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STRATEGIC FOREIGN DIRECT INVESTMENT AND EXCHANGE-RATE UNCERTAINTY*

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We investigate how exchange-rate uncertainty affects the foreign direct investment decision of a risk-neutral multinational firm (MNF). We assume the firm can open plants, each with decreasing average costs, in two different countries. Under certainty, the MNF would open only one plant. We demonstrate that with sufficient exchange-rate volatility, the firm can increase expected profits by opening several plants. We also show that if the MNF faces a competitor in the foreign market, the exchange risk, by inducing the MNF to open plants in both markets, may prevent entry by the local competitor.

1. INTRODUCTION

The increasing openness of the world economy has led not only to expanded trade but also to significant increases in foreign direct investment (FDI) in both developed and developing countries. The level of FDI is likely to continue to expand as multinational corporations look for profitable overseas production facilities and markets. Furthermore, if international negotiations are successful in further liberalizing rules governing FDI and as former nonmarket economies switch to market-based policies, the amount of FDI will continue to grow.

International firms operate in different currency units and thus may be affected by exchange-rate movements and exchange-rate uncertainty. An exchange-rate change can affect the firm's decisions as to where to produce, as well as its profits. Following the collapse of the Bretton Woods system, exchange rates have fluctuated freely, and their volatility has exceeded prior expectations. The exchange-rate crises in Asia during 1997 amply illustrate this increased volatility. If exchange-rate changes merely offset price movements so that real purchasing power parity is maintained, the exchange-rate movements would have little real effects. However, there is empirical evidence to indicate that purchasing power parity does not hold for all time periods, and thus exchange-rate changes can affect the competitiveness of plants in different countries. As such, exchange-rate volatility creates both problems and opportunities for international firms, requiring them to manage the

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risk inherent in volatile exchange rates but also presenting the opportunity of moving production to lower cost facilities.

Most previous articles that studied the effect of exchange-rate risk on FDI concentrated on the role of risk aversion. Goldberg and Kolstad (1995), using a model in which firms produce under constant marginal costs but make production decisions before the resolution of uncertainty, showed that increased exchange-rate uncertainty led a risk-averse firm to alter its FDI in order to reduce risk. Bailey and Tavlas (1991) showed that exchange-rate risk has an ambiguous effect on the FDI of a risk-averse firm. Cushman (1985) analyzed the effects of real exchange-rate risk and expectations on direct investment for four different cases, depending on where inputs were purchased, where output was produced, where financial capital was acquired, and where output was sold. He found that the direct effect of risk is to lower foreign capital costs and thus to increase foreign direct investment. However, when other input costs are affected, induced productivity changes or output price changes may offset the direct effect, reducing foreign direct investment. While these theoretical studies found that exchange-rate uncertainty has ambiguous effects on the level of FDI, some empirical studies[2] show that increases in exchange-rate risk are positively and significantly correlated with FDI flows.

In this article we study how the ability to shift production in response to *realized* exchange-rate movements affects the FDI decisions of a monopolistic firm. While our model is similar to that of Goldberg and Kolstad (1995), it differs from theirs because we assume that (1) each plant exhibits decreasing average cost and (2) the firm makes production decisions *after the exchange rate is known* (investment decisions are made prior to the resolution of uncertainty). Given this cost structure, the firm would not open more than one plant in a deterministic setting. While we work with a single production period, allowing for a sequence of production periods would reinforce the point we are making, since sequential movements in the exchange rate are more likely to lead to adjustments in where output is produced.

Our view of FDI parallels that taken in the real options literature (see, e.g., Dixit and Pindyck, 1994). By opening more than one plant, and thus postponing the decision as to where to produce, the multinational firm (MNF) purchases a real option whose value depends on exchange-rate variability. Our model is similar to that of Kogut and Kulatilaka (1994), who assume that a MNF may switch production from one facility to another in response to exchange-rate movements. In their model, the firm incurs costs in switching production (closing one plant). Additionally, their model differs from ours in that they assume that the firm's output is constant and that it faces no competitor.

Sunk costs also play a key role in the hysteresis literature (see Dixit, 1989a, 1989b; Baldwin and Krugman, 1989). If sunk costs must be incurred to enter a market, then transitory exchange-rate movements may have a permanent effect. While our model also depends crucially on sunk costs, we focus on the net benefits of maintaining multiple production facilities and on how exchange-rate volatility affects the strategic position of a multinational firm.

In Section 2 we develop the basic model and show how exchange-rate risk affects the investment and production decisions of a monopoly firm that can produce at

[2] For example, see Cushman (1985) and Goldberg and Kolstad (1995).

home or abroad but can sell only in its home market. We show that a risk-neutral firm (potentially) benefits from exchange-rate volatility and that this volatility may lead to increased investment or that it may divert investment from one location to another. In Section 3 we extend the model by assuming that the MNF can sell both at home and abroad and that it faces a local competitor in the foreign market. We show that the exchange risk benefits the MNF and may drive the domestic firm from the market, even though firms move simultaneously and are risk-neutral. Our result, which is due solely to the exchange-rate risk, parallels other work in strategic trade policy that shows that import protection can promote exports. In a related article, Spencer and Brander (1992) studied the tradeoff between precommitment and flexibility in a strategic setting with uncertainty. In their model, firms had to balance the strategic advantage of precommitting (output or investment) against the benefit of waiting to act until they had complete information. They found that increased volatility may induce the firm with a first-move advantage to defer its output decision (or in a simultaneous-move game, both firms may choose to defer their decisions). However, in our model, firms move simultaneously, so the only asymmetry between firms is that the MNF can produce and sell in both markets, while the local firm is confined to its own market.

2. OPTIMAL INVESTMENT WITH DOMESTIC SALES ONLY

In this article we develop a simple model that highlights the role of exchange-rate uncertainty on the FDI decision of a risk-neutral MNF. For this section we assume that the firm sells only in the domestic market and thus—absent foreign investment—has no exposure to exchange-rate risk. Within this framework, we show that (1) increased exchange-rate variability increases the option value of opening both plants, and (2) even if sunk costs are such that it is profitable to open only one plant, increased exchange-rate variability increases the relative profitability of opening the *foreign* plant. This result contrasts with the traditional result that the firm will alter its investment in order to reduce its exposure to risk.

Throughout we assume that the risk-neutral MNF produces a homogeneous good either in a plant in the "home" market (the United States) or in a plant in the "foreign" market (Mexico). We assume that each plant exhibits decreasing average cost so that, in a deterministic setting, only one plant will be used.[3] More specifically, we assume (1) that there is a sunk cost associated with opening each plant, (2) that marginal production cost in each plant is constant, and (3) that expected marginal costs are the same for each plant, but sunk costs are higher for the foreign plant.[4] More formally,

$$(1) \qquad TC_h = F + cq \qquad TC_f = e_0\bar{F} + e\bar{c}\bar{q} \qquad c = E(e)\bar{c} \qquad F < e_0\bar{F}$$

[3] Under increasing average cost it will, in general, be desirable to open both plants. We make our assumption to highlight the role played by exchange-rate risk in increasing the option value of opening a second plant.

[4] The higher sunk costs in Mexico may be due to extra costs the firm incurs in familiarizing itself with local regulations and any extra requirements imposed on nonnational firms. Similar results would hold if expected marginal costs also were lower in the United States.

where TC_h (TC_f) denotes costs in the U.S. (Mexican) plant, F is the sunk cost of opening the U.S. plant, c is the constant marginal cost of producing at home (in dollars), $\bar{F}$ and $\bar{c}$, measured in pesos, are the corresponding parameters for the foreign plant, q and $\bar{q}$ denote output in each plant, e_0 denotes the prevailing exchange rate (dollars/peso) when the investment decision is made, and e is the actual exchange rate when production decisions are made. Though e is not known when the investment (plant-opening) decision is made, we assume[5] $e_0 = E(e)$ so that any exchange-rate innovation is unanticipated. In a deterministic setting, only the U.S. plant would be used.

Decisions are made in the following sequence: (1) the firm decides which plants to open, (2) the exchange rate (e) that will prevail when production occurs is determined, and (3) the firm decides where and how much to produce. Turning to demand, in this section we assume that the firm can sell only in the U.S. market, where it faces the linear (inverse) demand curve $P(Q)$:

$$P(Q) = A - bQ \quad \rightarrow \quad R(Q) \equiv PQ = AQ - bQ^2 \tag{2}$$

where Q denotes domestic sales. The firm's profit functions for the three cases (U.S. plant only, Mexican plant only, and both plants) are given by

$$\begin{aligned} &\pi_h(Q) = \{R(Q) - cQ - F\} \qquad \pi_f(e,Q) = \{R(Q) - e\bar{c}Q - e_0\bar{F}\} \\ &\pi_b(e,q,\bar{q}) = \{R(Q) - cq - e\bar{c}\bar{q} - F - e_0\bar{F}\} \qquad q + \bar{q} = Q \end{aligned} \tag{3}$$

where the subscript indicates which case pertains (h for home plant, f for foreign plant, and b for both plants). Its optimal output and maximum realized profits for each case are given by

$$Q_h^* = \left(\frac{A-c}{2b}\right) \qquad \pi_h^* = \left(\frac{(A-c)^2}{4b}\right) - F \qquad \pi_h^* > 0 \text{ by assumption} \tag{4}$$

$$Q_f^*(e) = \left(\frac{A-e\bar{c}}{2b}\right) \qquad \pi_f^*(e) = \left(\frac{(A-e\bar{c})^2}{4b}\right) - e_0\bar{F} \tag{5}$$

$$Q_b^* = \left(\frac{A-c_{\min}}{2b}\right) \qquad c_{\min} = \min[c, e\bar{c}] \quad \rightarrow \tag{6}$$

$$\text{for} \quad e > e_0 \equiv \frac{c}{\bar{c}}, \quad Q_b^* = Q_h^*, \pi_b^*(e) = \pi_h^* - e_0\bar{F}$$

$$\text{for} \quad e < e_0, \quad Q_b^* = Q_f^*(e), \pi_b^*(e) = \pi_f^*(e) - F$$

From Equations (4) to (6), we see that (1) the firm is isolated from exchange-rate changes if it opens only its home plant, (2) if it opens only its foreign plant, output varies inversely with e, and the strict convexity of the profit function in e implies

[5] The expectation is taken based on information available at the time the investment decision is made.

that exchange-rate variability increases expected profits, and (3) increased exchange-rate variability increases the value to the firm of the option obtained by opening both plants. Expected profits when only the foreign plant is opened are given by

$$(7)\qquad \underset{e}{E}\left[\pi_f^*(e)\right] = \left[\frac{(A - e_0\bar{c})^2}{4b}\right] - e_0\bar{F} + \frac{\sigma^2\bar{c}^2}{4b}$$

$$\sigma^2 \equiv E\left[(e - e_0)^2\right] \qquad e_0 = E(e)$$

Opening both plants allows the firm to *defer* the decision as to where to produce, granting the firm a real option whose gross cost is the sunk cost associated with opening the (second) plant. The net realized value of the option is the difference between π_b and π_h, and the expected value of opening the foreign plant V_f, *given that the home plant will be opened*, is

$$(8)\qquad V_f = E\left[\pi_b^*(e) - \pi_h^*\right] = -e_0\bar{F} + \underset{e<e_0}{E}\left\{\left[\frac{(A - e\bar{c})^2}{4b}\right] - \left[\frac{(A - c)^2}{4b}\right]\right\}$$

$$= -e_0\bar{F} + \underset{e<e_0}{E}\left\{\frac{\bar{c}(e_0 - e)\left[2A - \bar{c}(e + e_0)\right]}{4b}\right\}$$

It is readily shown that a mean-preserving spread of e increases V_f. Similarly, the expected value of opening the home plant V_h, *given that the foreign plant will be opened*, is

$$(9)\qquad V_h = E\left[\pi_b^*(e) - \pi_f^*\right] = V_f + E(\pi_h^* - \pi_f^*) = V_f + \left[e_0\bar{F} - F - \frac{\sigma^2(e)\bar{c}^2}{4b}\right]$$

where $V_f \gtreqless V_h$ as $E(\pi_f^*) \gtreqless \pi_h^*$. Thus the risk-neutral firm's decision is given by[6]

$$(10)\qquad \begin{array}{lll} \text{if} \quad V_h > V_f \quad \text{and} \quad V_f \leq 0 & & \text{open home plant only;} \\ \text{if} \quad V_f > V_h \quad \text{and} \quad V_h \leq 0 & & \text{open foreign plant only;} \\ \text{if} \quad \text{Min}\{V_h, V_f\} > 0 & & \text{open both plants} \end{array}$$

Under our cost assumptions, for low exchange-rate variability, the firm will open only its home plant. As the variability increases, the firm may find it profitable to either (1) open the foreign plant *instead* of the home plant or (2) open both plants. The former case is likely to occur when the sunk costs for each plant are large but not too dissimilar, whereas the latter case will be more likely to occur when sunk costs are relatively low. To be more specific requires specifying the density function for the exchange rate. We assume that e is uniformly distributed, with mean e_0: $e \in [e_0(1 - \mu), e_0(1 + \mu)]$. Under these assumptions, the option values are given by

[6] We assume that it is always profitable to open the home plant, i.e., $(A - c)^2 > 4bF$.

$$(11) \qquad V_f = \frac{c\left[3(A-c)\mu + c\mu^2\right]}{24b} - e_0\bar{F} \qquad V_h = \frac{c\left[3(A-c)\mu - c\mu^2\right]}{24b} - F$$

$$\underset{e}{E}\left[\pi_f^*(e)\right] - \pi_h^* = V_f - V_h = \frac{\mu^2 c^2}{12b} - \Delta$$

$$\Delta \equiv e_0\bar{F} - F > 0 \qquad \sigma^2(e) = e_0^2(\mu^2/3)$$

The plant-opening pattern that emerges depends on the parameters of the problem: Define μ_0 such that $V_f(\mu_0) - V_h(\mu_0) = 0$; thus $\mu_0 = (\sqrt{12b\Delta}/c)$. Similarly, define μ_1 such that $V_f(\mu_1) = 0$ and μ_2 such that $V_h(\mu_2) = 0$. Note that

$$\mu_0 < \mu_1 \leftrightarrow \frac{3(A-c)^2}{4b} < \frac{\left(F + e_0\bar{F}\right)^2}{\left(e_0\bar{F} - F\right)}$$

Since both V_f and V_h are increasing in μ in the relevant domain, it is readily seen that

1. If $\mu_0 < \mu_1$, then $\mu_1 < \mu_2$; for this case, if $\mu \in [0, \mu_0]$, the MNF opens only the U.S. plant; if $\mu \in [\mu_0, \mu_2]$, it opens only the foreign plant; and if $\mu > \mu_2$, it opens both plants.
2. If $\mu_0 > \mu_1$, then for $\mu \in [0, \mu_1]$, the MNF opens only the U.S. plant, whereas for $\mu > \mu_1$, it opens both plants.

The results of this section are summarized below:

PROPOSITION 1. *Consider a risk-neutral MNF that can open plants at home or abroad.*[7] *Given the cost structure specified in Equation* (1) *and the demand structure specified in Equation* (2), *and assuming plant-opening decisions are made prior to*, *but production decisions are made after*, *exchange-rate realizations*, *then increased exchange-rate variability raises expected profits if the foreign plant is opened and leads to the following plant-opening decisions*:

(i) *If sunk costs are relatively large but similar across plants*, *then* (*a*) *for low exchange-rate variability*, *only the home plant will be opened*, (*b*) *for intermediate values*, *only the foreign plant will be opened*, *whereas* (*c*) *for large exchange-rate variability*, *both plants will be opened*; *or*:

(ii) *If sunk costs are not too large* (*or are relatively different across plants*), *then* (*a*) *for low exchange-rate variability*, *only the home plant will be opened*, *whereas* (*b*) *for larger values of exchange-rate variability*, *both plants will be opened*.

3. STRATEGIC ADVANTAGE

In this section we extend our model by assuming (1) that the MNF can sell in both

[7]For simplicity, we ignore transportation costs, which would have the same effect as increasing marginal production costs in the foreign plant.

the domestic and foreign markets and (2) that the MNF faces a local competitor in the foreign market (but no competition in the home market). The former assumption does not alter the result that increased exchange-rate variability increases the option value of opening both plants.[8] The presence of a local competitor in the foreign market adds a potential strategic dimension to the model and implies that the equilibrium solution may be affected by exchange-rate variability.

The MNF's cost function and demand in the U.S. market are as in Section 2. The Mexican firm, *which can sell only in its own market*, has the same basic cost structure:

$$\bar{C} = \bar{G} + \bar{d}\bar{y} \tag{12}$$

where $\bar{G}$ is the sunk cost, $\bar{d}$ is the constant marginal cost (in pesos), and $\bar{y}$ is the output of the local firm. Letting $\bar{P}$ denote price and $\bar{Q}$ total sales in the Mexican market, the inverse demand is

$$\bar{P} = \bar{A} - \bar{b}\bar{Q} \tag{13}$$

Decisions are made in the following sequence: (1) firms simultaneously make plant-opening decisions (the local firm decides whether to open a plant at home, while the MNF decides where to open its plants), (2) nature determines the exchange rate, and (3) given stage 1 decisions, firms simultaneously make production and sales decisions. Neither firm has a first-move advantage, nor does the MNF's ability to open both plants confer a strategic advantage under certainty.

Each firm's profits depend on the plant-opening decisions and the realized exchange rate. There are six possible cases; let $i = h, f, b$ (*h*ome, *f*oreign, *b*oth) index the MNF's three plant-opening decisions and $j = e, d$ (*e*nter, *d*on't enter) index the local firm's decision.[9] Further, let $Q_{i,j}$ denote the MNF's sales in its home market, $y_{i,j}$ its sales in the foreign market, and $\bar{y}_{i,j}$ the local firm's sales in its own market (by definition, $\bar{y}_{i,d} = 0$, $\forall i$). Finally, let $\pi_{i,j}$ and $\bar{\Pi}_{i,j}$ denote realized profits for the MNF and local firm, respectively.

The variable profits (exclusive of sunk costs) for each firm are given by

$$\begin{aligned} \pi^{v}_{i,j} &= (A - bQ_{i,j})Q_{i,j} + e\left[\bar{A} - \bar{b}(y_{i,j} + \bar{y}_{i,j})\right]y_{i,j} - c_{i,j}(Q_{i,j} + y_{i,j}) \\ \bar{\Pi}^{v}_{i,j} &= \left[\bar{A} - \bar{b}(y_{i,j} + \bar{y}_{i,j})\right]\bar{y}_{i,j} - \bar{d}\bar{y}_{i,j} \\ c_{h,j} &= c \qquad c_{f,j} = e\bar{c} \qquad c_{b,j} = \min(c, e\bar{c}) \end{aligned} \tag{14}$$

We assume that parameters are such that under certainty, the local firm would find it profitable to enter and the MNF would open only its home plant. The following *ex post* profit-maximizing solutions for each case in which the local firm

[8] For the case in which the firm opens only one plant, there no longer is the presumption that exchange-rate variability favors opening the plant in the foreign market, since sales are derived in both markets.

[9] We assume that cost and demand parameters are such that the MNF will always open at least one plant.

enters are readily verified:

$$Q^*_{h,e} = \left(\frac{A-c}{2b}\right) \qquad y^*_{h,e} = \left[\frac{\bar{A}+\bar{d}-2(c/e)}{3\bar{b}}\right] \qquad \bar{y}^*_{h,e} = \left[\frac{\bar{A}+(c/e)-2\bar{d}}{3\bar{b}}\right]$$

(15) $$\pi^*_{h,e} = \frac{(A-c)^2}{4b} + \frac{e\left(\bar{A}+\bar{d}-2(c/e)\right)^2}{9\bar{b}} - F;$$

$$\bar{\Pi}^*_{h,e} = \frac{\left(\bar{A}+(c/e)-2\bar{d}\right)^2}{9\bar{b}} - \bar{G}$$

$$Q^*_{f,e} = \left(\frac{A-e\bar{c}}{2b}\right) \qquad y^*_{f,e} = \left(\frac{\bar{A}+\bar{d}-2\bar{c}}{3\bar{b}}\right) \qquad \bar{y}^*_{f,e} = \left(\frac{\bar{A}+\bar{c}-2\bar{d}}{3\bar{b}}\right)$$

(16) $$\pi^*_{f,e} = \frac{(A-e\bar{c})^2}{4b} + \frac{e\left(\bar{A}+\bar{d}-2\bar{c}\right)^2}{9\bar{b}} - e_0\bar{F}$$

$$\bar{\Pi}^*_{f,e} = \frac{\left(\bar{A}+\bar{c}-2\bar{d}\right)^2}{9\bar{b}} - \bar{G}$$

$$Q^*_{b,e} = \left(\frac{A-e\bar{c}_m}{2b}\right) \qquad y^*_{b,e} = \left(\frac{\bar{A}+\bar{d}-2\bar{c}_m}{3\bar{b}}\right) \qquad \bar{y}^*_{b,e} = \left(\frac{\bar{A}+\bar{c}_m-2\bar{d}}{3\bar{b}}\right)$$

$$\bar{c}_m \equiv \min\{(c/e), \bar{c}\}$$

(17) $$\pi^*_{b,e} = \frac{(A-e\bar{c}_m)^2}{4b} + \frac{e\left(\bar{A}+\bar{d}-2\bar{c}_m\right)^2}{9\bar{b}} - F - e_0\bar{F}$$

$$\bar{\Pi}^*_{b,e} = \frac{\left(\bar{A}+\bar{c}_m-2\bar{d}\right)^2}{9\bar{b}} - \bar{G}$$

Similarly, if the local firm does not enter, the following solutions are readily derived:

(18) $$Q^*_{h,d} = \left(\frac{A-c}{2b}\right) \qquad y^*_{h,d} = \left[\frac{\bar{A}-(c/e)}{2\bar{b}}\right]$$

$$\pi^*_{h,d} = \frac{(A-c)^2}{4b} + \frac{e\left[\bar{A}-(c/e)\right]^2}{4\bar{b}} - F$$

(19) $$Q^*_{f,d} = \left(\frac{A-e\bar{c}}{2b}\right) \qquad y^*_{f,d} = \left(\frac{\bar{A}-\bar{c}}{2\bar{b}}\right)$$

$$\pi^*_{h,d} = \frac{(A - e\bar{c})^2}{4b} + \frac{e(\bar{A} - \bar{c})^2}{4\bar{b}} - e_0\bar{F}$$

(20)
$$Q^*_{b,d} = \left(\frac{A - e\bar{c}_m}{2b}\right) \qquad y^*_{b,d} = \left(\frac{\bar{A} - \bar{c}_m}{2\bar{b}}\right)$$

$$\pi^*_{b,d} = \frac{(A - e\bar{c}_m)^2}{4b} + \frac{e(\bar{A} - \bar{c}_m)^2}{4\bar{b}} - F - e_0\bar{F}$$

The qualitative properties of the solution are as follows: If the MNF opens only its home plant, its U.S. sales are unaffected by the exchange rate, while its sales in the Mexican market vary directly with the exchange rate (thus exchange-rate changes affect the Mexican firm's profits, even though its costs and revenue are in pesos). If the MNF opens only its foreign plant, converse results hold: The Mexican market is isolated from exchange-rate movements, but the MNF's sales in the United States move inversely with the exchange rate. If the MNF opens both plants, then its sales in each market are the upper envelope of the two preceding cases, and its *expected variable* profits are higher than when it opens only one plant.

From Equations (15) to (20), it is apparent that exchange-rate variability increases the MNF's expected profits. However, the crucial question is how this variability affects the *relative* payoffs to different strategies. For notational convenience, assume that the distribution of e (given its mean) can be characterized by its variance, σ_e^2. Define $V_{i,j}(\sigma_e^2) = \underset{e}{E}[\pi^*_{i,j}(e)]$ and $\bar{V}_{i,j}(\sigma_e^2) = \underset{e}{E}[\bar{\Pi}^*_{i,j}(e)]$; by definition, $\bar{V}_{i,d}(\sigma_e^2) = 0$ for all i. These payoffs are presented in Table I.

Under certainty, $V_{h,e}(0) > V_{f,e}(0) > V_{b,e}(0)$ and $V_{h,d}(0) > V_{f,d}(0) > V_{b,d}(0)$, so opening only the home plant is a dominant strategy for the MNF. Similarly, $\bar{V}_{h,e}(0) = \bar{V}_{f,e}(0) = \bar{V}_{b,e}(0) > 0$, so under certainty, entering is a dominant strategy for the local firm.[10] We know from the preceding section that changes in exchange-rate variability will change the payoff to each plant-opening strategy and will increase the option value of opening both plants. At the same time, the payoffs to the local firm will be affected by the volatility of the exchange rate and by the MNF's decision regarding which plant to open. Thus exchange-rate variability may alter the solution

[10] The local firm's profits do not depend on the plant opened by the MNF because marginal costs are the same in all plants. The key assumption is that the local firm earns positive profits regardless of which plant the MNF opens.

TABLE 1
PAYOFF MATRIX

MNF \ Local Firm	Enter	Do Not Enter
Open home plant	$\{V_{h,e}(\sigma_e^2), \bar{V}_{h,e}(\sigma_e^2)\}$	$\{V_{h,d}(\sigma_e^2), 0\}$
Open foreign plant	$\{V_{f,e}(\sigma_e^2), \bar{V}_{f,e}(\sigma_e^2)\}$	$\{V_{f,d}(\sigma_e^2), 0\}$
Open both plants	$\{V_{b,e}(\sigma_e^2), \bar{V}_{b,e}(\sigma_e^2)\}$	$\{V_{b,d}(\sigma_e^2), 0\}$

to the game.

To ascertain how exchange-rate uncertainty alters each firm's optimal strategy, we must determine how the uncertainty affects the *relative payoffs* for each scenario. The following properties of these payoffs are readily verified from Equations (15) to (20)[11]:

P1. Due to exchange-rate uncertainty, the expected profits of the local firm: (a) *increase* in the {Home, Enter} case, (b) *are unchanged* in the {Foreign, Enter} case, and (c) *decrease* in the {Both, Enter} case.

P2. Mean-preserving spreads of the exchange-rate distribution reduce $\overline{V}_{b,e}(\sigma_e^2)$.

P3. For plausible parameters, the MNF will *not* open the foreign plant *instead* of the home plant.

P4. If the local firm's costs are similar to the MNF, the option value of opening the foreign plant is higher when the local firm does not enter: $\{V_{b,d}(\sigma_e^2) - V_{h,d}(\sigma_e^2)\} > \{V_{b,e}(\sigma_e^2) - V_{h,e}(\sigma_e^2)\}$.

The significance of these properties is as follows: P1 and P2 imply that "entering" may not be a dominant strategy for the local firm under uncertainty. If there exists $\tilde{\sigma}_e^2$ such that $\overline{V}_{b,e}(\sigma_e^2) \gtreqless 0$ as $\sigma_e^2 \lesseqgtr \tilde{\sigma}_e^2$, then entering is a dominant strategy for the local firm if $\sigma_e^2 < \tilde{\sigma}_e^2$. However, for $\sigma_e^2 > \tilde{\sigma}_e^2$, the local firm's best response is *do not enter* if the MNF opens both plants (and *enter* otherwise). P3 implies that opening only the foreign plant is a dominated strategy for the MNF, so we restrict the strategy space to "open home" or "open both." P4 implies that the option value of the second plant is higher when the local firm does not enter.[12] The key remaining question is how increased exchange-rate variability alters the MNF's strategy. While it is plausible that increased variability always increases the option value of opening the second plant, it does not seem possible to obtain analytical results for general distributions. However, for a uniform distribution, we have:

P5. Assume that the exchange rate has a uniform distribution. Then increased variability increases the value of opening the foreign plant [increases in σ_e^2 increase $(V_{b,e} - V_{h,e})$ and $(V_{b,d} - V_{h,d})$].[13]

P5 implies that there are parameter values that will make "open both plants" a dominant strategy if exchange-rate variability is large. Thus, depending on parameter values, a variety of Nash equilibria could emerge. (1) If $\overline{V}_{b,e} > 0$, then entering is a dominant strategy for the local firm, and the Nash equilibrium will be {Open home, Enter} if $V_{h,e} > V_{b,e}$ (and {Open both, Enter} otherwise).[14] If $\overline{V}_{b,e} < 0$, as may

[11] Details are in an Appendix, which is available on the Web at *http://www.econ.iastate.edu/faculty/lapan/*.

[12] P4 guarantees a pure-strategy equilibrium by precluding the case $\overline{V}_{b,e} < 0$, $V_{b,e} > V_{h,e}$ and $V_{b,d} < V_{h,d}$.

[13] Details are available in the Appendix, cited in footnote 11.

[14] If $V_{h,e} = V_{b,e}$ and $\overline{V}_{b,e} > 0$, then there are two pure strategy Nash equilibria, and although the MNF is indifferent between the two, the local firm strictly prefers the {Open home, Enter} solution.

TABLE 2
PAYOFFS FOR DIFFERENT EXCHANGE-RATE VARIABILITY

MNF \ Local Firm		Enter	Don't Enter
(i)	Deterministic case		
	Open home	**{58.78; 1.78}**	{86; 0}
	Open both	{44.78; 1.78}	{72; 0}
(ii)	$\varepsilon = 0.1$		
	Open home	**{59.44; 2.16}**	{86.37; 0}
	Open both	{52.21; 0.32}	{79.71; 0}
(iii)	$\varepsilon = 0.14$		
	Open home	**{60.07; 2.54}**	{86.73; 0}
	Open both	{55.44; −0.18}	{82.98; 0}
(iv)	$\varepsilon = 0.20$		
	Open home	**{61.46; 3.37}**	{87.51; 0}
	Open both	{60.53; −0.86}	**{88.08; 0}**
(iv)	$\varepsilon = 0.22$		
	Open home	{62.04; 3.73}	{87.83; 0}
	Open both	{62.30; −1.07}	**{89.82, 0}**

Parameters: $A = 35$, $\bar{A} = 35$, $F = 12$, $\bar{F} = 14$, $\bar{G} = 20$, $c = \bar{c} = \bar{d} = 21$, $e_0 = 1$.

happen for *high exchange-rate variance*, then a number of possibilities emerge. (2A) If $\bar{V}_{b,e} < 0$ and $V_{b,e} > V_{h,e}$ (which, by P4, implies that $V_{b,d} > V_{h,d}$), then {Open both, Don't Enter} is the unique Nash equilibrium. However, if (2B) $\bar{V}_{b,e} < 0$, $V_{b,e} < V_{h,e}$, and $V_{b,d} > V_{h,d}$, then there are two Nash equilibria [{Open home, Enter}; and {Open both, Don't Enter}], while if (2C) $\bar{V}_{b,e} < 0$, $V_{b,e} < V_{h,e}$, and $V_{b,d} < V_{h,d}$, the unique Nash equilibrium is {Open home, Enter}. These latter two cases are particularly interesting because if the MNF could precommit to opening both plants, it would benefit by doing so (provided $V_{b,d} > V_{h,e}$). *Thus the increased uncertainty could increase the value of precommiting*, a result that is contrary to the usual intuition that it pays to defer decisions in the face of uncertainty.

Table 2 provides a numerical illustration of how exchange-rate variability affects each firm's payoffs and the resulting Nash equilibrium. The parameters used ensure that "open foreign only" is a strictly dominated strategy, and thus we restrict the MNF's strategies to "open home" or "open both." The simulation, which assumes that the exchange rate is uniformly distributed with $e \in [(1-\varepsilon), (1+\varepsilon)]$, reinforces our earlier discussion. First, the MNF will not open both plants under certainty due to the extra sunk cost. Second, the MNF gains no strategic advantage by moving first under certainty. Third, increased exchange-rate variability (1) always benefits the MNF, (2) benefits the local firm if the MNF opens only its U.S. plant, but (3) hurts the local firm if the MNF opens both plants.

From the table we see that for low exchange-rate variability ($\varepsilon = 0$ or $\varepsilon = 0.1$), each firm has a dominant strategy with the resulting unique Nash equilibrium {Open home; Enter}. An increase in variability (to, e.g., $\varepsilon = 0.14$) implies that the local firm would lose money if the MNF opened both plants, but {Open home; Enter} remains the unique Nash equilibrium if firms move simultaneously. *However, for this case it would be advantageous for the MNF to move first and open both plants, thereby deterring entry by the local firm.* A further increase in variability (e.g., $\varepsilon = 0.2$) results in two Nash equilibria: {Open home; Enter} and {Open both, Don't enter}. Finally, for even larger variability (e.g., $\varepsilon = 0.22$) "open both" becomes a dominant strategy for the MNF, with the unique Nash equilibrium {Open both, Don't enter}.

This table illustrates all the points discussed in this article: (1) exchange-rate uncertainty increases the option value of multiple facilities, (2) the exchange-rate uncertainty may give the MNF a strategic advantage even though no such advantage exists in a deterministic setting, and (3) the uncertainty may *increase* the incentive for the MNF to move first even though there is no first-move advantage under certainty. This latter result is contrary to Spencer and Brander's (1992) result that uncertainty increases the value of deferring actions. Though our result seems different (precommit or not), the principle is the same—increased uncertainty raises the value of the option to defer output choices.[15]

4. SUMMARY AND CONCLUSIONS

Most previous articles studying the link between exchange-rate volatility and FDI have focused on the role of risk aversion. In this article we emphasize that exchange-rate volatility creates opportunities for multinational firms to move production to lower-cost plants. High volatility increases the option value of FDI and may stimulate new investment (or change the magnitude of investment in each facility). Thus our model is very much in the spirit of the recent real options literature. We also have shown that when a MNF is in competition with a local firm, the exchange-rate volatility, by increasing the value of the option the MNF has to operate in several localities, effectively gives the MNF a strategic advantage that may force the local firm from the market. This result, though derived from different premises, is analogous to articles that demonstrate that protecting a home market can confer a strategic advantage in foreign markets. Finally, our results also indicate that increased uncertainty may, under certain circumstances, raise the value of precommiting actions, a result that is counter to previous results.

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[15] In our model, the MNF does not lose information by precommiting its plant-opening decision before the local firm moves. However, we could enlarge the game by assuming that variability of the exchange rate $\{\varepsilon\}$ was initially unknown and then allowing the MNF to precommit to either (1) open plant(s) before the exchange-rate variability was resolved or (2) wait until ε became known and move simultaneously with the local firm. This game would support our conclusion that, in this model, higher variability *increased* the incentive to precommit.

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