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Precommitment and Random Exchange Rates in Symmetric Duopoly: A New Theory of Multinational Production

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Abstract

Recent volatility in real exchange rates has renewed interest in the nature of multinational firms. One increasingly common phenomenon involves the foreign sourcing of production, in which certain domestic firms choose to produce part or all of their product abroad and then export the commodity for domestic sale. Multinational production has been rationalized on the basis of inherent asymmetries between firms, such as the possession of certain firm-specific assets or differences between firms in their perceptions of foreign production costs, access to foreign subsidy programs, and the possibility of tariff preemption. Such behavior has also been rationalized in terms of corporate risk-aversion and a desire to hedge real exchange rate risk through the diversification of production locations.

This paper presents an entirely novel explanation for the existence of multinational firms and the foreign sourcing of production. Rather than relying on exogenous asymmetries between firms or on assumptions about corporate aversion to risk, this explanation recognizes that exchange rate uncertainty may offer a *purely strategic* motive for symmetric and risk-neutral domestic oligopolists to precommit to foreign production in order to attain a position of industry leadership. This explanation is presented in the specific context of a two-period model of strategic foreign production by domestic duopolists. Strategically symmetric and risk-neutral firms are confronted by a unique source of uncertainty in the form of a randomly fluctuating exchange rate. Exchange rate uncertainty is resolved, for the purposes of current production production decisions, between the two periods. Precommitted foreign production in the first period yields a leadership advantage relative to firms that do not precommit, but this decision must be evaluated against the value of the alternative of remaining flexible to adopt a production plan after the resolution of exchange rate uncertainty. A unique symmetric sequential equilibrium in mixed strategies is determined in this market, allowing a Stackelberg leader to endogenously emerge through a credible precommitment to the foreign sourcing of production.

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I. Introduction

The dramatic increase in exchange rate volatility during the last decade has focussed attention on the influence of random exchange rate fluctuations on corporate behavior in concentrated industries. One aspect of this influence concerns the observation that leading firms in such industries frequently tend to be multinational in character, while their rivals remain purely domestic. Another aspect concerns the increasingly common phenomenon of foreign sourcing of production by domestic firms, in which dominant firms in one economy frequently choose to produce part or all of their product abroad and then export the commodity to their home economy for domestic sale. [1]

Several rationales for multinationalism and the foreign sourcing of production among industry leaders have appeared in both academic journals and the business press. The most obvious explanation for foreign production sourcing involves the opportunity for cheap production abroad as a result of a belief in the persistant strength of domestic currency. The emergence of certain firms as multinationals can subsequently be explained through the presence of some inherent asymmetry between rival firms in an industry. The possession by one firm of some internal advantage, such as proprietary knowledge from research expenditures or superior management and marketing techniques, could yield a substantial cost advantage over both foreign and domestic rivals and allow it to become an industry leader. Other asymmetries between firms which could induce multinational production include differential access to foreign subsidy programs, imperfect domestic capital markets, or the desire by certain domestic firms to secure access to a foreign economy, under the expectation of future trade barriers, for eventual sales in the foreign market. Yet another explanation for multinationalism and the foreign sourcing of production involves the hedging of exchange rate risk through the diversification of production locations. While all of these explanations are plausible, each relies, in some measure, on either the exogenous existence of explicit or implicit asymmetries between rival firms in an industry, or on a corporate aversion to risk and associated imperfections in domestic and international capital markets.

When the industry producing for the domestic market is concentrated, however, multinational production may arise among completely *symmetric*, *risk-neutral* firms and may underlie the *endogenous* emergence of industry leadership. Foreign production sourcing can occur precisely because

[1] Examples of this latter phenomenon include American firms, such as Apple, choosing to produce some lines of personal computers in Taiwan for sale in the US, or Japanese firms, such as Honda, producing automobiles in the US for ultimate sale in Japan.

uncertainty over real exchange rates offers a *purely strategic* motive for initially symmetric, risk-neutral domestic oligopolists to precommit to foreign production for domestic sale. A decision to incur a fixed investment cost and credibly commit to foreign production in advance may, as a result of random exchange rate fluctuations, offer a domestic firm a lower marginal cost of production and the opportunity to obtain the increased expected profits associated with being a Stackelberg leader in the domestic market. This advantage of precommitment, however, must be weighed against the opportunity cost of precommitment, which involves surrendering the option to remain flexible under such uncertainty and to select a production location and production volume after the resolution of that portion of exchange rate uncertainty which is relevant for current production and investment decisions.

Our objective in this paper is to proffer this new explanation of multinational production. We examine the role of exchange rate randomness in creating endogenous industry leadership, through strategic precommitment to multinational production, in the context of a symmetric duopoly with risk-neutral firms. We analyze a stylized model of an industry in which each firm can produce its commodity domestically, under certain demand and cost conditions, or, by incurring a fixed cost, credibly precommit to foreign production and domestic sale under cost uncertainty induced by a random real exchange rate. When decisions concerning production volume and location are made simultaneously, a domestic firm must assess the tradeoff between precommitting to a volume of foreign production under uncertainty and possibly obtaining the position of a Stackelberg leader in the industry, or remaining flexible and waiting until short-run exchange rate uncertainty is resolved to make its decision about production location, at the cost of possibly becoming a follower to its rival in the industry.

The optimal precommitment decision under exchange rate uncertainty is characterized by a unique symmetric sequential equilibrium in mixed strategies with respect to the *timing* of the selection of production location by the symmetric domestic duopolists in our model. When the fixed cost of exercising the option to engage in foreign production is small relative to the expected cost advantage of foreign production created by the randomly fluctuating exchange rate, each firm will select a positive probability of foreign production sourcing, thereby obtaining the leadership advantage of precommitment, but, as long as there is some uncertainty about the exchange rate, both firms will not, with certainty, exercise their option to produce abroad. Such randomization in the timing of the production location decision implies that exchange rate uncertainty can induce

multinational production, even among firms that are entirely risk-neutral and display an initial symmetry, and that foreign production is, for purely strategic reasons, quite naturally associated with the endogenous emergence of industry leadership.

While this paper considers a novel source of influence of exchange rate uncertainty on strategic and irreversible decisions about the foreign sourcing of production, it is related to earlier literature concerning the existence of multinational firms and also to recent literature examining the implications of precommitment and irreversibility for domestic market structure.

Several theories rationalize the existence of multinational firms in a deterministic economy. These include the *industrial organization* theory of direct foreign investment, most notably associated with Caves (1971) and Hymer (1976), in which firms in oligopolistic industries are argued to possess intangible, firm-specific assets, such as management and marketing techniques and proprietary knowledge from research expenditure, which give them an advantage over rivals in foreign markets; the *eclectic* theory of Dunning (1973), (1977), in which it is argued that some firms possess unique firm-specific assets which can be fully utilized only through combination with factor inputs specific to a foreign economy; and the *internalization* theory, primarily owing to the work of Rugman (1980), (1981), (1986), in which reputational effects and other considerations can create advantages for the creation of foreign subsidiaries by a domestic firm, relative to its licensing the production of its commodity by autonomous foreign firms. Each of these theories reflect a common assumption that multinational firms emerge from the *asymmetric* possession by some firms of unique nonmarketable assets. These assets have a public-good component, which induces multiplant scale economies, giving those firms which possess them a potential cost advantage over both foreign and domestic rivals and, in the presence of tariffs or international transportation costs, an obvious incentive to engage in direct foreign investment. Grosse (1985) provides an early description of some game-theoretic aspects of multinational production and sales, while Buckley and Casson (1981), Helpman (1984), Horstmann and Markusen (1987), Grossman and Helpman (1988) and Butler (1989) provide rigorous models of the incentives created for foreign direct investment by the possession of firm-specific assets.

An alternative explanation for the practice of foreign production sourcing, offered by Hodder and Jucker (1985), Shapiro (1987), and others, relies directly on the presence of randomness in (real) exchange rates. Firms which exhibit risk-averse behavior may choose to diversify their production between foreign and domestic locations in order to hedge against exchange rate risk. The

veracity of this explanation, of course, relies on a fundamental inability of individual equityholders to fully diversify their own portfolios, requiring firms in which they hold equity to also provide intermediation services, as well as an inability of such firms to hedge against exchange rate risk through international capital markets.

The strategic role of precommitment through irreversible investments in a purely domestic context has also been extensively studied, most notably by Eaton and Lipsey (1979), (1980) and by Dixit (1980), in the context of deterministic two period games. More complex game-theoretic models, which use first-period cost or demand uncertainty to study the trade-off between the advantages of irreversible precommitment and the advantages of remaining flexible and delaying irreversible decisions until the resolution of uncertainty, have been studied in Gal-Or (1987), Green and Sadanand (1987), Nickerson and Sadanand (1990) and Robson (1990).

Observations of exchange rate volatility offer an opportunity to apply the insights about irreversibility and commitment from the studies cited above to questions about the influence of market structure on the pattern of international production and trade. An explicit demonstration of the analogy between irreversible investments in a nonstrategic context and the optimal exercising of financial options first appears in Pindyck (1987), and a particularly important application of financial option-pricing techniques to the question of entry and exit by purely competitive firms under exchange rate uncertainty appears in Dixit (1988). Dixit examines the optimal exercise, by foreign firms operating under an infinite horizon, of the option to enter or exit a domestic industry by incurring a sunk cost. Exchange rate uncertainty evolves according to geometric Brownian motion and the option to enter or exit the domestic industry can be exercised only by incurring an abstract fixed cost. The first paper to explore the option value of foreign investment under exchange rate uncertainty in a strategic context is Nickerson and Sadanand (1989), who, in response to the question posed by Dixit concerning the implications of imperfect competition for his results, examine the emergence of endogenous Stackelberg leadership under simultaneous cost and demand uncertainty in a two- period model in which exchange rate volatility may prompt a foreign firm to exercise its option to produce in a domestic market. A related paper is by Khoury and Nickerson (1989), who examine the effects of precommitment under exchange rate variability on the pricing and production decisions undertaken by firms in a homogeneous-commodity oligopoly.

The current paper differs from these earlier papers on multinational production and on strategic domestic precommitment, in allowing firms to be initially symmetric and risk-neutral, and in

considering the role that the purely strategic implications created by the endogenous timing of simultaneous production location and volume decisions by domestic firms operating under exchange rate uncertainty has on the emergence of multinational production.

The paper is organized as follows. The essential features of our model of symmetric duopoly are discussed in Section II. Asymmetric market equilibria, induced by the assumption that exogenous asymmetries distinguish firms and used as a benchmark against which to compare our symmetric equilibrium, are analyzed in Section III. Sequential equilibrium in mixed strategies for our symmetric, risk-neutral duopolists is described in Section IV. Concluding remarks appear in the final section.

II. A Model of Duopoly

We consider a model of production decisions undertaken by risk–neutral duopolists who exclusively sell a nondurable good in their common domestic market under certain consumer demand and who may produce this good either domestically or abroad. [2] Such firms have two aspects to their production decisions. They must decide on the volume of production they wish to sell to domestic consumers and they must also choose a domestic or foreign location for their production. [3] The option to produce the commodity abroad can be exercised, for each of these firms, by incurring a certain plant–specific cost G. [4] This expenditure, which is analogous to the exercise price of a financial option, represents the general fixed costs of activating a foreign plant for production. The presence of such a cost allows, as in Helpman (1984), Horstmann and Markusen (1987) and Dixit (1988), for the potential existence of plant-specific scale economies, which the firm must balance against potential reductions in the marginal costs of foreign production created by a randomly fluctuating exchange rate.

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[2] Since our analysis examines the potential influence of multinational production on *domestic* market structure, we refrain from explicit consideration of the symmetric problem of domestic (foreign) multinationals serving a foreign (domestic) market through the creation of a local subsidiary. Our results will also, however, apply identically to that case. We also assume, following Helpman (1984), Markusen (1984), Horstmann and Markusen (1987) and others, the implicit existence of firm–specific sunk costs, representing the value of activities internal to the established firm, such as research, management and marketing. Such sunk costs allow us to distinguish between a firm and its plants, and, in order to retain our focus on the strategic behavior of incumbent duopolists, are assumed to of a magnitude sufficient to preclude entry into the domestic market by new firms.

[3] Although firms are, in general, free to share production intended for domestic sale between domestic and foreign plants, the presence in our model of constant marginal production costs implies that each firm will optimally produce at only one plant. This assumption, traditional in the literature on multinational firms, allows us to clearly exposit the purely strategic aspects of foreign production sourcing and can readily be relaxed without qualifying any of our results.

[4] The analogous expenditure for maintaining the domestic plant is, following Horstmann and Markusen (1987) and others, assumed to have already been incurred by each of the domestic firms or, alternatively, to be negligible relative to the cost G of investing in the foreign plant.

The fixed cost G of activating a foreign plant for production also, however, has *strategic* significance in our model, because it allows the firm which incurs it to credibly precommit to an aggressive production and sales strategy in the domestic market. [5] The strategic value of such a precommitment depends crucially on its credibility, as perceived by the rival firm, since only a credible precommitment will influence the production and sales strategy adopted by this rival. Credibility requires any ex ante decision to incur a cost of producing abroad to be an irreversible action. A firm, consequently, may choose to sign binding contracts to make its precommitment credible, which, in the context of our model, involves making an irreversible investment G to activate the foreign plant under exchange rate uncertainty. [6]

The real exchange rate e is assumed to be the unique source of uncertainty facing firms in our duopoly. [7] The stochastic value of this exchange rate which is relevant for current production decisions is revealed exogenously at a certain time. Periods 1 and 2 respectively refer to the periods before and after the common observation of the realization of the exchange rate. The timing of this revelation allows for the existence of two distinct periods enabling firms to precommit to a volume and location of production. [8] The costs of domestic production, as well as the magnitude of domestic demand, are assumed to be deterministic and common knowledge between the firms. Domestic production and domestic sales are, consequently, done under full certainty. [9]

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[5] We assume that the only extant source of uncertainty faced by firms in our model is real exchange rate uncertainty and, consequently, the only precommitment device available to these firms is the option each holds to produce abroad. This assumption is made because real exchange rate fluctuations are the purest theoretical example of relative price changes and also because, for many American and Canadian firms, real exchange rate volatility was the predominant source of uncertainty during the last several years.

[6] A recent case of multinational corporate behavior which is entirely compatible with such a strategic interpretation is that of Ford Motor Company, which has recently engaged in extensive and irreversible commitments to the foreign sourcing of production components and which, most remarkably, precommited to binding design and engineering contracts with the Japanese automaker Mazda in the development of the new Ford Escort model. Details of this episode appear in Treece and Borrus (1990).

[7] Although no real distinction between the real and nominal exchange rates is necessarily implied by our model, this distinction is empirically useful when applying our theoretical results to the analysis of real corporate behavior. We are grateful to a referee for also pointing out that the value of incurring the cost G of exercising the option to produce abroad should be measured with respect to real exchange rate uncertainty, and that fluctuations in the real rate have a greater tendency toward mean-reversion than do nominal exchange rate fluctuations. See Coughlin and Koedijk (1990) and Meese and Rogoff (1988) for evidence regarding this latter point.

[8] While games of a finite number of periods, such as the one analyzed in this paper and those commonly employed in the study of industrial organization, allow us to explicitly consider the role of uncertainty in a strategic context, the compression of infinite planning horizons and continuous price or cost uncertainty into an essentially static structure is a liability of such models. The exogenous resolution of exchange rate randomness, for the purposes of the production decision in our model, requires us to interpret the production decision of our firms as a short-run decision, or alternatively, if we view the fixed cost G of foreign production as an irreversible long-run investment, requires us to interpret the uncertainty in the exchange rate as being relative to some expected long- run average, since the ex ante periods of investment in real plants can be of a year or more in duration.

[9] While we assume that only foreign production is subject to random cost, when measured in domestic units, in order to emphasize the strategic opportunity afforded firms by exchange rate uncertainty, the essence of our results will remain robust to the inclusion of uncertainty in domestic demand or cost as long as the variance from these sources of randomness are small relative to that provided by the real exchange rate.

Since exchange rate uncertainty offers strategic opportunities to each of the domestic duopolists, optimal corporate behavior depends crucially upon the *timing* of production location and volume decisions. A firm can either precommit itself, through incurring the fixed investment cost G, to a desired production volume abroad before exchange rate uncertainty is resolved or, alternatively, it can remain flexible, making its production location and volume decisions after the uncertainty relevant for current production costs is resolved. Precommitment is, as a result, credible only when a foreign production level is chosen under uncertainty.

Each alternative strategy, precommitment or the retention of flexibility, has benefits and costs. By irreversibly precommitting in the first period to a foreign location for production, a firm suffers cost uncertainty but, because precommitment involves choosing both a location and a volume of production, the firm may obtain the advantage of potentially more profitable Stackelberg leadership in the domestic market if the rival firm delays its production decisions until the second period, after the relevant value of the exchange rate is realized and its implications for the marginal costs of foreign production, denominated in domestic units, are observed by both firms. By remaining flexible and delaying its production decisions until period 2, a firm does not have to face exchange rate uncertainty but will necessarily acquiesce to being a potentially less profitable Stackelberg follower in the domestic product market if the rival firm has, in the first period, precommited itself to foreign production. After the revelation of the value of the exchange rate in period 2, a firm that has not previously precommitted itself to foreign production will, of course, simply choose to produce where it is cheaper.

The firms in this duopoly, as a consequence of the benefits and costs associated with precommitment and with flexibility, can be regarded as playing a noncooperative game of timing in which each firm has to decide "location timings" as well as the optimal associated volumes of production. Firms that make their decisions about where to locate at the same time, whether this occurs under exchange rate uncertainty in the first period or after the resolution of this uncertainty in the second period, realize that the simultaneity of their decisions will create a Cournot equilibrium in sales in the second period. Alternatively, if one firm decides to commit to foreign production in the first period but the rival firm chooses to delay its location decision, then the precommited firm will act as a Stackelberg leader, producing and selling the volume of output corresponding to this status, while the flexible firm will, believing its rival's commitment to leadership status to be credible, necessarily wish to act as a Stackelberg follower in regard to the volume of its production and sales.

While the expenditure G required to activate a foreign plant must be incurred in the first period in order for a firm to credibly precommit, it should be noted that actual production and sales occur only during the second period. Precommitment to foreign production through foreign plant activation in the first period, therefore, is analogous to entry decisions in industrial organization models of stochastic oligopolies. Firms failing to exercise their option to activate a foreign plant in the first period will produce abroad or domestically, whichever is cheapest, in the second period. Three possible structures for the domestic industry could, consequently, endogenously emerge as a result of the influence of exchange rate uncertainty on each firm's strategic behavior. If neither of the firms precommits in the first period to foreign production, then both firms participate in a Cournot equilibrium in the domestic market in the second period, and make production location and volume decisions based on the realized value of the exchange rate. If one firm precommits in the first period to foreign production while the other firm remains flexible and waits for the exchange rate to be revealed, then the precommitted firm will be a Stackelberg leader in the output game and the other firm will be a follower. The follower firm may or may not produce abroad, depending on the realization of the exchange rate, and we can have foreign and domestic production coexisting, among initially symmetric firms, in the industry equilibrium. Finally, if both firms choose to precommit in the first period to foreign production, the industry is again in a Cournot equilibrium.

One of the primary implications of our analysis, then, will be that multinational firms and foreign production in equilibrium do not only arise because of *exogenously assumed* asymmetries among firms, such as the incumbent–entrant relationship between an established domestic firm and a potential foreign rival analyzed by Markusen (1984), Helpman (1984), Horstmann and Markusen (1987), Kogut and Kulatilka (1989) and others; nor does their existence necessarily rely on risk aversion and a desire to hedge against the nondiversifiable risk posed by a random real exchange rate, as discussed in Hodder and Jucker (1985) and in Shapiro (1987). Multinational firms and the foreign sourcing of production can *endogenously* arise among initially *identical* firms, owing only to the pure leadership advantage of precommitment under uncertainty. This is a unique explanation of the relationship between exchange rate volatility and multinational production, and serves to both

[10] The role of uncertainty in creating this tradeoff between precommitment and flexibility between ex ante symmetric firms can be clarified by considering what each such firm would wish to do if no exchange rate uncertainty existed. Since firms are identical, neither firm would wish to be a Stackelberg follower. Stackelberg leadership, however, is also precluded as a Nash equilibrium, since neither firm could credibly convince its rival of a commitment to produce a quantity sufficient to establish industry leadership. Under these conditions precommitment cannot occur between symmetric firms and such firms would knowingly participate in a Cournot equilibrium in production and domestic sales.

link market structure to multinational production through the strategic opportunities offered by a fluctuating exchange rate, and to establish a robust correlation between multinational production and industry leadership. [11]

Assumptions about technology and consumer preferences in our model of duopoly are chosen for expositional simplicity. [12] Each of the two domestic duopolists enjoys common, deterministic and constant marginal costs C when production occurs at a domestic plant. The aggregate preferences of domestic consumers are assumed to be described by a linear inverse demand surface with a price intercept of A and a slope of -1. Such preferences are also assumed to satisfy the inequality $A - C > 0$ since, otherwise, neither firm will engage in any production. Production costs for each firm are the same domestically and are the same abroad, in the common location of (potential) foreign production, in the sense that identical factor prices obtain for each firm and each firm shares the same technology as its rival at home and abroad. While relaxing this assumption of symmetry does not alter the qualitative nature of the results, such symmetry makes our results more interesting because now firms may choose different production locations for *purely strategic reasons.*

Due to the real rate of exchange e between foreign and domestic units of measurement, the marginal cost of foreign production is denoted by θ in domestic units and the exchange rate is defined by $e = \theta/C$. Since C is deterministic and is common knowledge between the firms, θ is regarded by the firms as stochastic and the magnitude of the difference between marginal costs of production at a domestic plant and at a foreign plant, measured in domestic units, is the unique common source of uncertainty faced by each firm. θ could, if desired, be measured as inclusive of constant and deterministic unit transportation costs or tariffs, incurred in shipping the commodity to the domestic market.

Domestic costs and demand are common knowledge, and the firms are also assumed to have identical beliefs about the distribution of θ. Again, while differences in initial beliefs about the

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[11] While our explanation of the influence of exchange rate uncertainty is unique in its demonstration of multinational production among symmetric firms, it can be viewed as being complementary to the traditional explanations of multinational production among asymmetric firms described above. It also establishes a direct linkage between anticipated real exchange rate volatility and the volume of direct foreign investment which does not depend, as do the explanations of this phenomenon advanced by Shapiro (1987), Hodder and Jucker (1985), and others, on implicit assumptions about capital market imperfections which must be invoked to justify risk-averse corporate behavior.

[12] Selection of linear demand and constant marginal costs is made strictly for expositional convenience. While it is straightforward but mathematically tedious to prove propositions analogous to those appearing in the text in a more general context of cost and demand, assuming only continuous differentiability and compactness where required, no new insights are obtained by so doing and potential advantages of this generality for empirical implementation are, in our opinion, modest. The interested reader can refer to Nickerson and Sadanand (1989) for a discussion of these analogous propositions in a more general model.

distribution of θ do not change the nature of the results, our results are made more striking by the assumption that the firms have identical beliefs about exchange rate uncertainty. Firm are also assumed to behave as if they were risk- neutral and, consequently, do not engage in direct foreign investment or production for the purposes of hedging real exchange rate risk.

The strategy of each firm i consists, in period 1, of a probability, denoted by ν_i, that firm i will incur the fixed cost G of foreign plant activation in that period, and the corresponding quantity, denoted by x_{i1}, that firm i will announce in period 1 that it has credibly precommited to produce abroad in period 2, conditional on its expenditure of G. If firm i wishes to remain flexible and defer, with probability one, its decision on a production location until exchange rate uncertainty is resolved, ν_i and x_{i1} will each be zero, and, in this case, x_{i2}^r will denote the production volume of firm i in period 2, where $r = d$ corresponds to production at the domestic plant and $r = f$ corresponds to production at a foreign plant. Φ denotes the expectation operator over the distribution of θ and G denotes the fixed cost to each firm of activating a foreign plant to produce for the domestic market. Market equilibria are derived using the concept of sequential equilibrium. [13]

III. Equilibria in an Asymmetric Duopoly

As a useful benchmark against which to compare our later equilibrium among symmetric firms, we will first illustrate an obvious but important point: if strategic interaction in the domestic product market is *not* allowed to affect the choice of production location by firms, then the location selected by each firm has no strategic value and depends solely on the realized value of the exchange rate e and the fixed cost G of activating the foreign plant. We can obtain coexistence of foreign and domestic production in this artificial case only by a specification of the sales game in the domestic product market in which differential production locations are driven by the exogenous presence of some ad hoc form of asymmetry between firms. We will then show, in Section IV below, that in our general game, different production locations emerge endogenously as a result of the interaction between the timing of the choice of production location by each firm and its strategic behavior in the domestic product market, even though our firms are strategically and informationally symmetric.

Suppose first that firms are exogenously specified to play a Cournot game in outputs. Output and production timing decisions are made separately. Since the firms have no strategic advantage to precommitment in period 1, it is a dominant strategy for both firms to defer production decision

[13] See Kreps and Wilson (1982) for the original discussion of this equilibrium concept for dynamic games.

until period 2. Since the firms are symmetric, in the symmetric Cournot equilibrium their outputs will be identical. This implies that the decision to produce will also be identical. It is easy to see that if the firms choose foreign production, then each firm's output will be $(A-\theta)/3$, and if they produce domestically, each firm's output will be $(A-C)/3$. Production takes place abroad in period 2 whenever the profits from doing so are at least as large as the profits from domestic production. A sufficient condition for this to occur, taking into account the non-negativity of profits under either production location, is

$$2\theta\left(\frac{A-\theta}{3}\right)-2C\left(\frac{A-C}{3}\right)>2A\theta-2AC+C^2-\theta^2+G.$$

Consequently, both firms will produce abroad whenever the realization of θ is less than the positive zero of the quadratic $\theta^2-4A\theta+(4AC-C^2-3G)$, and both firms will produce domestically otherwise. Regardless of the realization of θ, however, the symmetry between firms and the exogenously imposed separation of any strategic interaction between the timing of the choice of production location and firm behavior in the product market guarantee that precommitment to a foreign production location under exchange rate uncertainty has no value and that rival firms will not endogenously select different production locations. On the other hand, we can induce rival firms to select different production locations in equilibrium, but only if we introduce an ad hoc asymmetry between the rival firms, while keeping production volume and location timing decisions separate, by exogenously specifying a a Stackelberg game in the domestic product market. Allow one firm to produce abroad first with probability one and require the second firm to remain flexible and delay its choice of production location until period 2, when exchange rate uncertainty is resolved. It is clear that once θ is revealed, the firm that has delayed will decide whether or not to produce abroad by comparing the relative magnitudes of the fixed cost G and the relative change in marginal costs, $\theta-C$. This behavior will, in turn, affect the ex ante behavior of the first firm in period 1. Optimal behavior for the follower firm in this case, which is similar to the Cournot behavior it exhibits in the equilibrium above, is described by the following proposition:

Proposition 1. *Given that one firm has decided to produce abroad in period 1, the decision rule for the follower firm is as follows: For sufficiently small G and for some $0 \leq \delta \leq C$ foreign production will occur if and only if $\theta < \delta$.*

Proof. Let x_1 denote, in this example, the output of the firm that has decided to produce abroad first, i.e., the exogenously specified Stackelberg leader. Then, if he were to produce abroad, the

follower would choose an output

$$x_{22}^{f} = \frac{A - x_1 - \theta}{2}. \tag{1}$$

But if the follower firm were to produce domestically, then its reaction function is

$$x_{22}^{d} = \frac{A - x_1 - C}{2}. \tag{2}$$

The leader firm's output x_1 will depend upon whether the follower firm has reaction function (1) or reaction function (2). Let γ be the probability perceived by the leader that the follower produces abroad under this Stackelberg specification. [14] The leader's optimal behavior is described as the solution to:

$$\max_{x_1} \Phi\left\{\left((A - x_1 - \frac{A - x_1 - \theta}{2} - \theta)x_1 - G\right)\gamma + (1-\gamma)\left((A - x_1 - \frac{A - x_1 - C}{2} - \theta)x_1 - G\right)\right\}.$$

Consequently,

$$x_1 = \frac{\gamma \cdot \Phi(\theta) - \gamma \cdot C + C + A}{2} - \Phi(\theta) \tag{3}$$

Now, the follower's profit when it produces abroad is

$$\pi_f^f = \frac{(A - x_1 - \theta)^2}{4} - G \tag{4}$$

and its profit when it produces domestically is

$$\pi_f^d = \frac{(A - x_1 - C)^2}{4}, \tag{5}$$

so, the follower firm produces abroad whenever

$$\pi_f^f > \pi_f^d.$$

A sufficient condition for this inequality to hold is

$$2x_1\theta - 2x_1C > 2A \cdot \theta - 2A \cdot C + C^2 - \theta^2 + G. \tag{6}$$

Substituting for x_1 from (3) above, and since for values of θ which imply foreign production $\gamma = 1$, from condition (6) we see that all production takes place abroad if and only if θ is less than the positive zero of the quadratic $\theta^2 + \theta(A + \Phi(\theta)) - (3AC - C^2 - C\Phi(\theta) - G)$.

□

[14] Since these are subjective probabilities, and since the follower will never adopt a mixed strategy in this situation, we assume zero covariance between the leader's subjective forecast of γ and the random exchange rate e.

As long as the foreign marginal costs in domestic currency and the fixed cost of foreign plant activation are sufficiently low, the follower firm will produce abroad. Multinational production is cost driven, rather than being strategy driven, in this case, and the possibility of differential production locations arises here only as a result of the exogenous imposition of an asymmetric Stackelberg equilibrium in the domestic product market.

IV. Equilibrium in the Symmetric Duopoly

The endogenous emergence of multinational firms and foreign sourcing of production, as a direct response to the opportunity that exchange rate uncertainty creates for risk-neutral symmetric firms, will exist only when interaction between strategic behavior in the product market and the timing of each firm's production decisions is allowed to occur. Allowing this interaction to appear in an oligopolistic model of investment and production seems highly realistic, since most real business firms appear to be fully aware of their desired production and sales volumes prior to undertaking fixed investments, such as the creation or activation of a foreign plant.

We show below, as argued in Section II, that when symmetric, risk- neutral firms are allowed to make decisions concerning the volume and location of production *simultaneously*, and can choose to make these decisions either before or after the resolution of exchange rate uncertainty, a multinational firm will endogenously emerge and act as the Stackelberg leader in its industry. The strategy pursued by each firm i in the first period consists of announcing *both* ν_i and x_{i1}.

This is illustrated by an example of the extensive form of this game, as described in Section II, which appears in Figure 1. This example represents a case in which the support of the distributions of e and, consequently, θ, consist of two points. During the first stage of the game, which is illustrated in Figure 1, firms have the option, under uncertainty about the exchange rate, to either precommit (P) to foreign production, or remain flexible (F) to decide on a production location after the resolution of exchange rate uncertainty. Selection of the option to precommit in this first stage will also simultaneously involve a first-stage announcement of a volume of production to be undertaken in the second stage. Figure 1 depicts, for each firm, two such actions, each involving both a precommitment (P) to foreign production and an implicit quantity which will be produced in the second period. [15] Contingent on the first-stage choices described in Figure 1, second-stage Cournot or Stackelberg behavior by the firms in the domestic product market is then determined.

[15] Since the volume of production is a continuous variable, there are implicitly a continuum of such branches in Figure 1.

Insert Figure 1 here

A unique symmetric sequential equilibrium in mixed strategies of the timing of the production decision, ν_i, and in pure strategies for the volume of production to be announced in the first period, x_{i1}, exists for this game. Firms in this symmetric equilibrium play a completely mixed strategy in production timing and pure strategies in output levels x_{i1}. Precommitment to foreign production occurs with a certain probability strictly between zero and one, while the volume of production, to which firms may precommit in the first period with this probability, is deterministic.

This symmetric sequential equilibrium in mixed strategies also exists under more general assumptions regarding the distributions of e and θ, as shown by the following proposition:

Proposition 2. *A unique symmetric sequential Nash equilibrium in mixed strategies, describing the timing of each firm's production decisions, will exist for the strategic model of production under exchange rate uncertainty for any distribution of the real exchange rate e.*

Proof. The method of proof involves derivation of the optimal volume of production to which a firm would optimally precommit under exchange rate uncertainty. If this volume of production is positive, substitution of this quantity into a condition expressing an equivalence between the expected value of becoming a Stackelberg leader in the product market, through precommitment to foreign production, and the expected value of remaining flexible and delaying decisions concerning production until period 2, generates the mixed strategy equilibrium. This equilibrium is expressed in terms of a value of ν_i for each firm i which lies in the strictly open unit interval.

In a symmetric sequential equilibrium, the optimal volume of production to which each firm i would optimally precommit in period 1, x_{i1}, solves the problem:

$$\max_{x_{i1}} \Phi\Big[\nu_j\Big\{\big(A - x_{i1} - x_{j1} - \theta\big)x_{i1} - G\Big\} + (1-\nu_j)\Big\{\epsilon\Big(\big(A - x_{i1} - x^f_{j2} - \theta\big)x_{i1} - G\Big) + (1-\epsilon)\big((A - x_{i1} - x^d_{j2} - \theta)x_{i1} - G\big)\Big\}\Big]. \tag{7}$$

where ν_j is the probability that the rival firm j will also precommit to foreign production in period 1 and where ϵ is the probability that the rival firm, should it remain flexible, decides, in period 2, to produce abroad. [16] Equation (7) is the ex ante expected profit of precommitted foreign production,

[16] Note that this latter probability, ϵ, is, in general, different from the analogous probability γ appearing in equation (3) because the firms are in a different equilibrium.

conditional on the perceived belief by firm i that the rival firm j will simultaneously precommit to foreign production in period 1 with probability ν_j, while in period 2 the rival firm, should it not so precommit, may choose either domestic or foreign production after the revelation of the value of the exchange rate. Equation (7) exactly reflects the imperfect information embedded in the game and also makes the firms strategically and informationally symmetric.

If firms i and j are in fact identical, then the generalized mixed strategy symmetric equilibrium reflected in equation (7) must also satisfy the following symmetry conditions:

(a) $\nu_1 = \nu_2 = \nu$

(b) $x_{11} = x_{21} = x$

(c) $x_{12}^f = x_{22}^f = x_2^f$

(d) $x_{12}^d = x_{22}^d = x_2^d$

(e) The ex ante expected profit of precommiting to foreign production in period 1 is equal to the ex ante expected profit of remaining flexible and deferring the production location and volume decisions until period 2.

The above conditions imply that, in the symmetric mixed strategy equilibrium, the optimal volume of production under a precommitment to a foreign location for production in period 1 must satisfy:

$$\begin{aligned}\Phi\Big[\nu[(A-x-x-\theta)x-G]+(1-\nu)[\epsilon\big((A-x-x_2^f-\theta)x-G\big)\\ +(1-\epsilon)\big((A-x-x_2^d-\theta)x-G\big)]\Big]\\ =\Phi\Big[\nu[\epsilon\big((A-x-x_2^f-\theta)x_2^f-G\big)+(1-\epsilon)\big((A-x-x_2^d-C)x_2^d\big)]\\ +(1-\nu)[\epsilon\big((A-x_2^f-x_2^f-\theta)x_2^f-G\big)+(1-\epsilon)\big((A-x_2^d-x_2^d-C)x_2^d\big)]\Big] \qquad (8)\end{aligned}$$

Solving for the symmetric volume of production x under first period precommitment in the maximization problem (7), using conditions (a) and (b) above, we obtain:

$$x=\frac{(1-\epsilon)(1-\nu)(C-\Phi(\theta))+(1+\nu)(A-\Phi(\theta))}{3(1+\nu)} \qquad (9)$$

Substituting for x from equation (9) into condition (8) above we obtain a third degree polynomial in ν, the symmetric probability of first period precommitment to foreign production, with a constant

term, which is a function of C, A, ϵ and $\Phi(\theta)$. The real–valued zero of this polynomial gives us a generalized mixed strategy symmetric equilibrium.

□

Proposition 2 demonstrates that multinational firms may arise because randomness in the exchange rate offers symmetric firms the strategic opportunity to emerge as industry leaders. Geographical dispersion in production is a mixed strategy symmetric equilibrium whenever the fixed costs of foreign production are sufficiently small and there is a potential leadership advantage to precommitted foreign production. Most importantly, this dispersion is, in our model, truly *endogenous*, with strategically symmetric firms facing identical costs and holding identical ex ante beliefs about the distribution of exchange rate fluctuations.

The intuition underlying the symmetric mixed strategy equilibrium described in Proposition 2 involves the timing of the production location decision undertaken by each firm, as well as the recognition that each firm rationally perceives that exchange rate uncertainty offers a unique but costly chance to credibly precommit to that volume of production which would enable it to emerge as a potentially profitable Stackelberg leader. First, note that the randomization in the strategy of each firm i is in the *timing* of the decisions concerning the location of its production and not in the volume x_{i1} of production itself. Decisions concerning the optimal volume of production reflect the outcome of accurately anticipated Cournot or Stackelberg equilibria in the domestic product market, resulting in the adoption by each firm of a pure strategy in the desired quantity of production. The probability ν_i adopted by each firm i as part of its mixed strategy in the timing of the production location decision, however, changes the expected gain of being a Stackelberg leader in the product market. Since firms make production location and volume decisions simultaneously, a symmetric mixed strategy equilibrium will ensue if each risk-neutral firm rationally perceives an equality to obtain between the expected value of precommiting to foreign production under exchange rate uncertainty and the value of retaining flexibility by delaying its location and volume decision until after the resolution of such uncertainty. This equality is expressed by equation (8).

Four specific implications for the relations between exchange rate volatility, the existence of multinational firms and the endogenous emergence of industry leadership through a strategic commitment to the foreign sourcing of production are immediate from equations (8) and (9). First, in the above polynomial, because of the constant term, $\nu = 0$ is not a solution, for sufficiently small

G. [17] This means that a situation in which both firms choose to remain flexible and defer their production decisions until period 2, with probability one, cannot be an equilibrium. Consequently, even though there is a chance that the exchange rate may make foreign production unprofitable ex post, there is a positive probability that one firm may choose to become a multinational and invest in the activation of a foreign plant in period 1. This occurs, not because of an asymmetry between firms or because of some implicit imperfection in capital markets which drives risk-averse firms to hedge against real exchange risk through diversification of production locations, but precisely because there is a leadership advantage to precommitment, even if firms are entirely risk-neutral, and this advantage should clearly not be offset by G, the fixed cost of investing in a foreign plant. [18] Even approaching the limit, when θ is known almost surely to be equal to C, and when therefore ϵ will approach zero for any positive value of G, $\nu = 0$ cannot be a solution to the polynomial generated by equations (8) and (9). [19]

Second, as long as there is some uncertainty that foreign production, under the realized value of foreign marginal production cost θ, may not be profitable, $\nu = 1$ is not a zero of the polynomial. Consequently, both firms choosing foreign production in period 1 with probability one is also *not* an equilibrium. Precommited multinational production with probability one by both firms will result, as both firms rationally anticipate, in a Cournot equilibrium in the domestic product market. This, of course, cannot be a Nash equilibrium with timing as strategies, since given that one firm is producing a Cournot quantity in period 1 with probability one, the other firm knows that it is better off choosing Cournot outputs in the second period after the random value of the exchange rate e is revealed, as long as there is some chance that θ may not be profitable.

Third, the quantity of production in period 2 to which either firm would optimally precommit in period 1, x, may, from equation (9), be seen to be a linearly increasing function of the optimal expected quantity the firm would produce in a simple Cournot equilibrium, $(A - \Phi(\theta))/3$. The quantity x, which corresponds to the expected value of the quantity which would be produced by a Stackelberg leader in the domestic product market, may also be seen to be increasing in the known value of domestic marginal unit cost, C, decreasing in ν, the probability of the rival

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[17] $G < \frac{(A^2 - 2AC - 3C^2 + 8C\Phi(\theta) - 4\Phi^2(\theta))}{4}$

[18] Although we concentrate our analysis solely on the *symmetric* equilibrium in mixed strategies, Nickerson and Sadanand (1989) show that, in a related model and under certain parametric assumptions on costs and the distribution of θ, an asymmetric market equilibrium may exist in pure strategies, with one of the duopolists committing with probability one to foreign production, and the rival firm acquiesing to its status as a follower in the domestic market with probability one.

[19] In fact, under those circumstances, the outcome of a mixed strategy symmetric equilibrium will be a simple Stackelberg equilibrium.

firm also precommitting to foreign production in period 1, and decreasing in $\Phi(\theta)$, the expected value of marginal unit production costs at a foreign plant. These results all accord well with our intuition of the firm's optimal strategy in the domestic market: having decided to precommit to foreign production, the firm wishes to produce more as the expected difference between foreign and domestic marginal costs increases and as the probability that the rival firm will also precommit in the first period decreases.

Finally, the decision to engage in multinational production, even with risk-neutral firms, will in general depend, as illustrated by the dependence of the quantity x on the probability ν of precommitment in equation (9), on higher-order moments of the distribution of the exchange rate, as well as on its mean. Equations (8) and (9) imply, for example, that, in a symmetric equilibrium, both firms will randomize their production between domestic and foreign locations for finite values of the variance of the exchange rate, but that the probability of precommitment to multinational production can decline to zero for the limiting values, zero and infinity, of the variance of the exchange rate. [20] This implies that, for a sufficiently large variance in the exchange rate, the potential benefits of precommitment are dominated by the advantages of flexibility and both firms will choose domestic production. Alternatively, when exchange rate variance is zero, the value of precommitment disappears and both firms engage in a Cournot behavior under certainty, choosing to produce in the cheapest location.

V. Concluding Remarks

Conventional wisdom in both the academic literature and the business press explains corporate decisions to become multinational and to engage in foreign production sourcing for domestic sales as being motivated by one of two reasons. The first reason depends largely, if not entirely, on asymmetries which are assumed to exogenously distinguish firms. These asymmetries are especially assumed to exist in regard to intangible, firm-specific assets, such as management and marketing skills and the returns to previous expenditures on research and development, and also on such factors as expectations concerning firm-specific opportunities for lower foreign production costs, due to differential beliefs about the permanency of exchange rate movements or impending changes in trade barriers, or access by some firms to foreign subsidies for investment abroad, or differential access by firms to domestic and foreign capital markets. The second reason rationalizes the diversification

[20] Derivation of this relationship in (8) and (9) is straightforward but tedious, and is left for the interested reader.

of production locations among nations as a means that risk-averse firms might use to hedge against real exchange rate risk. This explanation would be plausible if, for example, domestic equityholders cannot fully diversify their individual portfolios, so that corporations provide some intermediation services, international capital markets cannot be used to sufficiently hedge against exchange rate risk, and the return to hedging through foreign sourcing of production exceeds the potentially substantial fixed costs of investment in foreign plants.

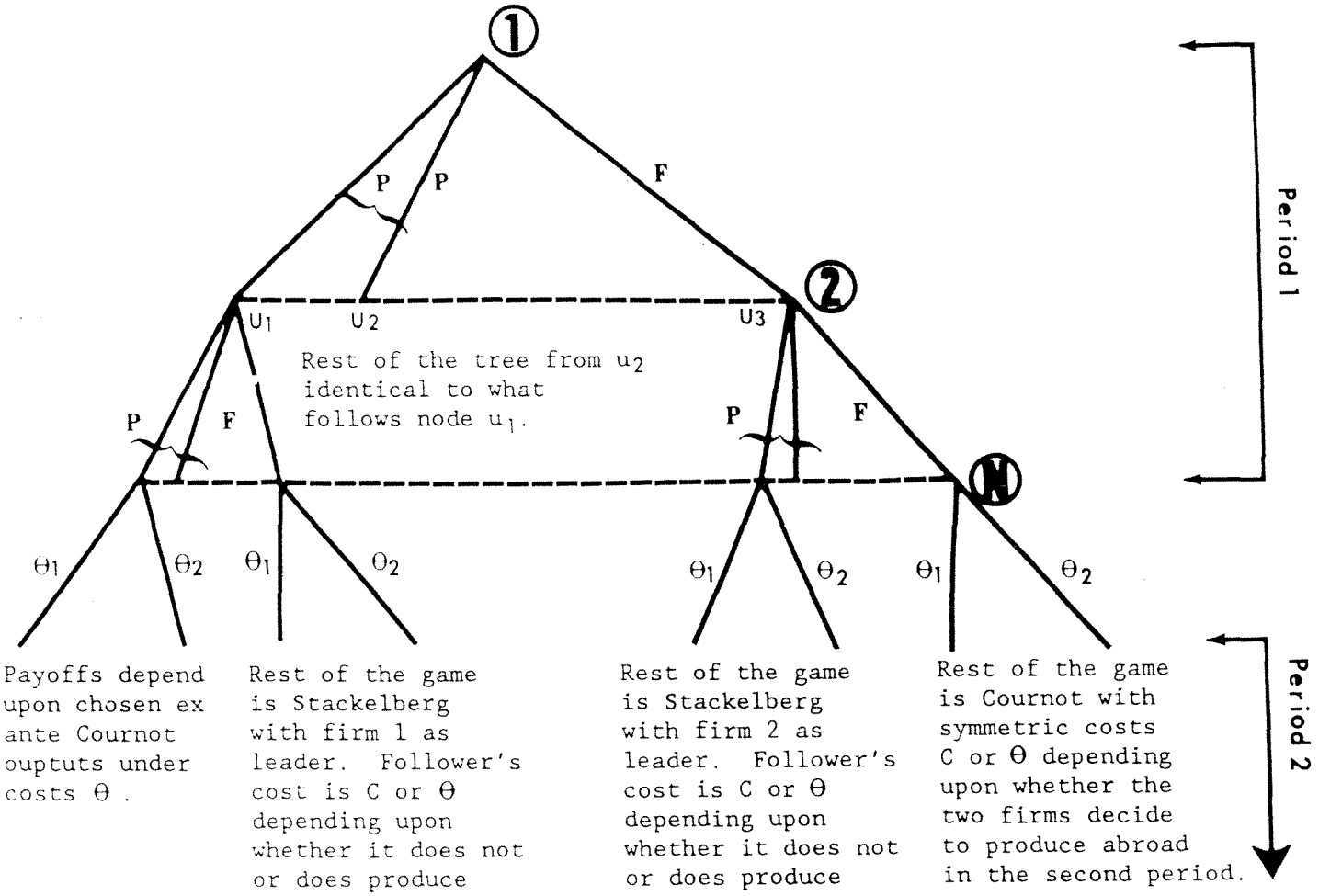
This paper offers a new explanation of the endogenous emergence of multinational production, one that relies neither on assumptions about exogenous asymmetries between firms nor on assumptions about corporate risk aversion and imperfections in capital markets. The model of multinational production in this paper treats the decisions about *where* to produce and *how much* to produce as an inextricably linked equilibrium outcome of a purely strategic situation where *identical risk-neutral* firms evaluate the costs and benefits of the trade-off between precommitted foreign production under exchange rate uncertainty with market leadership on one hand, and the flexibility generated by temporarily deferring production decisions in order to obtain better information about the exchange rate and cost conditions relevant for current production, but possibly at the cost of being an industry follower, on the other.

The primary result of our paper is that multinational firms may arise for the purely strategic reasons of potentially profitable industry leadership which are created by random fluctuations in the exchange rate. Specifically, in a duopoly with identical firms and first-period uncertainty about the real exchange rate, there is a unique mixed strategy equilibrium which may result in a geographical dispersion of production. Under this equilibrium, foreign production may endogenously be undertaken by some firms and not others, solely due to the leadership advantages associated with precommitment to foreign production under exchange rate uncertainty. The nature of this equilibrium implies that the probability of precommitment to foreign production is strictly bounded between zero and one, for positive finite values of exchange rate variance, with the simultaneous selection of either domestic or foreign production by both firms being precluded as equilibrium outcomes. These results provide an explicit link between real exchange rate volatility, market structure and multinational production, and imply that, for purely strategic reasons, dominant or leading firms in an industry may be naturally multinational.

These results must, however, be interpreted in the context of our model, which was designed to exposit the intuition of strategic production opportunities under exchange rate uncertainty but

is necessarily focused solely on the behavior of domestic duopolists. Desirable refinements to our model include the following extensions. First, in the current model, precommitment is tantamount to foreign production. We can relax this assumption by allowing firms to make simultaneously three decisions: quantity of output, timing of output and production location. Assuming both foreign and domestic plants require fixed investment expenditures in this case, this extension will not alter our results, since a mixed strategy equilibrium in the timing of production location decisions will still occur. It would, however, more fully depict the strategic options available to many domestic firms. Second, we have followed the traditional literature on multinational firms by implicitly assuming the presence of firm-specific, as well as plant-specific, fixed costs. These firm-specific costs can preclude foreign firms from simultaneoulsy entering the domestic market, as discussed in Nickerson and Sadanand (1989), as well as the possibility of domestic and foreign firms producing and selling in both domestic and foreign markets. The inclusion of these features would enhance the realism of our model, as well its complexity. Third, we can allow domestic firms to confront multiple sources of uncertainty, each of which would offer them a strategic opportunity for precommitment. Finally, we need not have a complete resolution of exchange rate uncertainty, but rather we can model periods of decreasing and increasing uncertainty in this rate.

The primary point we wish to emphasize in this paper is that exchange rate volatility offers a purely strategic explanation for the endogenous emergence of industry leadership and multinational production among initially symmetric risk-neutral firms. Our model provides an interesting and important example of this.



Notes:

1. This is a sample extensive form game with two realizations of the random exchange rate θ/C. Similar looking paths have not all been drawn. Dashed lines denote information sets.
2. "P" denotes "Precommit to foreign production" and "F" denotes "Remain flexible to decide production after resolution of uncertainty."
3. If a firm chooses to produce abroad then it has to choose its output level depicted by any one line under the heading "P". One line or branch will exist for each of the possible levels of production to which a firm could credibly precommit under exchange rate uncertainty, although we depict only two such lines for each firm.
4. The players are ①, ② and Ⓝ = nature.

FIGURE 1

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