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International Monopoly under Uncertainty

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A domestic monopolistic firm has the option to service a foreign market through export or by setting up a plant in the host country under exchange rate uncertainty. We analyze the effect of the parameters of the demand and cost functions on hysteresis. We also show results on the effect of taxation and labor cost in attracting or avoiding relocation. We find that when the firm is multinational it pays more taxes. Much more importantly, a tax rate reduction is effective in attracting investment and avoiding relocation. When the firm is multinational it also incurs lower labor costs. However, labor cost is not determinant in the location of production.

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1. INTRODUCTION

The decision of where to locate the production of a tradable good is an investment decision made under uncertainty and is costly to reverse. An exporting firm has the option of setting up a plant in a host country at any time. In the same way, a multinational firm has the option at any time of abandoning the host country and serving it through exports. In any case, the firm finds it convenient to wait for better conditions. A firm facing this problem can be understood as having a financial option. Dixit (1989) developed a model for the decision whether to enter and exit a market based on financial option theory. The argument is simple: "an opportunity to make a real investment is a call option on a stock that consists of the capital in place". Accordingly, the option value of an investment project is evaluated to represent the value of waiting. The investment decision entails sunk costs, which can be understood as the strike price.

In this article we consider that the uncertainty comes from the exchange rate. Theoretical models such as Goldberg and Kolstad (1995), Sung and Lapan (2000) and Aray and Gardeazabal (2006) show that exchange rate movements influence the location decisions of firms. The empirical evidence available on the relationship between exchange rate fluctuations and FDI includes Blonigen (1997), who argues that the exchange rate may affect FDI because acquisitions involve firm-specific assets which can generate returns in domestic currency, and Campa (1993), who finds a negative effect of exchange rate volatility on the number of foreign firms entering the U.S. market.

In this paper we use the methodology of Dixit (1989) and Dixit and Pyndick (1994) as well as the model of Aray and Gardeazabal (2006) to study a monopolist's location decision in

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an uncertain environment. We analyze the effect of changes in the parameters of the demand and cost functions, local and foreign taxation and the role of labor costs in deciding where to locate production.

2. THE MODEL

2.1 General Framework

Based on Dixit's model, Aray and Gardeazabal (2006) developed a model of the entry and exit decisions of a domestic oligopolistic firm competing à la Cournot with *n* foreign firms in a host country where all the firms have linear demand and cost functions. We follow their model to explain the case of a monopolist facing nonlinear demand and cost functions.

Assume that the exchange rate, *S*, changes over time as a Brownian motion, and hence all uncertainty arises from the exchange rate.

$$\frac{dS}{S} = \mu dt + \sigma dz \tag{1}$$

where *dz* is the increment of a standard Wiener process, normally distributed with zero mean and variance *dt*, μ is the trend rate of growth of the exchange rate or the deviation of the exchange rate from its equilibrium path at each point in time, and σ is a measure of its potential volatility.

According to the Dixit's model, the firm's decision problem is reduced to the problem of exercising an option. The approach has two state variables: the current exchange rate, *S*, and a discrete variable, $j = 0, 1$, that indicates whether the firm is an exporter ($j = 0$) or a multinational ($j = 1$). In state $(S, 0)$ the firm decides whether to produce only in the domestic market and to export or to begin to produce (and sell) in the foreign market, which means exercising the option of going multinational. In state $(S, 1)$ it decides to continue producing (and selling) in the host county or to go domestic again, which means exercising the option of being an exporter.

The current profit of a firm in state *j* as a function of the exchange rate is $\pi_j(S)$ and the expected discounted value of the firm given an initial exchange rate *S* and state *j* can be expressed as $V_j(S)$.

A firm facing such a problem and able to change flexibly from one state to another has to price both options simultaneously. Under non-arbitrage opportunities the following must be satisfied

$$\frac{E(dV_j(S))}{dt} + \pi_j(S) = \rho V_j(S) \tag{2}$$

where ρ is a discount rate and *E* is the expectation operator. By Ito's Lemma, we have

$$\frac{1}{2}\sigma^2 S^2 V_j''(S) + \mu S V_j' - \rho V_j(S) = \pi_j(S)$$

The general solution of (3) can be written as

$$V_j(S) = A_j S^{\eta_0} + B_j S^{\eta_1} + E\int_0^{\infty} \pi_j(S(t)) e^{-\rho t}\, dt \tag{3}$$

where

$$\eta_0 = \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} < 0$$

$$\eta_1 = \frac{1}{2} - \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1$$

It can be considered that exporting is profitable when the domestic currency is depreciated and setting up a plant abroad is profitable when the domestic currency is appreciated. This simple reasoning introduces the restrictions $A_1 = B_0 = 0$. Eliminating the sub-index we write

$$V_j(S) = (1 - j) A_j S^{\eta_j} + jB_j S^{\eta_j} + E\int_0^\infty \pi_j(S(t)) e^{-\rho t}\, dt \tag{4}$$

Let $\underline{S}$ ($\bar{S}$) be the level of exchange rate low enough to induce the firm to invest in the host country, that is, the exchange rate at which the firm exercises the option to go multinational (abandon the host country). Thus, the firm retains its option to go multinational over the interval ($\underline{S}$, ∞). However, a multinational firm will continue operating in the host country over the interval (0, $\bar{S}$). Notice that $\bar{S} > \underline{S}$.

Let I and D be the sunk costs in foreign currency of undertaking the projects of going multinational and exporting respectively. The value matching and the smooth pasting conditions will be given by

$$\begin{aligned} V_0(\underline{S}) &= V_1(\underline{S}) - SI \\ V_0'(\underline{S}) &= V_1'(\underline{S}) - I \\ V_1(\bar{S}) &= V_0(\bar{S}) - SD \\ V_1'(\bar{S}) &= V_0'(\bar{S}) - D \end{aligned} \tag{5}$$

The equations in (5) form a nonlinear system that has to be solved for A, B, $\underline{S}$, and $\bar{S}$.

2.2 The Case of Nonlinear Demand and Cost Functions

Let the foreign currency market price be given by the following inverse nonlinear demand function

$$P_j = \alpha Q_j^{\beta} \quad \text{with} \quad \alpha > 0, -1\ \beta > 0 \tag{6}$$

The total cost is assumed to be also nonlinear

$$C(Q_j) = \gamma_j Q_j^{\delta j} \quad \text{with} \quad \gamma_j > 0, \delta_j > \beta + 1 \tag{7}$$

The firm solves the following problem whatever the state

$$\max (1 - t_j) S^j \left[\left[1 - \tau\right]^{1-j} \alpha Q_j^{\beta+1} - \gamma_j Q_j^{\delta j}\right] \tag{8}$$

where τ [0,1]. Positive values of τ can be interpreted as iceberg-type transport costs rather than as an ad-valorem tariff because trade restriction are normally used to protect local producers from foreign competition, so in this case a tariff makes no sense. t_j is a tax rate on profits. The solution of the maximization problem gives

$$Q_j = \left(\frac{[S(1-\tau)]^{1-j}\,\alpha(\beta+1)}{\gamma_j \delta_j} \right)^{\frac{1}{\delta_j - \beta - 1}}$$

$$P_j = \alpha \left(\frac{[S(1-\tau)]^{1-j}\,\alpha(\beta+1)}{\gamma_j \delta_j} \right)^{\frac{\beta}{\delta_j - \beta - 1}}$$

The profit as a function of S is given by

$$\pi_j(S) = (1 - t_j)\,[((1-\tau)\,S)^{k_j}]^{1-j}\,S_j K_j$$

where $$k_j = \frac{\delta_j}{\delta_j - \beta - 1} \quad \textit{and} \quad K_j = \gamma_j \left(\frac{\alpha(\beta+1)}{\gamma_j \delta_j} \right)^{k_j} \left(\frac{\delta_j}{\beta+1} - 1 \right)$$

With the expected present value of the current profits being

$$E \int_0^{\infty} \pi_j(S(t))\, e^{-\rho t}\, dt = (1 - t_j) \left[\frac{[((1-\tau)\,S)^{k_j}]^{1-j}\, S^j\, K_j}{\left(\frac{1}{2}\sigma^2 (k_j^{1-j} - 1) + \mu \right) k_j^{1-j} - \rho} \right]$$

3. NUMERICAL RESULTS

3.1 Baseline Case

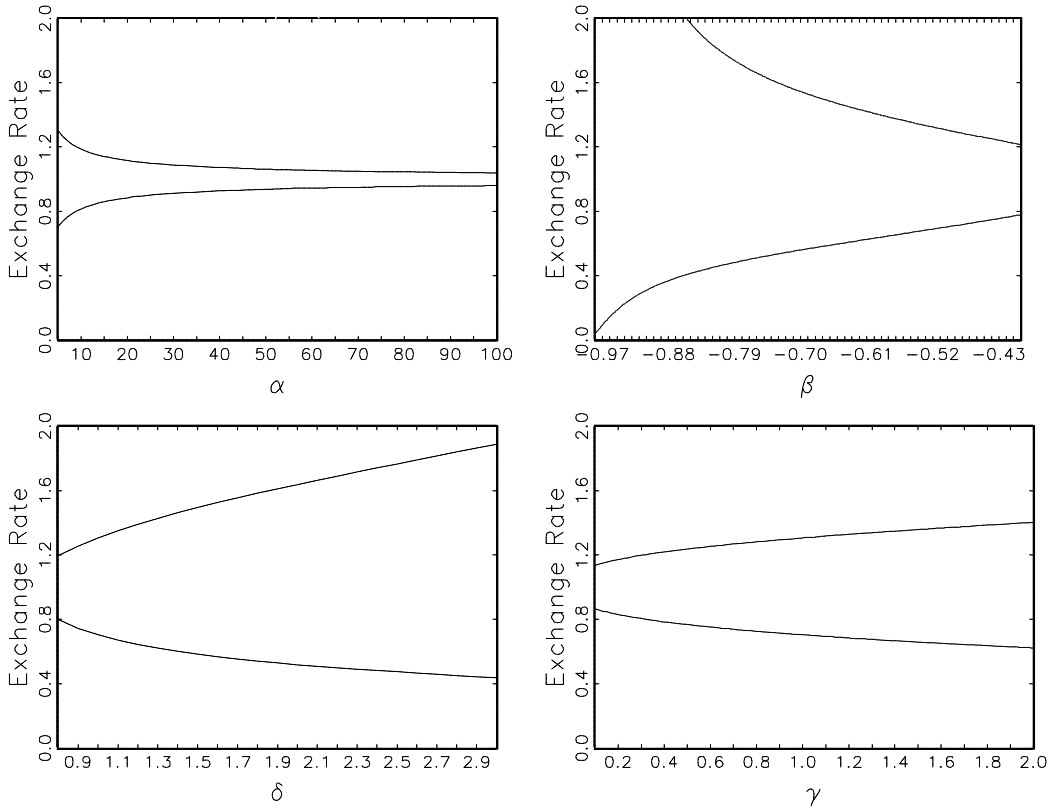
Consider a set of baseline parameter values to attiain the numerical solution. Assume that $\alpha = 5$, $\beta = -0.5$, $\gamma = \delta = 1$, $\tau = t_0 = t_1 = 0$, $\sigma = 0.1$, $\mu = 0$, $\rho = 0.025$, and $I = D = 10$.

Figure 1 shows the effect of changes in the parameters of the demand and cost functions on the trigger exchange rates ($\underline{S}$, $\overline{S}$). The upper left panel shows the case of changes in α, which can be interpreted as changes in the market size. This is the case of an exogenous shift in demand that causes equilibrium prices and quantities to rise. $\underline{S}$ rises and $\overline{S}$ falls as α increases, leading to a decrease in the degree of hysteresis. The higher price and quantity push operating profits up. Therefore, if the firm is exporting; going multinational would be profitable at a higher $\underline{S}$. However, if the firm is multinational; to abandon the host country it will require a lower $\overline{S}$ because the higher profits make exporting more profitable. However, it should be noticed that in small markets the trigger exchange rate is more sensitive, while in medium and large markets the trigger exchange rates hardly vary.

The upper right panel of Figure 1 shows that lower absolute values of β make hysteresis decrease. Notice that a lower absolute value of β implies in absolute value a higher price elasticity of the demand function, which is $1/\beta$. A higher price elasticity increases operating profits, so we can apply reasoning similar to the case of market size.

The lower left and right panels of Figure 1 show the case for γ and δ. In both cases $\underline{S}$ ($\overline{S}$) decreases (increases) with higher values of these parameters, pushing the degree of hysteresis down. Notice that an increase in these parameters pushes operating profits down, so if the firm is exporting it will undertake the multinational project if the cost of investment is lower, which implies that the exchange rate would have to be lower. Similarly, if the firm is multinational it will require a higher exchange rate to stop producing in the host country and become an exporter.

Figure 1
Effect of Changes in the Parameters of the Demand and Cost Functions on Hysteresis

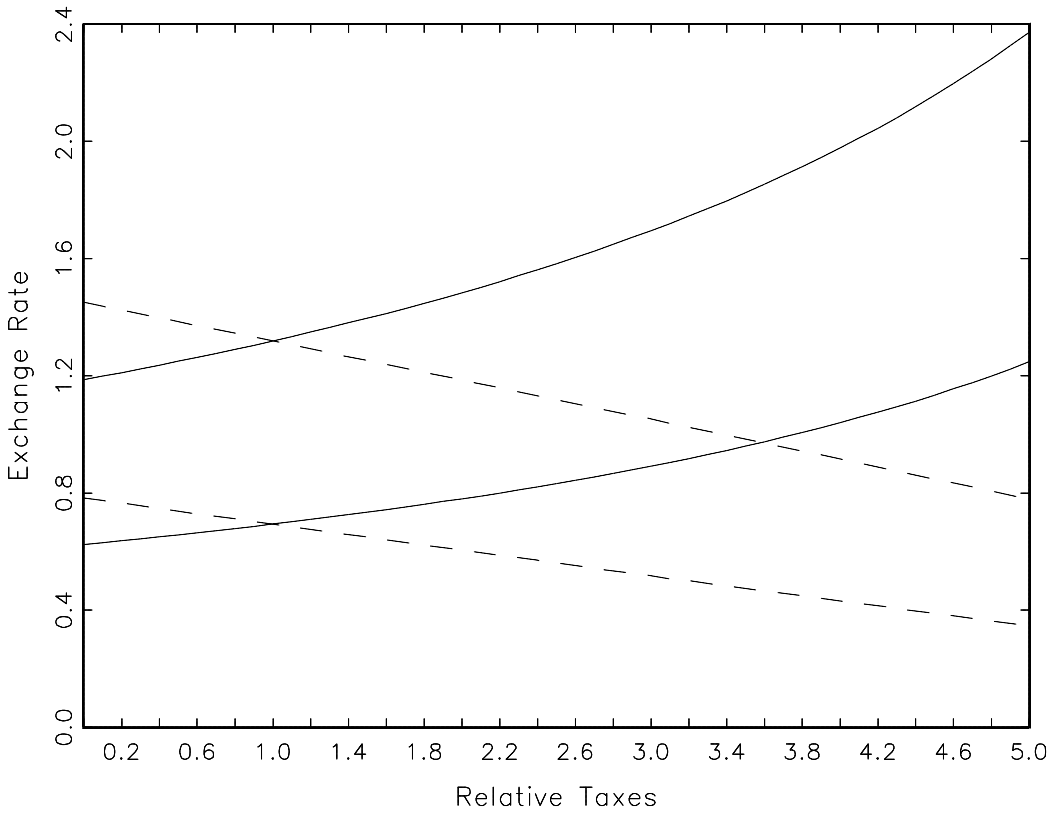


3.2 Taxation

We are interested in results that show the effect of tax policy on the decision of where to locate production. Tax reduction could be used as a tool for attracting or avoiding relocation of firms.

Figure 2 shows how the trigger exchange rate reacts to changes in taxation in both countries. The solid lines are the trigger exchange rates when the domestic tax rate varies from zero to five times the foreign tax rate. The dashed lines are the trigger exchange rates when the foreign tax rate varies from zero to five times the domestic tax rate. The results in both cases support the intuition. Consider the case of changes in the tax policy of the domestic economy. If the firm is exporting, a decrease in the domestic tax rate respect to the foreign tax rate will drive $\underline{S}$ down, so it can be interpreted as a way of deterring the firm from going multinational. Along the same lines, if the firm is multinational a reduction in the domestic tax rate will drive $\overline{S}$ down, so the multinational firm will soon become an exporter, which can be interpreted as an incentive to attract the domestic firm to produce in its own country. A similar argument applies in the case of changes in foreign taxation relative to domestic taxation (dashed line). If the firm is exporting, a decrease in the foreign tax rate respect to the domestic tax rate will drive $\underline{S}$ up, so it can be interpreted as a way of attracting foreign direct investment, and if the firm is multinational the same policy will also drive $\overline{S}$ up, which is a way of avoiding relocation.

Figure 2
Relative Taxes: Domestic (Solid Line) and Foreign (Dashed Line)



We also compute the total tax paid by the firm in state *j*.

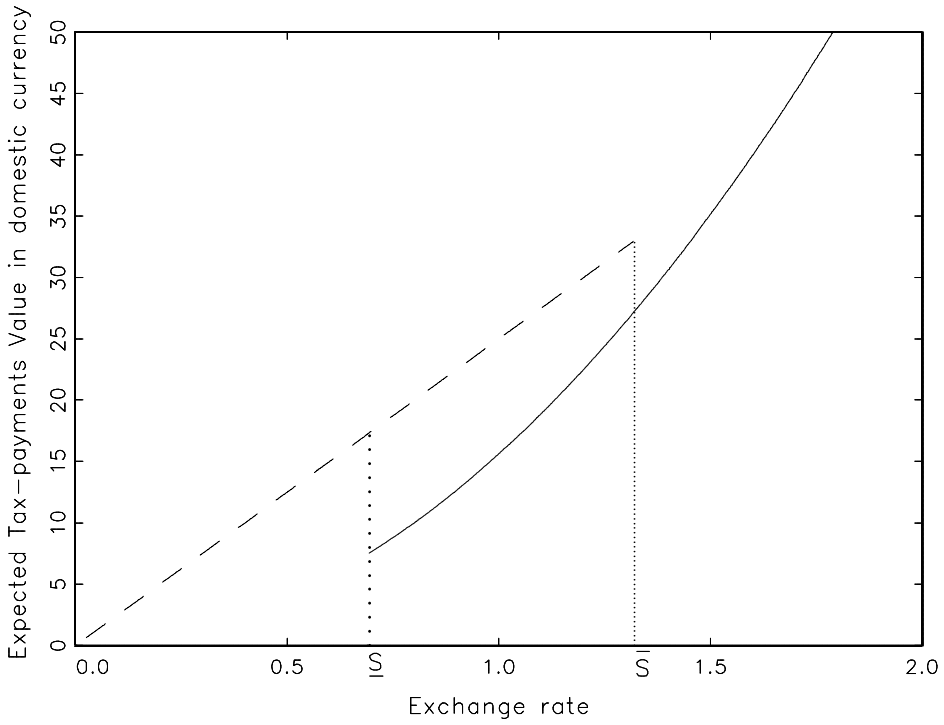
$$T_j(S) = t_j[((1-\tau)S^{kj}]^{1-j}\, S_j K_j$$

With the expected present value of taxes being

$$E\int_0^{\infty} T_j(S(t))e^{-\rho t}\,dt = t_j\left[\frac{[((1-\tau)S)^{k_j}]^{1-j}\,S^{j}\,K_j}{\left(\frac{1}{2}\sigma^2(k_j^{1-j}-1)+\mu\right)k_j^{1-j}-\rho}\right]$$

Figure 3 shows the expected present value of tax payments in domestic currency by the firm in state *j*. The figure is drawn for $t_0 = t_1 = 0.1$. It should be noticed that with an equal tax rate in the range ($\underline{S}$, $\bar{S}$) if the firm is multinational it pays more taxes. It is also very striking that if the firm is exporting, the differences in tax payments are higher as long as *S* tends to $\underline{S}$. Thus, if *S* reaches $\underline{S}$ the firm will go multinational even if the difference in tax payments is higher. Therefore, with an equal tax rate, tax payments are not determinant in the decision whether to relocate of production.

Figure 3
Expected Present Value of Tax Payments. Solid Lines (j = 0) and Dashed Lines (j = 1)



3.3 Labor Costs

It is often argued that, in general, relocation of production is attracted by low labor cost. In this section we want to know whether in the case of exchange rate uncertainty a firm locates production to take advantage of low labor costs. Let w_j be the wage rate in state j. As w_j is not explicitly defined in our model, let us work on the cost function in order to obtain it.

Equation (7) could be generated by a Cobb-Douglas production function as

$$Q_j = f(H_j L_j) = H_j^{aj} L_j^{bj} \quad a_j, b_j > 0$$

where L_j are units of labor used in the production process and H_j are units of any other input. Solving the problem of minimizing cost, the cost function can be written as

$$C_j(w_j, r_j, Q_j) = \left[\left(\frac{a_j}{b_j} \right)^{\frac{b_j}{a_j + b_j}} + \left(\frac{a_j}{b_j} \right)^{\frac{-a_j}{a_j + b_j}} \right] r_j^{\frac{a_j}{a_j + b_j}} \; w_j^{\frac{b_j}{a_j + b_j}} \; Q_j^{\frac{1}{a_j + b_j}}$$

where r_j is the price of input H_j.

The input demand functions are

$$H_j(w_j, r_j, Q_j) = \left(\frac{a_j}{b_j} \right)^{\frac{b_j}{a_j + b_j}} r_j^{\frac{-a_j}{a_j + b_j}} \; w_j^{\frac{b_j}{a_j + b_j}} \; Q_j^{\frac{1}{a_j + b_j}}$$

$$L_j(w_j, r_j, Q_j) = \left(\frac{a_j}{b_j}\right)^{\frac{-a_j}{a_j+b_j}} r_j^{\frac{a_j}{a_j+b_j}} w_j^{\frac{-a_j}{a_j+b_j}} Q_j^{\frac{1}{a_j+b_j}}$$

From our cost function (7), notice that

$$\gamma_j = \left[\left(\frac{a_j}{b_j}\right)^{\frac{b_j}{a_j+b_j}} + \left(\frac{a_j}{b_j}\right)^{\frac{-a_j}{a_j+b_j}}\right] r_j^{\frac{a_j}{a_j+b_j}} w_j^{\frac{b_j}{a_j+b_j}}$$

$$\delta_j = \frac{1}{a_j + b_j}$$

Finally the labor cost can be written as a function of the exchange rate

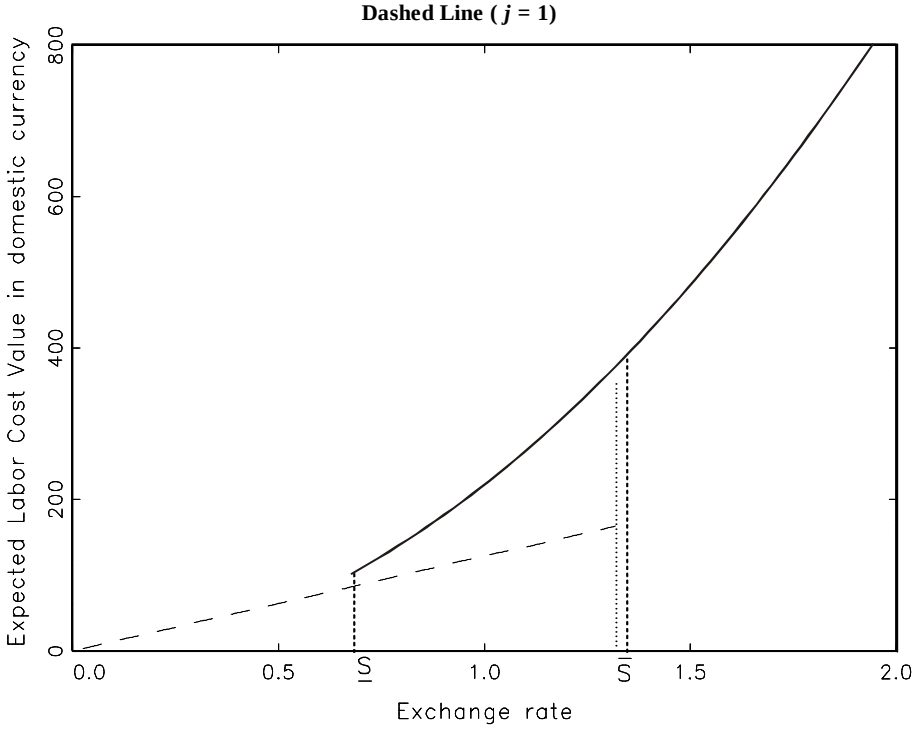
$$LC_j(S) = S^j w_j L_j$$

The expected present value is

$$E\int_0^\infty LC_j(S(t)e^{-\rho t}\, dt$$

Figure 4 shows the expected present value of labor costs in both states. Notice that in the range ($\underline{S}$, $\overline{S}$) if the firm is multinational it incurs lower labor costs. However, if the firm is exporting it bears higher costs. Notice also that cost differences are much higher as S moves

Figure 4
Expected Present Value of Labor Costs in Domestic Currency. Solid Line (j = 0) and Dashed Line (j = 1)



away from $\underline{S}$. It is also striking that when the firm switches from exporting to setting up a plant in the host country labor costs are similar, which means that in this case labor cost plays no role in attracting foreign direct investment. However, when a multinational firm decides to become an exporter the changes in costs are larger. The explanation of this apparent contradiction is that the depreciation of the exchange rate can offset the higher labor costs, making exporting more profitable than being a multinational. In any case we can see that labor costs are not determinant in the decision where to locate production under exchange rate uncertainty.

4. CONCLUSIONS

We present a model of an international monopolist under exchange rate uncertainty. We consider that the firm has the option to locate production domestically and export to a foreign market or to locate production in the host country and serve it as a multinational. This decision is affected by changes in the parameters of the demand and cost functions. Tax reduction can be used as tool to attract and avoid relocation. Much more interestingly, with equal tax rates in the range of the exchange rate in which the firm could be multinational or an exporter, it would pay more taxes as a multinational. Our results on labor costs show that the firm would incur lower labor costs as a multinational. However, we have shown that labor costs are not determinant in the decision where to locate production under exchange rate uncertainty.

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