For the monopolist to invest in the first period, the threshold level of demand is high and the expected demand should be substantially high enough to compensate for the opportunity loss of option value of waiting created by uncertainty. In duopoly's case, however, the loss of option-value can be offset by the gain from preemptive-value which is also created by uncertainty. Even for a small demand, preemptive-value by commitment to FDI can bring a larger profit for a leader by limiting output and profit for the follower, thus a firm has an incentive to switch to FDI given the other firm waits.

These results are also compared to Sadanand and Sadanand (1996). Their two-stage duopoly model implies that, for sufficiently small amounts of uncertainty, asymmetric leader-follower equilibrium may arise, partly supporting the argument of proposition 1 and 2 in this paper. However, their result contrasts the exclusion of symmetric equilibrium under small uncertainty in our model. In S&S, symmetric Cournot equilibrium at t=2 occurs at any amount of risks, while in our model, it obtains usually when the uncertainty about demand is sufficiently large. For a small uncertainty, the symmetric equilibrium is replaced by leadership equilibrium in our model.

5. Conclusions

In this paper, we analyze exporters' decision on switching time to FDI for given condition of market structure, demand parameter, and uncertainty. In our model, the uncertainty about demand determines the nature of the game. In the absence of uncertainty, there is no option-value of waiting that Nash equilibrium consists of simultaneous-move equilibrium and the demand level is the only criterion for investment decision. We find, however, that introducing uncertainty creates both option-value of waiting and preemptive-value of commitment, and thus the game has multiple stages and the trade-offs between two values affect the equilibrium of the game. The low level of uncertainty to the switching time model of duopoly increases the preemptive-value of commitment that can allow asymmetric sequential equilibrium to occur as subgame perfect Nash equilibrium. Here, of course, firms should not be overly risk averse. The more risk averse the firm is, the less likely that a firm has an incentive to preempt the market even for a small uncertainty. Symmetric Cournot-type equilibrium is derived if the uncertainty is sufficiently high (This argument is visually summarized in Figure 1).

Figure 1. Equilibrium under Demand Uncertainty[15]



Our model can be extended in several ways. First, we assume that entry barrier in oligopoly can be maintained by MNE's firm-specific advantage over domestic firms. But what if the domestic firms in developing countries can catch up with MNE's technology and penetrate the market through learning or knowledge spillovers from inward FDI?[16] It might be an interesting extension, if MNEs are assumed to face the potential threat of entry by domestic firms, though the analysis could become more complicated. Second, introducing a learning process to obtain knowledge about demand can alter the result of the model. For simplicity of the analysis, this paper assumed that firms are involved in rational expectation and the demand uncertainty is resolved by nature in the second period. If the uncertainty is assumed to be resolved only through learning-by-FDI (either by rival or the firm itself), the equilibrium is likely to be determined depending on the probability of deviation of an estimation from the true value. Third, firm productivity may affect the timing of FDI. In their empirical analysis, Mühlen and Nunnenkamp (2009) find that firm productivity matters for self-selection of FDI by German firms while it declines over time with diminishing

[15] This diagram describes equilibrium under the assumption that $\gamma_4\sigma_4^2 = \gamma_1\sigma_1^2$. The region of export equilibrium may be varied according to the size of $\gamma_4\sigma_4^2$ compared to $\gamma_1\sigma_1^2$ which is determined by the relative size of fixed cost of FDI to marginal cost of export, i.e., if $\gamma_4\sigma_4^2 > \gamma_1\sigma_1^2$, the export region will shrink. Likewise, under the assumption of Cournot leadership, the commit-commit equilibrium region is determined by the amount of joint effect of uncertainty and risk aversion $\gamma_5\sigma_5^2$ (not indicated).

[16] There is a famous anecdote about Bangladesh stating that few multinational incumbents caused the boom in textile industry after the labor-turnover and technology transfer to domestic firms. (Hausmann and Rodrik, 2003)

uncertainty in the Czech Republic. Incorporating firm heterogeneity into the optimal timing of FDI[17] under uncertainty may provide rich implication for industrial reallocation. Lastly, provided that information on the timing of investment conducted by two rivals are available in firm level data, the application of our theoretical background to empirical test will generate strong support for our model.

[17] See also Raff, H., M.J. Ryan and F. Stähler (2008)

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Appendix 1: The Derivation of a Monopolist's Problem

When we assume CARA (Constant Absolute Risk Aversion), the monopolist's problem with respect to FDI output becomes

$$\underset{x}{Max}\ E[-e^{-r\pi}] = E[-e^{-r((\hat{\theta}-x)x-F)}]$$

where r is a coefficient for risk aversion.

From the assumption $\hat{\theta} \sim N(\theta,\sigma^2) = \theta+\varepsilon$, $\varepsilon \sim N(0,\sigma^2)$

$$\underset{x}{Max}\ E[-e^{-r((\theta-x)x+\varepsilon x-F)}]$$

$$= -\int_{-\infty}^{+\infty} e^{-r((\theta-x)x+\varepsilon x-F)} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{\varepsilon^2}{2\sigma^2}} d\varepsilon$$

$$= -\int_{-\infty}^{+\infty} e^{-r((\theta-x)x-F)} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{\varepsilon^2}{2\sigma^2}-rx\varepsilon} d\varepsilon$$

$$= -e^{-r((\theta-x)x-F)} \int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{1}{2\sigma^2}(\varepsilon^2+2r\sigma^2 x\varepsilon+r^2\sigma^4x^2-r^2\sigma^4x^2)} d\varepsilon$$

$$= -e^{-r((\theta-x)x-F)} \left(\int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{1}{2\sigma^2}(\varepsilon+r\sigma^2x)^2} d\varepsilon\right) e^{\frac{1}{2\sigma^2}r^2\sigma^4x^2}$$

$$= -e^{-r((\theta-x)x-F)} e^{\frac{1}{2}r^2\sigma^2x^2}$$

$$= -\exp[-r((\theta-x)x-F-\frac{r\sigma^2x^2}{2})]$$

Thus, the problem is equivalent to

$$\underset{x}{Max}\ (\theta-x)x-F-\frac{r\sigma^2x^2}{2}$$
$$= (\theta-x)x-F-\gamma\sigma^2x^2$$

where $\gamma = \frac{r}{2}$

By similar process, the monopolist's problem when it exports becomes

$$\underset{x}{Max}\ (\theta-x)x-cx-\gamma\sigma^2x^2, \text{ where } \gamma=\frac{r}{2}$$

Appendix 2: The derivation of duopolists' expected value under perfect foresight

If both firms commit to FDI, then firm i's problem is

$$Max\ EV_i^F = (\theta-x_i-x_j)x_i - F$$

$$F.O.C)\quad \frac{\partial EV_i^F}{\partial x_i} = \theta-x_i-x_j-x_i = 0$$

$$x_i = \frac{\theta - x_j}{2}; \qquad \text{firm i's best response function} \qquad (1)$$

$$S.O.C) \qquad \frac{\partial (EV_i^e)^2}{\partial^2 x_i} = -2 < 0$$

Firm j's problem is

$$Max\ \ EV_j^F = (\theta - x_i - x_j)x_j - F$$

$$F.OC\ ) \qquad \frac{\partial EV_j^F}{\partial x_j} = \theta - x_i - x_j - x_j =$$

$$x_j = \frac{\theta - x_i}{2}; \qquad \text{firm j's best response function} \qquad (2)$$

$$S.O.C) \qquad \frac{\partial (EV_j^F)^2}{\partial^2 x_j} = -2 < 0$$

From intersection between reaction function (1) and (2),

$$x_i^* = x_j^* = \frac{\theta}{3}, \ \ EV_i^F = EV_j^F = \frac{\theta^2}{9} - F$$

If one firm (i) is engaged in FDI while the other firm (j) remains an exporter, firm i's problem is

$$Max\ \ EV_i^F = (\theta - x_i - x_j)x_i - F$$

$$F.OC\ ) \qquad \frac{\partial EV_i^F}{\partial x_i} = \theta - x_i - x_j - x_i =$$

$$x_i = \frac{\theta - x_j}{2}; \quad \text{firm i's best response function} \qquad (3)$$

$$S.O.C) \qquad \frac{\partial (EV_i^e)^2}{\partial^2 x_i} = -2 < 0$$

Firm j's problem is

$$Max\ \ EV_j^e = (\theta - x_i - x_j - c)x_j$$

$$F.OC\ ) \qquad \frac{\partial EV_j^e}{\partial x_j} = \theta - x_i - x_j - c - x_j =$$

$$x_j = \frac{\theta - c - x_i}{2}; \quad \text{firm j's best response function} \qquad (4)$$

$$S.O.C) \qquad \frac{\partial (EV_j^e)^2}{\partial^2 x_j} = -2 < 0$$

From intersection between reaction function (3) and (4),

$$x_i^* = \frac{\theta + c}{3}, \ \ x_j^* = \frac{\theta - 2c}{3}, \text{ thus, } \ EV_i^F = \frac{(\theta + c)^2}{9} - F, \ \ EV_j^e = \frac{(\theta - 2c)^2}{9}$$

If both firms keep exporting, firm i's problem becomes

$$Max\ \ EV_i^e = (\theta - x_i - x_j - c)x_i$$

$$F.O.C) \qquad \frac{\partial EV_i^e}{\partial x_i} = \theta - x_i - x_j - c - x_i = 0$$

$$x_i = \frac{\theta - c - x_j}{2} \ ; \quad \text{firm i's best response function} \qquad (5)$$

$$S.O.C) \qquad \frac{\partial (EV_i^e)^2}{\partial^2 x_i} = -2 < 0$$

Likewise, firm j's problem is

$$Max \ EV_j^e = (\theta - x_i - x_j - c)x_j$$

$$F.O.C) \qquad \frac{\partial EV_j^e}{\partial x_j} = \theta - x_i - x_j - c - x_j = 0$$

$$x_j = \frac{\theta - c - x_i}{2}; \quad \text{firm j's best response function} \qquad (6)$$

$$S.O.C) \qquad \frac{\partial (EV_j^e)^2}{\partial^2 x_j} = -2 < 0$$

From intersection between reaction function (5) and (6),

$$x_i^* = \frac{\theta - c}{3}, \ x_j^* = \frac{\theta - c}{3} \qquad EV_i^e = EV_j^e = \frac{(\theta - c)^2}{9}$$

<u>Appendix 3: Proof for proposition 1</u>

1) Given firm j switches to FDI, $EV_i^F = \frac{\theta^2}{9} - F > \frac{(\theta - 2c)^2}{9} = EV_i^e$ from the parameter condition $\theta > \bar{\theta}$ and equation (3). This relationship holds also when firm i believes that firm j will export. That is, FDI is a dominant strategy. Firm j thinks the same way as firm i does. Thus, both firms choose to invest.

2) From equation (3) and for $\theta < \bar{\theta}$, $EV_i^F = \frac{\theta^2}{9} - F < \frac{(\theta - 2c)^2}{9} = EV_i^e$ given firm j invests. Thus, firm i has no incentive to switch to FDI and it will choose to remain an exporter if firm j is expected to invest. From $\theta > \tilde{\iota}$ and equation (4), however, FDI will be preferred by firm i given its rival keeps exporting: $EV_i^F = \frac{(\theta + c)^2}{9} - F > \frac{(\theta - c)^2}{9} = EV_i^e$. This strategy is true to firm j and there are two equilibria where one firm would choose FDI while the other would choose to keep exporting.

3) In this case, demand level is sufficiently small that exporting is the dominant strategy of each firm. Given firm j invests, $EV_i^F = \frac{\theta^2}{9} - F < \frac{(\theta - 2c)^2}{9} = EV_i^e$ since $\theta < \bar{\theta}$. Given firm j exports, $EV_i^F = \frac{(\theta + c)^2}{9} - F < \frac{(\theta - c)^2}{9} = EV_i^e$ as $\theta < \tilde{\iota}$. Firm j thinks the same way as firm i does and exporting is its dominant strategy. Thus, the resulting equilibrium is that both remain exporters.

Appendix 4 : The Derivation of Expected Value in Duopoly Game

For Commit-delay equilibrium, the leader i and follower j's expected values are obtained based on their expectation on the future profit incorporating belief about rival's decision. Taking firm i's output as given, firm j determines its output by solving

$$\max \hat{\pi}_j^{Ff} = R(x_j^{Ff}, \hat{\theta}) - F$$
$$= (\hat{\theta} - x_i^{Fl} - x_j^{Ff})x_j^{Ff} - F$$

By F.O.C., firm j's best response function is derived.

$$\frac{\partial \hat{\pi}_j^{Ff}}{\partial x_j^{Ff}} = \hat{\theta} - x_i^{Fl} - 2x_j^{Ff} = 0$$

$$x_j^{Ff} = \frac{\hat{\theta} - x_i^{Fl}}{2} = X_j^{Ff}(x_i^{Fl})$$

Considering firm j's reaction, firm i will make its output decision by solving

$$\max \hat{\pi}_i^{Fl} = R(x_i^{Fl}(X_j^{Ff}), \hat{\theta}) - F$$
$$= (\hat{\theta} - x_i^{Fl} - X_j^{F}(x_i^{Fl}))x_j^{Fl} - F$$
$$= (\hat{\theta} - x_i^{Fl} - \frac{\hat{\theta} - x_i^{Fl}}{2})x_j^{Fl} - F$$

By F.O.C., firm i's output is determined.

$$\frac{\partial \hat{\pi}_i^{Fl}}{\partial x_i^{Fl}} = \frac{\hat{\theta} - x_i^{Fl}}{2} - \frac{x_i^{Fl}}{2} = 0$$

$$x_i^{Fl} = \frac{\hat{\theta}}{2}$$

Plugging this result into firm j's reaction function, $x_i^{Ff} = \dfrac{\hat{\theta}}{4}$

Thus, $\hat{\pi}_i^{Fl} = \dfrac{\hat{\theta}^2}{8} - F$ and $\hat{\pi}_j^{Ff} = \dfrac{\hat{\theta}^2}{16} - F$

As a function of profit, firm i's expected value function can be derived as follows.

$$E[-e^{-r\hat{\pi}}] = E[-e^{-r(\frac{\hat{\theta}^2}{8} - F)}]$$

$$= -\frac{1}{\sqrt{2\pi\sigma^2}} \int_{-\infty}^{+\infty} e^{-r(\frac{(\theta+\varepsilon)^2}{8} - F)} e^{-\frac{\varepsilon^2}{2\sigma^2}} d\varepsilon$$

$$= -\frac{1}{\sqrt{2\pi\sigma^2}}\int_{-\infty}^{+\infty} e^{-\frac{1}{2\sigma^2}[\varepsilon^2+2r\sigma^2(\frac{(\theta+\varepsilon)^2}{8}-F)]}d\varepsilon$$

$$= -\frac{1}{\sqrt{2\pi\sigma^2}}\int_{-\infty}^{+\infty} e^{-\frac{1}{2\sigma^2}(1+\frac{r\sigma^2}{4})[(\varepsilon+\frac{r\sigma^2\theta}{4(1+\frac{r\sigma^2}{4})})^2+\frac{r\sigma^2(\frac{\theta^2}{4}-2F)}{1+\frac{r\sigma^2}{4}}-\frac{r^2\sigma^4\theta^2}{16(1+\frac{r\sigma^2}{4})^2}]}d\varepsilon$$

$$= -\sqrt{1+\frac{r\sigma^2}{4}}\, e^{-\frac{1}{2\sigma^2}[r\sigma^2(\frac{\theta^2}{4}-2F)-\frac{r^2\sigma^4\theta^2}{16(1+\frac{r\sigma^2}{4})}]}$$

$$= -\sqrt{1+\frac{r\sigma^2}{4}}\, e^{-\frac{1}{2}[r(\frac{\theta^2}{4}-2F)-\frac{r^2\sigma^2\theta^2}{16(1+\frac{r\sigma^2}{4})}]}$$

$$= -\exp[-r\{(\frac{\theta^2}{8}-F)-\frac{\theta^2}{8}\cdot\frac{\frac{2r\sigma 2}{8}}{1+\frac{2r\sigma^2}{8}}-\frac{1}{2r}\ln(1+\frac{2r\sigma^2}{8})\}]$$

By certainty equivalence, expected value for firm i can be expressed as

$$\frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) \qquad \text{where } \gamma=\frac{r}{2}$$

Taking similar procedures as above, the expected payoff for firm j is derived as

$$E[-e^{-r\hat{\pi}}] = E[-e^{-r(\frac{\hat{\theta}^2}{16}-F)}]$$

$$= -\frac{1}{\sqrt{2\pi\sigma^2}}\int_{-\infty}^{+\infty} e^{-r(\frac{(\theta+\varepsilon)^2}{16}-F)} e^{-\frac{\varepsilon^2}{2\sigma^2}}d\varepsilon$$

$$= -\frac{1}{\sqrt{2\pi\sigma^2}}\int_{-\infty}^{+\infty} e^{-\frac{1}{2\sigma^2}[\varepsilon^2+2r\sigma^2(\frac{(\theta+\varepsilon)^2}{16}-F)]}d\varepsilon$$

$$= -\frac{1}{\sqrt{2\pi\sigma^2}}\int_{-\infty}^{+\infty} e^{-\frac{1}{2\sigma^2}(1+\frac{r\sigma^2}{8})[(\varepsilon+\frac{r\sigma^2\theta}{8(1+\frac{r\sigma^2}{8})})^2+\frac{r\sigma^2(\frac{\theta^2}{8}-2F)}{1+\frac{r\sigma^2}{8}}-\frac{r^2\sigma^4\theta^2}{64(1+\frac{r\sigma^2}{8})^2}]}d\varepsilon$$

$$= -\sqrt{1+\frac{r\sigma^2}{8}}\, e^{-\frac{1}{2\sigma^2}[r\sigma^2(\frac{\theta^2}{8}-2F)-\frac{r^2\sigma^4\theta^2}{64(1+\frac{r\sigma^2}{8})}]}$$

$$= -\sqrt{1+\frac{r\sigma^2}{8}}\, e^{-\frac{1}{2}[r(\frac{\theta^2}{8}-2F)-\frac{r^2\sigma^2\theta^2}{64(1+\frac{r\sigma^2}{8})}]}$$

$$= -\exp[-r\{(\frac{\theta^2}{16}-F)-\frac{\theta^2}{16}\cdot\frac{\frac{2r\sigma 2}{16}}{1+\frac{2r\sigma^2}{16}}-\frac{1}{2r}\ln(1+\frac{2r\sigma^2}{16})\}]$$

By certainty equivalence, expected value for firm j can be expressed as

$$\frac{\theta^2}{16+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) \qquad \text{where } \gamma=\frac{r}{2}$$

Taking similar steps as above, the expected payoff for firms under each scenario can be derived.

Appendix 5: Proof for proposition 2

1)For $\theta > \theta'$ and $\gamma\sigma^2 < \gamma_1\sigma_1^2$, exporting is dominated by Delay-strategy for both firms because demand is above the threshold level for both firms to switch to FDI, θ'. Note that from its definition, θ' equates $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$ and $EV_i^e = \frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$ given firm j invests at t=1. Thus, for $\theta > \theta'$, $EV_i^{Ff} > EV_i^e$. Also, since θ'' and θ''' are demand parameters that equate EV_i^{Ff} and EV_i^e given firm j invests at t=3 or exports at t=3 respectively and $\theta''' < \theta'' < \theta' < \theta$, it is straightforward to show that the inequality $EV_i^{Ff} > EV_i^e$ holds given firm j invests at t=3 or keeps exporting. When both firms are involved in warfare[18] by behaving as if other firm is a follower while itself is a leader, both increase output to $x_{h,1} = \frac{\hat{\theta}}{2}$. Thus, expected value of both firms become $-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4})$. Accordingly, the expected value for firm i by FDI in the first period would be the lowest among the results from three options while the expected value by FDI in period 3 would be the highest; $EV_i^{Ff} > EV_i^e > EV_i^{Fl}$. Thus, firm i's strategy is to invest in the host country and produce x_i^{Ff}.

In a similar fashion of inference, when firm i expects firm j to choose to be a FDI follower, its best response is to invest prior to its rival. (Under the condition that $\gamma\sigma^2 < \gamma_1\sigma_1^2$ $EV_i^{Fl} > EV_i^{Ff}$ as $\gamma_1\sigma_1^2$ is the threshold level that equates $EV_i^{Fl} = \frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ and $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ For $\theta>\theta'>\theta''$, $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > EV_i^e = \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ at t=3.

In sum, the inequality $EV_i^{Fl} > EV_i^{Ff} > EV_i^e$ holds. Again, given firm j remains an

[18] See Dowrick (1986) for this argument.

exporter in the next period and for $\theta > \theta' > \theta'''$, $EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) >$ $\frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ implying that exporting is dominated by investment at t=3. Also, since $\frac{\theta^2}{8+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{\theta^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ for $\gamma\sigma^2 < \gamma_1\sigma_1^2$, $EV_{i,1}^{Fl} =$ $\frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$. Thus, again, the relation $EV_i^{Fl} > EV_i^{Ff} > EV_i^e$ holds and firm i has an incentive to invest in the first stage given firm j remains an exporter at t=3. Strategically, the firm j will think the same way as firm i would, its choice on entry mode is to be a FDI follower given firm i being FDI leader, FDI leader given firm i FDI follower or an exporter. Therefore, two SPNEs are that one firm invests as a leader in FDI and the other firm follows its rival in FDI at t=3.

2) Assuming Cournot-duopoly game instead of warfare when both firms are engaged in FDI as leaders, the expected value of commitment to FDI in the first period can be modified as

$$EV_i^{Fl} = EV_j^{Fl} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$$

For $\theta > \theta'$ and $\gamma\sigma^2 < \gamma_5\sigma_5^2$, exporting is dominated by Delay-strategy because demand is above the threshold level to switch to FDI, θ'. Given the firm j is a leader, firm i will choose FDI in the first stage of the game depending on the order of expected values. Since $\gamma\sigma^2 < \gamma_5\sigma_5^2$, the expected value for firm i by FDI in the first period would be the maximum value among the results from three options while the expected value by exporting in period 3 would be the lowest; the inequality condition $\theta > \theta'$ implies that $EV_i^{Ff} =$ $\frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > \frac{(\theta-3c)^2}{16+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^e$ and $EV_i^{Fl} =$ $\frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^{Ff}$ for $\gamma\sigma^2 < \gamma_5\sigma_5^2$.

Thus, firm i's strategy is to invest in the host country at t=1.

Similarly, when firm i expects firm j to choose to be a FDI follower, its best response is to invest prior to its rival. $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$

$> \frac{(\theta-2c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ holds for $\theta > \theta' > \theta''$ and $EV_i^{Fl} = \frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ for $\gamma\sigma^2 < \gamma_5\sigma_5^2 < \gamma_1\sigma_1^2$. Thus, $EV_i^{Fl} > EV_i^{Ff} > EV_i^e$.

Given firm j remains as an exporter in the next period, firm i has an incentive to invest in the first stage. $EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > \frac{(\theta-c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ .Since $\theta > \theta' > \theta'''$, $EV_i^{Fl} = \frac{(\theta+c)^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta+c)^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ for $\gamma\sigma^2 < \gamma_5\sigma_5^2 < \gamma_1\sigma_1^2 < \gamma_3\sigma_3^2$ i.e, $EV_i^{Fl} > EV_i^{Ff} > EV_i^e$. Strategically, the firm j will think the same way as firm i would, its choice on entry mode is to be a FDI leader regardless of its belief on the strategy of its rival. Thus, the subgame perfect Nash equilibrium is a Commit-commit equilibrium.

3) As in case 1) and 2), for $\theta > \theta'$, export is dominated by wait-and-FDI strategy. Given j a leader, $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > \frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^e$. Since $EV_i^e = \frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > -F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4}) = EV_i^{Fl}$, $EV_i^{Ff} > EV_i^e > EV_i^{Fl}$ and firm i will choose to be a follower: same to case 1). Believing that j is FDI follower, in the third period, firm i's expected payoffs become $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ from the demand condition $\theta > \theta' > \theta''$ and equation (6). At t=1, firm i's payoffs are $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > \frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) = EV_i^{Fl}$. This is because, for $\gamma\sigma^2 > \gamma_1\sigma_1^2$, the expected variance of error term ε in demand parameter is higher than the threshold level of variance that equates FDI leader's profit to FDI follower's profit under uncertainty, contributing to delaying in investment. Thus, under a sufficiently large uncertainty and large demand, firm i's strategy is to invest at the third period rather than to invest earlier given firm j waits and

invest at the third stage.

When the rival firm j holds on and chooses to keep exporting in period 3, At t=3 $EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ $> EV_i^e = \frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ since the inequality $\theta > \theta' > \theta'''$ holds. In the face of decision on time to invest by firm i, EV_i^{Ff} = $\frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ $>$ $\frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ = EV_i^{Fl} from the inequality $\frac{\theta^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ $>$ $\frac{\theta^2}{8+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ which is equivalent to the condition that $\gamma\sigma^2$ $>$ $\gamma_1\sigma_1^2$. Thus, given firm j exports, firm i's best response it to wait and invest later. Applying symmetry, the subgame perfect Nash equilibrium of the whole game is that both firms wait and invest in period 3.

4) Given firm j is a leader, for θ'' $<$ θ $<$ θ' and $\gamma\sigma^2$ $<$ $\gamma_1\sigma_1^2$, Delay option at t=3 is dominated by export strategy, since at t=3, the expected demand is not high enough to make FDI more profitable than exporting: firm i's expected payoffs $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$ $<$ $\frac{(\theta-3c)^2}{16+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^e$ from the demand condition θ'' $<$ θ $<$ θ' and equation (5). Also, it is the best response for firm i to become a follower given firm j becomes a leader in FDI, as $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$ $>$ $-F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4}) = EV_i^{Fl}$. Therefore, EV_i^e $>$ EV_i^{Ff} $>$ EV_i^{Fl} and given firm j is a leader in FDI, firm i's strategy is exporting in the third period. However, taking firm j's choice to become a late investor or to remain as an exporter in period 3 as given, firm i's strategy is to invest in the first period since the gain from preemptive value over profit from waiting is sufficiently high enough to outweigh its profit loss from uncertainty. Given firm j investing at t=3, $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > EV_i^e (= \frac{(\theta-2c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}))$ is guaranteed for θ'' $<$ θ. At t=1, $EV_i^{Fl} = \frac{\theta^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ $>$ $\frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$, for $\gamma\sigma^2$ $<$ $\gamma_1\sigma_1^2$. Hence, $EV_i^{Fl} > EV_i^{Ff} > EV_i^e$ and firm i will choose to become a leader in FDI given firm j invests at t=3. Likewise, given firm j exporting, in the third period,

$EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > EV_i^e = \frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ holds for $\theta'' < \hat{\theta}$ $EV_i^{FI} = \frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ at t=1, since $\frac{\theta^2}{8+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{\theta^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ holds from $\gamma\sigma^2 < \gamma_1\sigma_1^2$. In sum, $EV_i^{FI} > EV_i^{Ff} > EV_i^e$ and switching to FDI in the first stage is the dominant strategy for firm i given firm j waiting and exporting. Firm j's strategy given firm i's strategy is determined in the same way. As a result, two asymmetric Commit-export equilibria occur.

5)For a sufficient degree of uncertainty, FDI in the first period by firm i is dominated by waiting option regardless of firm j's choice: $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > -F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4}) = EV_i^{FI}$ and $EV_i^e = \frac{(\theta-3c)^2}{16+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > -F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4}) = EV_i^{FI}$. Given firm j investing in the first period, firm i's best response at t=3 will be to export as $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) < \frac{(\theta-3c)^2}{16+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^e$ from the demand condition $\theta'' < \theta < \theta'$ and equation (5). As long as $\theta > \theta''$, however, firm i has an incentive to invest rather than to export at t=3 given firm j becomes a follower in FDI. This is because, at t=3, firm i's expected payoff becomes $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > \frac{(\theta-2c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$.

At t=1, firm i's choice of when to invest is based on $EV_i^{FI} = \frac{\theta^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) < \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$, from the uncertainty condition $\gamma\sigma^2 > \gamma_1\sigma_1^2$. Therefore, given firm j waits and makes investment in the third period, the expected value of firm i's late investment has the maximum value relative to values of other choices and firm i will choose to switch to FDI in the third period. This strategy is true to the case where firm j is believed to export after waiting. In this scenario, firm i's strategy is to invest in the third stage based on the relations that $EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ $> \frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) =$ EV_i^e which is equivalent to demand condition $\theta''' < \theta$. When it comes to firm i's decision on when to invest, $EV_i^{Fl} = \frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) < \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ (Note that the inequality $\frac{\theta^2}{8+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ $<$ $\frac{\theta^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ holds under the assumption that $\gamma\sigma^2$ $>$ $\gamma_1\sigma_1^2$). As a result, given its rival becomes a follower in FDI, firm i will choose wait-and-invest strategy after the uncertainty is resolved. Considering firm j's choice, the resulting SPNE is that both firms invest after waiting.

6) For $\theta''' < \theta < \theta''$ and $\gamma\sigma^2 < \gamma_2\sigma_2^2$ given firm j will choose FDI either in period one or three, export is dominant strategy over the late FDI for firm i, since the expected demand is less than threshold level of demand parameter for investment at t=3: $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$ $<$ $\frac{(\theta-3c)^2}{16+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$ $= EV_i^e$ from the demand condition $\theta < \theta'' < \theta'$. Given firm j leader, commitment to FDI will incur negative payoff for both players, thus export is firm i's best response. However, if firm i believes that firm j will invest later, it will prefer investing at t=1 to exporting at t=3 because even though $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ $<$ $\frac{(\theta-2c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ for $\theta < \theta''$ at t=3, $EV_i^{Fl} = \frac{\theta^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta-2c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ under sufficiently small amount of uncertainty $\gamma\sigma^2 < \gamma_2\sigma_2^2$. The resulting inequality $EV_i^{Fl} > EV_i^e > EV_i^{Ff}$ implies that firm i has an incentive to commit to FDI in the first period given firm j invests in the third period. Based on the belief that firm j waits and exports, $EV_i^{Fl} > EV_i^{Ff} > EV_i^e$, since demand is expected to be still high enough for switching to FDI from exporting (Note that EV_i^{Ff} $=$ $\frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ $>$ $\frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ under $\theta''' < \theta$) and the uncertainty is sufficiently small that preemptive value from early FDI is higher than option value of waiting and investment (It is

straightforward to show that EV_i^{Fl} = $\frac{(\theta+c)^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ > $\frac{(\theta+c)^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ = EV_i^{Ff} from the inequality that EV_i^{Fl} = $\frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ > $\frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ = EV_i^{Ff} which can be derived from the above inequality $EV_i^{Fl} > EV_i^{e} > EV_i^{Ff}$ for $\gamma\sigma^2 < \gamma_2\sigma_2^2$. Thus, $EV_i^{Fl} > EV_i^{Ff} > EV_i^{e}$ and given firm j exports, firm i's strategy is to invest in the first period. Considering firm j's best response, SPNE of the game is asymmetric Commit-export equilibrium.

Also under condition that $\theta''' < \theta < \theta''$ and $\gamma_2\sigma_2^2 < \gamma\sigma^2 < \gamma_1\sigma_1^2$, export is the dominant strategy of firm i over both *ex ante* and *ex post* FDI given firm j invests first. Given firm j commits to FDI at t=1, firm i has an incentive to remain exporter since $EV_i^{Ff}=\frac{\theta^2}{16+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})$ < $\frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})=EV_i^{e}$ from $\theta < \theta'' < \theta'$ and $EV_i^{e}=\frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16})>-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4})=EV_i^{Fl}$. FDI strategy at either t=1 or t=3 is dominated by exporting strategy given firm j invests as demand is lower for investment. Given firm j invests in the third period, firm i will again choose to export rather than FDI strategy. At t=3, $EV_i^{Ff}=\frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ < $\frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})=EV_i^{e}$ from $\theta < \theta''$ and under the given variability of demand ($\gamma_2\sigma_2^2 < \gamma\sigma^2$), the gain from being a FDI leader is lower than that from remaining an exporter: $EV_i^{Fl}=\frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ < $\frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})=EV_i^{e}$. Also, $EV_i^{Fl}=\frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ > $\frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})=EV_i^{Ff}$ for $\gamma\sigma^2 < \gamma_1\sigma_1^2$.

In sum, given firm j waits and invests at t=3, the inequality relationship $EV_i^{e} > EV_i^{Fl} > EV_i^{Ff}$ holds. If firm j is believed to remain an exporter, $EV_i^{Ff}=\frac{(\theta+c)^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})>EV_i^{e}=\frac{(\theta-c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ at t=3 from the demand condition $\theta''' < \theta$. Thus, firm i will choose to switch to invest and at t=1, its choice is made based on the inequality $EV_i^{FI} = \frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ as for $\gamma\sigma^2 < \gamma_1\sigma_1^2$, $\frac{\theta^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$. (See the definition of $\gamma_1\sigma_1^2$.) Thus, $EV_i^{FI} > EV_i^{Ff} > EV_i^e$ and FDI at t=1 is the best response for firm i given firm j exports. As firm j's strategy given firm i's strategy is determined in the same way, there are two Commit-export equilibria. Combining two parameter condition of uncertainty ($\gamma\sigma^2 < \gamma_2\sigma_2^2$ and $\gamma_2\sigma_2^2 < \gamma\sigma^2 < \gamma_1\sigma_1^2$), it can be said that Commit-export equilibrium occurs for $\theta''' < \theta < \theta''$ and $\gamma\sigma^2 < \gamma_1\sigma_1^2$.

When $\theta''' < \theta < \theta''$ and $\gamma_1\sigma_1^2 < \gamma\sigma^2 < \gamma_3\sigma_3^2$, given firm j invests at t=1, firm i's strategy is to export at t=3. The inference is exactly the same as the previous case 5). Given firm j invests at t=3, commitment is dominated by waiting strategy and Delay option is dominated by exporting by firm i for the low demand as $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) < \frac{(\theta-2c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ for $\theta < \theta''$ at t=3 and $EV_i^{FI} = \frac{\theta^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) < \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ for $\gamma\sigma^2 > \gamma_1\sigma_1^2$ i.e, $EV_i^e > EV_i^{Ff} > EV_i^{FI}$. As a result, exporting is firm i's best response to late FDI strategy by firm j. However, firm i will choose to wait and invest at t=3 if it believes that firm j will wait and export. Under this belief, demand is still high enough to switch to FDI from exporting that Delay option will dominate export strategy. ($EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > \frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ at t=3 from the demand condition $\theta''' < \theta$.) However, since the uncertainty is sufficiently low enough ($\gamma_1\sigma_1^2 < \gamma\sigma^2 < \gamma_3\sigma_3^2$), firm i has an incentive to commit in the first period. ($EV_i^{FI} = \frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ from $\gamma\sigma^2 < \gamma_3\sigma_3^2$ and the definition of $\gamma_3\sigma_3^2$). Considering firm j's choice, there are two Commit-export equilibria.

7)For $\theta''' < \theta < \theta''$ and $\gamma_3\sigma_3^2 > \gamma\sigma^2$, the proofs for firm i's strategy given firm j waits and invests or waits and exports are exactly the same as the case in which $\theta''' < \theta < \theta''$ and $\gamma_1\sigma_1^2 < \gamma\sigma^2 < \gamma_3\sigma_3^2$. Given firm j commits to FDI, $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > -F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4}) = EV_i^{FI}$ and $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) < \frac{(\theta-3c)^2}{16+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^e$ from the demand condition $\theta < \theta'' < \theta'$. Given firm j delays FDI until t=3, $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) < \frac{(\theta-2c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ for $\theta < \theta''$ at t=3 and $EV_i^{FI} = \frac{\theta^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) < \frac{\theta^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ for $\gamma\sigma^2 > \gamma_1\sigma_1^2$ from the inequality condition $\gamma\sigma^2 > \gamma_3\sigma_3^2 > \gamma_1\sigma_1^2$. Thus, $EV_i^e > EV_i^{Ff} > EV_i^{FI}$.

When firm j is expected to remain exporter, firm i will choose to switch to FDI in t=3 based on the expected value function $EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) > EV_i^e = \frac{(\theta-c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ at t=3 from the demand condition $\theta''' < \theta$ and $EV_i^{FI} = \frac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) < \frac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^{Ff}$ from $\gamma\sigma^2 > \gamma_3\sigma_3^2$. (Note that $\gamma_3\sigma_3^2$ equates $\frac{(\theta+c)^2}{8+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8})$ and $\frac{(\theta+c)^2}{9+\gamma\sigma^2} - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$.) Thus, firm i has an incentive to delay its investment until the uncertainty is resolved. With the same way of inference by firm j, the resulting two SPNE refer to one firm investing and the other firm exports in the third period.

8) For $\theta < \theta'''$ and $\gamma\sigma^2 < \gamma_2\sigma_2^2$, Delay option is dominated by exporting strategy because of the low demand parameter. Given firm j invests in the first period, firm i has an incentive to continue exporting, because $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > -F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4}) = EV_i^{FI}$ and $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2} - F - \frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) <$

$\frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^e$ from the demand condition $\theta < \theta' < \theta'''$ i.e., $EV_i^e > EV_i^{Ff} > EV_i^{Fl}$. If firm j is believed to invest in t=3 after waiting, it is firm i's choice to become a leader rather than to become an exporter for small uncertainty based on the inequality $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) < \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ for $\theta < \theta''$ and $EV_i^{Fl} = \frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ for $\gamma\sigma^2 < \gamma_2\sigma_2^2$ i.e, $EV_i^{Fl} > EV_i^e > EV_i^{Ff}$. Given firm j exports, firm i will again choose to be a leader in FDI as $EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) < EV_i^e = \frac{(\theta-c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9})$ at t=3 from $\theta''' > \theta$ and $EV_i^{Fl} = \frac{(\theta+c)^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) > \frac{(\theta-c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ as $\gamma_4\sigma_4^2 > \gamma_2\sigma_2^2$ by their definition and $\gamma\sigma^2 < \gamma_2\sigma_2^2$ implies that $\gamma\sigma^2 < \gamma_4\sigma_4^2$. Thus, $EV_i^{Fl} > EV_i^e > EV_i^{Ff}$. Applying the symmetric strategy by firm j, the subgame perfect Nash equilibrium is one firm investing in the first period, while the other firm remaining as an exporter.

For $\theta < \theta'''$ and $\gamma_2\sigma_2^2 < \gamma\sigma^2 < \gamma_4\sigma_4^2$, firm i has the same strategy of exporting given firm j commits: $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) > -F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{4}) = EV_i^{Fl}$ and $EV_i^{Ff} = \frac{\theta^2}{16+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) < \frac{(\theta-3c)^2}{16+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{16}) = EV_i^e$ from the demand condition $\theta < \theta''' < \theta'$. Given firm j delays investments until t=3, firm i's strategy is to keep exporting based on its payoff relation $EV_i^{Ff} = \frac{\theta^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) < \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ for $\theta < \theta''$ and $EV_i^{Fl} = \frac{\theta^2}{8+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{8}) < \frac{(\theta-2c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$ for $\gamma\sigma^2 > \gamma_2\sigma_2^2$. Given firm j exports, firm i has incentive to commit at t=1, since $EV_i^{Ff} = \frac{(\theta+c)^2}{9+\gamma\sigma^2}-F-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) < \frac{(\theta-c)^2}{9+\gamma\sigma^2}-\frac{1}{\gamma}\ln(1+\frac{\gamma\sigma^2}{9}) = EV_i^e$

at t=3 from the demand condition $\theta''' > \theta$ and $EV_i^{Fl} = \dfrac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{8}) >$ $\dfrac{(\theta-c)^2}{9+\gamma\sigma^2} - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{9}) = EV_i^e$ for $\gamma\sigma^2 < \gamma_4\sigma_4^2$ i.e, $EV_i^{Fl} > EV_i^e > EV_i^{Ff}$. With the same reasoning for firm j's strategy, the resulting equilibrium is one firm investing in the first period, while the other firm remaining as an exporter.

9) Since demand parameter is below its threshold level and the uncertainty is high for the first mover, export is dominant strategy for the firm i. firm i has the same strategy of exporting given firm j commits. At t=3, $EV_i^{Ff} = \dfrac{\theta^2}{16+\gamma\sigma^2} - F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{16}) <$ $\dfrac{(\theta-3c)^2}{16+\gamma\sigma^2} - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{16}) = EV_i^e$ from the demand condition $\theta < \theta''' < \theta'$ and $EV_i^{Ff} = \dfrac{\theta^2}{16+\gamma\sigma^2} - F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{16}) > -F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{4}) = EV_i^{Fl}$. Given firm j delays investments until t=3, firm i's strategy is to keep exporting based on its payoff relation $EV_i^{Ff} = \dfrac{\theta^2}{9+\gamma\sigma^2} - F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{9}) < \dfrac{(\theta-2c)^2}{9+\gamma\sigma^2} - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{9}) = EV_i^e$ for $\theta < \theta''$ and $EV_i^{Fl} = \dfrac{\theta^2}{8+\gamma\sigma^2} - F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{8}) < \dfrac{(\theta-2c)^2}{9+\gamma\sigma^2} - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{9}) = EV_i^e$ for $\gamma\sigma^2 > \gamma_4\sigma_4^2 > \gamma_2\sigma_2^2$. Given firm j exports, firm i has an incentive to remain an exporter, since $EV_i^{Ff} = \dfrac{(\theta+c)^2}{9+\gamma\sigma^2} - F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{9}) < \dfrac{(\theta-c)^2}{9+\gamma\sigma^2} - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{9}) = EV_i^e$ at t=3 from the demand condition $\theta''' > \theta$ and $EV_i^{Fl} = \dfrac{(\theta+c)^2}{8+\gamma\sigma^2} - F - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{8}) <$ $\dfrac{(\theta-c)^2}{9+\gamma\sigma^2} - \dfrac{1}{\gamma}\ln(1+\dfrac{\gamma\sigma^2}{9}) = EV_i^e$ for $\gamma\sigma^2 > \gamma_4\sigma_4^2$. This is true to firm j and SPNE is both waiting and exporting.