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Hysteresis in Exports

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Abstract

This paper presents an empirical examination of the importance of hysteresis in international trade. An econometric model of export determination is developed where the presence of sunk costs causes discontinuous behavior and hysteresis so that individual exporters' decision to stay in or out of the market depends on the current value of the exchange rate as well as its past history. The aggregate level of exports is then determined by the proportion of exporters that stay in the market. The resulting non-linear model is estimated using data on manufacturing exports for the United States, Germany, and Japan. The paper finds strong evidence in favor of the presence of pricing-to-market and hysteresis only in the case of Japanese exports.

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Summary

Fluctuations in exchange rates have been large and frequent in the floating exchange rate period. The response of trade flows and current accounts to these fluctuations, however, has been limited. This seems at odds with the traditional view that the real exchange rate is a principal determinant of the volume of trade. Movements in the dollar and the U.S. current account provide an interesting example. The dollar appreciated by about 50 percent with respect to a basket of currencies in the span of five years (1980-85), and then fell to its 1980 value in only three years. In the meantime, the U.S. current account deficit soared and then continued to widen despite the huge dollar depreciation that followed the Louvre and Plaza agreements. The slow and confused response of trade flows to exchange rate changes is difficult to explain even after allowing for J-curve effects, information and transportation lags, and the increased uncertainty resulting from higher exchange rate volatility.

The persistence of trade imbalances, in particular between the United States, Japan, and Germany, and their apparent unresponsiveness to exchange rate changes, have led to a re-examination of the traditional adjustment processes. There have been a number of attempts to explain this persistence by allowing for a combination of strategic interaction in oligopolistic markets, sunk costs, and uncertainty in foreign trade. It has been argued that these factors adversely affect the working of the adjustment mechanism and cause hysteresis in trade flows, for example, by making trade flows dependent not only on the current value of the exchange rate but also its past history.

This paper attempts to examine the issue from an econometric point of view by distinguishing two types of hystereses: that arising from limited exchange rate pass-through and that arising from regime switches in supply. It starts with a benchmark model where export prices and quantities are determined along traditional lines, and then develops a model where the presence of sunk costs generates discontinuous behavior by individual firms. Such a behavior at the firm level gives rise to nonlinearities at the aggregate level. The models are then estimated using data for the United States, Japan, and Germany. The paper finds strong evidence in favor of the presence of pricing-to-market and hysteresis only in the case of Japanese exports.

I. Introduction

Fluctuations in exchange rates have been large and frequent in the floating exchange rate period. The response of trade flows and current accounts to these fluctuations, however, has been limited. This seems at odds with the traditional view that the real exchange rate is a principal determinant of the volume of trade. Movements in the dollar and the U.S. current account provide an interesting example. The dollar appreciated by about 50 percent with respect to a basket of currencies in the span of five years (1980-85), and then fell to its 1980 value in only three years. In the meantime, the U.S. current account deficit soared and then continued to widen despite the huge dollar depreciation that followed the Louvre and Plaza agreements.[1] The slow and confused response of trade flows to exchange rate changes is difficult to explain even after allowing for J-curve effects, information and transportation lags, and other factors. Moreover, the increased uncertainty resulting from higher exchange rate volatility appears to have an insignificant or relatively small effect on trade, when examined within the conventional framework (see, for example, De Grauwe (1988)).

The persistence of trade imbalances, in particular between the United States, Japan, and Germany, and their apparent unresponsiveness to exchange rate changes have led to a re-examination of the traditional adjustment processes. There have been a number of attempts to explain this persistence by allowing for a combination of strategic interaction in oligopolistic markets, sunk costs, and uncertainty in foreign trade.[2] It has been argued that these factors adversely affect the working of the adjustment mechanism and cause hysteresis in trade flows, for example, by making trade flows dependent not only on the current value of the exchange rate but also its past history.[3]

Alternative approaches have argued that "once the data is cleaned" the traditional adjustment mechanism works (see Bergsten (1991) and Krugman (1992)). Dixit (1994) has reconciled the two views by examining the implications of the hysteresis model for the J-curve type of adjustment. He argues that hysteresis implies a stochastic J-curve; hence, the two views of the effects of exchange rate changes on trade flows are related. He provides some preliminary empirical support for this view from the analysis of bilateral U.S.-Japan trade.[4]

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[1]Rose and Yellen (1989) find little evidence of a reliable long-run relationship between the U.S. trade balance and the real exchange rate.
[2]See, for example, Mann (1986), Dornbusch (1987), Baldwin (1988), Dixit (1989a, 1989b), Baldwin and Krugman (1989), Krugman (1989), and Dixit (1994).
[3]Exchange rate volatility can also influence export quantities and prices in hysteresis models of trade, although the direction of the effect is not always clear (see Dixit (1989a) and Froot and Klemperer (1989)).
[4]Note also that some studies find that the traditional determinants of trade flows, in particular the real exchange rate, perform well in explaining the external adjustment of Japan (see Corker (1989) and Meredith (1993)).

While the theoretical models put forward to explain hysteresis are innovative and elegant, the empirical examination of the issue has been mainly descriptive. In this paper we attempt to examine the issue from an econometric point of view by distinguishing two types of hystereses: that arising from limited exchange rate pass-through and that arising from regime switches in supply. We start with a benchmark model where export prices and quantities are determined along traditional lines, and then develop a model where the presence of sunk costs generates discontinuous behavior by individual firms. Such a behavior at the firm level (either "in" or "out" of a particular export market) gives rise to non-linearities at the aggregate level. The models are then estimated using data for the United States, Japan, and Germany.

The paper is organized as follows. Section II reviews the main concepts introduced by the recent theoretical and empirical literature. Section III develops testable supply and demand hysteresis models for exports. Section IV presents the econometric results, and Section 5 draws conclusions and comments on future research directions.

II. Sunk Costs and Hysteresis in Trade

Two interesting concepts introduced by the new literature are those of pricing-to-market and hysteresis. Pricing-to-market occurs when firms, rather than passing on exchange rate changes into export prices, try to hold onto their market shares by keeping prices stable in the importing country's currency. A possible theoretical explanation for pricing-to-market is provided by Dornbusch (1987) and is based on oligopolistic interactions between firms. Hooper and Mann (1989), Helkie and Hooper (1987), Giovannetti (1994), and Marston (1990) find evidence that Japanese producers cut profit margins on exports to the United States following the dollar depreciation that started in February 1985, in an attempt to maintain their market shares (although increasing their profit margins in other regions).[1]

Hysteresis in supply, on the other hand, implies that a market lost when a country's currency appreciates may not necessarily be regained when the currency returns to its original level. Moreover, markets entered in order to exploit profit opportunities provided by a temporary exchange rate movement are not immediately abandoned when the profit opportunities disappear. This would occur when market shares are perceived as a kind of investment made through costly creation of consumer reputation and of

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[1]This existing empirical evidence is mainly descriptive. A notable exception is Knetter (1994) where a model of price discrimination by a monopolist selling to several export destinations is used to allow for the possibility of destination-specific mark-ups. By using disaggregated industry-level data for Germany and Japan, he provides some econometric support for his model.

distribution networks (Dixit (1989a) and (1989b)). Once foreign firms have exploited profit opportunities from a high dollar, for example, and have invested to enter the U.S. market, much of which may be sunk costs, they may still consider it profitable to stay in the market even if the dollar returns to its pre-appreciation value. The importance of this phenomenon is strengthened by the volatility of exchange rates, which makes it difficult to distinguish permanent from transitory profit opportunities, and thus enhances a "wait-and-see-attitude" by the exporting firms.[1] The theoretical microeconomic models are based on two observations: that the exchange rate is a non-stationary stochastic process, and that imports and exports involve some irreversible costs. Hence, exporting firms initiate or stop trading (or more generally alter the volume of trade) only when the movement in the exchange rate is sufficiently large. There is only a limited literature on the econometric estimation of trade models with hysteresis.[2]

III. A Testable Model for Aggregate Exports

We develop a structural model of supply and demand in the export market to examine the response of export volumes and prices to shocks in the exchange rate. Hysteresis in this model arises from discrete changes in the distribution of exports, resulting from regime switches that follow shocks to the exchange rate, as well as from the possibility of partial adjustment of export prices to exchange rate changes.

The approach we adopt contrasts with a general time-series approach, where hysteresis or persistence results from non-stationarity in the form of the presence of unit roots in the data-generating process. In such a situation any non-specific temporary shock would have long-term impacts because of the presence of unit roots. The time-series approach could be extended to include specific shocks in the data-generation process, while preserving the essentially non-structural character of the approach.

We start by discussing, as a benchmark, a standard structural supply and demand export model.[3] In this model, hysteresis results from partial adjustment of export prices to exchange rate changes. In Section III.2 we shall allow hysteresis to also take the form of regime switches in supply.

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[1]Dixit (1989a and 1989b) uses an analogy with options prices: entering a new export market is like an option that an exporting firm can exercise now or later.

[2]The existing empirical tests of hysteresis often involve testing for unit roots rather than for non-stationarity of a more general nature. See Amable, et al. (1994).

[3]See Goldstein and Khan (1984) for a detailed account of export and import models, where both supply and demand are considered. See also Samiei (1994) for an application to the United Kingdom.

1. The Benchmark Model

Domestic manufacturing suppliers face two alternatives: to sell in the domestic market or to export. The supply of manufacturing exports, x_{st}, therefore, depends on export prices in local currency relative to domestic consumer prices (the relative price relevant to the suppliers), p_{st}, on unit labor costs c_t deflated by domestic prices, and on the nominal effective exchange rate, e_t (all variables are in logarithm).[1] We make the simplifying assumption that suppliers have perfect foresight about the movements of prices and the exchange rates:

$$x_t^s = F(p_{st}, c_t, e_t) .$$ (1)

Rewriting the supply function in terms of prices makes the discussion of the pricing policy of the exporting firms and the reasons for the separate inclusion of the exchange rate in (1) more transparent. Hence, consider:

$$p_{st} = G(x_t^s, c_t, e_t) .$$ (2)

In a competitive international market, exporting firms take prices in foreign currency as given and offset the effect of exchange rate fluctuations by appropriately adjusting export prices in local currency terms so that the law of one price holds. This effort to preserve market shares and competitiveness implies a negative relation between the exchange rate (defined as the price of local currency) and export prices in local currency. At the opposite extreme, setting prices in domestic currency based on domestic considerations implies that changes in the exchange rate are passed on to consumer prices in foreign currency in order to preserve profit margins. In this case, prices in local currency and the exchange rate would move independently of each other. The exchange rate is, therefore, included as a regressor in (1) (and, as a consequence, in (2)) in order to test the hypothesis of partial adjustment of export prices in foreign currency to exchange rate changes. When no adjustment takes place and *export prices in local currency terms do not respond to exchange rate changes*, the coefficient of the exchange rate (in a linear version of (2)) would be zero. However, if suppliers fully or partially adjust local currency export prices in order to modify the impact on consumers abroad and preserve international market shares, then the exchange rate would negatively affect prices.

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[1]Note that instead of a cost variable, the capital stock could be used as a determinant of export supply when rigidities in the production structure do not allow firms to fully optimize (see, for example, Holly and Wade (1991)).

To complete the model, a conventional demand function for exports that assumes imperfect substitution, is specified:

$$x_t^d = H(p_{dt}, y_t),$$ (3)

where p_{dt} is the export price in terms of foreign currency deflated by industrial countries' prices (the relative price relevant to the consumers) and y_t is industrial countries' GDP.

The equilibrium price and quantity exported are determined by the equality of supply and demand. A log-linear specification of (2) and (3) is used to estimate the model. Non-stationarity in the conventional sense of the presence of unit roots in the series is allowed for by employing a simultaneous error correction formulation. Rewriting the system in the error-correction form gives:

$$\Delta p_{st} = \rho_1 \Delta p_{s,t-1} + \alpha_1 \Delta x_t + \alpha_2 \Delta c_t + \alpha_3 \Delta e_t$$
$$+ \delta_1 (p_{s,t-1} - \beta_1 x_{t-1} - \beta_2 c_{t-1} - \beta_3 e_{t-1}) + u_{1t},$$ (4)

$$\Delta x_t = \rho_2 \Delta x_{t-1} + \gamma_1 \Delta p_{dt} + \gamma_2 \Delta y_t + \delta_2 (x_{t-1} - \omega_1 p_{d,t-1} - \omega_2 y_{t-1}) + u_{2t},$$ (5)

where x_t is the equilibrium quantity for the volume of manufacturing exports, and u_{it}, for i=1,2, is a normally distributed error term satisfying the standard assumptions of the linear regression model. The constant term is dropped since all the variables are written as deviations from the mean. The log-likelihood function for the above model (represented by (4) and (5), and referred to as M_1 in what follows), is:

$$l_1(\theta_1) = n\log|J| - \frac{n}{2}\log(2\pi\sigma_{u1}^2\sigma_{u2}^2) - \frac{u_{1t}'u_{1t}}{2\sigma_{u1}^2} - \frac{u_{2t}'u_{2t}}{2\sigma_{u2}^2},$$ (6)

where θ_1 is the vector of the parameters to be estimated, and J is the Jacobian of the transformation, i.e. the matrix of the partial derivatives of u_{it}'s with respect to the endogenous variables and is equal to

$$J = \begin{pmatrix} 1 & -\alpha_1 \\ -\gamma_1 & 1 \end{pmatrix}.$$ (7)

The elements of the Jacobian are in this case independent of the variables in the system.

2. A Model With Entry and Exit

We now discuss a model where regime switches may take place as a result of entry/exit decisions of firms. We derive export functions for individual firms using arguments similar to those elaborated in Dixit (1989a and 1989b), but without explicitly discussing the optimization exercise that leads to these functions. We then derive aggregate export functions by making assumptions regarding the distribution of thresholds for individual firms, and then aggregating individual export functions.

In order to enter a new market, a typical firm has to pay a sunk cost. At the beginning of the period, the firm can already be exporting or not, i.e. it can be "in" or "out". If it is in, a change in the volume of exports does not involve any sunk costs; but if it is out, getting in involves the payment of a sunk cost. Let the firm maximize the expected present value of profits, given the information available at time t, which includes current values of the exchange rate, costs, and prices. The optimal strategy for entry/exit is characterized by two threshold levels of the exchange rate, the upper and the lower bounds. Because of the presence of sunk costs, the value of the exchange rate that will make the foreign market profitable will be strictly higher than the value that makes it unprofitable, and therefore induces exit. The presence of sunk costs also implies that there is a range of values of the exchange rate for which the firm may stay in or out of the market, and what it actually does depends on its past history. If initially the firm is out of the market, it will not enter unless the exchange rate is above the upper bound. Therefore, for values of the exchange rate within and below the band, exports will be zero. If, on the other hand, initially the firm is selling in the foreign market, it will stay in if the exchange rate is within or above the band. Therefore, in the range of exchange rates between the upper and lower limits, the optimal policy is to continue with the status quo. As a consequence, the level of exports at any point in time will depend on the history of the exchange rate, as well as on its current level. Accordingly, for each particular firm, the supply of exports will be:

$$x_{it}^{s} = \begin{cases} 0 \, , & \text{if } e_t \leq e_{li} \, , \\ 0 \, , & \text{if } e_{li} < e_t < e_{ui} \text{ and } x_{i,t-1}^{s} = 0 \, , \\ x_t^{*} \, , & \text{if } e_{li} < e_t < e_{ui} \text{ and } x_{i,t-1}^{s} \neq 0 \, , \\ x_t^{*} \, , & \text{if } e_t \geq e_{ui} \, , \end{cases} \qquad (8)$$

where x_t^{*} is the quantity of exports when it is positive, expressed in logarithms.

Consider a large number of firms that are potential exporters, all identical in that they produce the same product with the same technology,

but different in the degree to which they are subject to entry and exit sunk costs. The presence of sunk costs implies that, for each firm, an exchange rate band exists within which the firm maintains the status quo (the hysteresis band). It is reasonable to allow for some heterogeneity in order to gain insights into the macroeconomic implications of discontinuous adjustment. Heterogeneity can take different forms. We assume that the width of the hysteresis band as a ratio to the lower bound, denoted by λ, is the same for all firms, but because of different cost structures, firms have different entry/exit thresholds.[1]

Let e_{ci} be the center of the hysteresis band for firm i, then $e_{li} = e_{ci} - \lambda/2$ and $e_{ui} = e_{ci} + \lambda/2$, are, respectively, the lower and upper bounds of the band, where the variables are defined in logarithms. The center of the hysteresis band, e_{ci}, is assumed to follow a normal distribution across firms (a plausible assumption when the number of potential exporters is large), with mean equal to zero (defining the exchange rate as deviation from the mean). Figure 1 illustrates the distribution of the central value of the band and the thresholds for a typical firm.

Figure 1. The Distribution of the Center of the Hysteresis Band

e_{li} e_{ci} e_{ui} e_c

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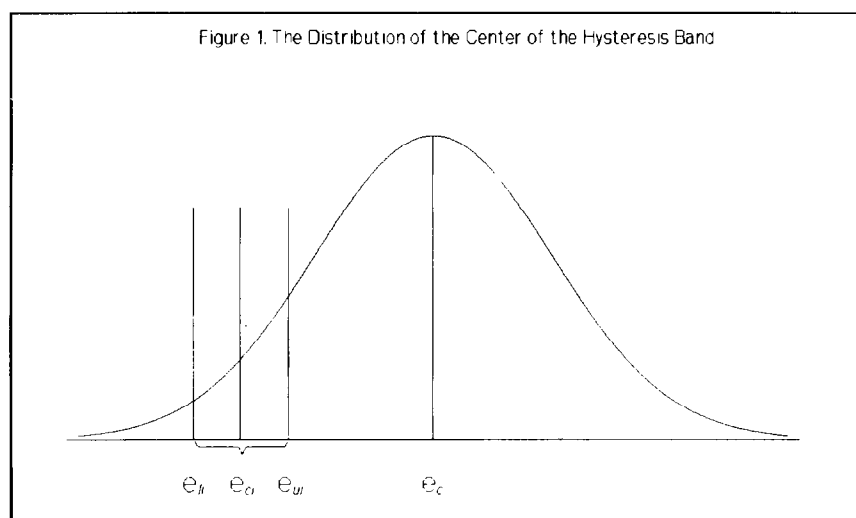
[1]In Dixit (1994), the thresholds can be different in different time periods or for different firms. He calculates entry and exit thresholds for the yen/dollar exchange rate in different periods. He divides the period 1979-89 into two sub-periods, 1979-84 and 85-89, derives lower and upper limits of 98 and 174 for the first sub-period, and 137 and 235 for the second sub-period. He also points out that since different exporters have different costs, these thresholds should be "interpreted as merely indicative of the position of what is actually a very fuzzy band, over which import penetration will gradually increase or decrease as the exchange rate moves through this range".

In order to derive total exports, note that the proportion of inactive firms is equal to:

$$\Psi(e_t, \lambda) = Prob(x_{it}^S = 0) =$$
$$Prob(e_t < e_{li}) + Prob(e_{li} \leq e_t \leq e_{ui}) Prob(x_{i,t-1}^S = 0) \ . \tag{9}$$

This proportion, as will become clear below, is a function of all the past values of the exchange rate (here suppressed for ease of exposition). Hence, under the assumption that e_{ci} follows a normal distribution with zero mean and standard deviation σ_e, we have:

$$Prob(e_t < e_{li}) = 1 - \Phi(\frac{e_t - \lambda}{\sigma_e}) = 1 - \Phi_{tl} \ , \tag{10}$$
$$Prob(e_{li} \leq e_t \leq e_{ui}) = \Phi(\frac{e_t + \lambda}{\sigma_e}) - \Phi(\frac{e_t - \lambda}{\sigma_e}) = \Phi_{tu} - \Phi_{tl} \ ,$$

where $\Phi(.)$ is the cumulative probability distribution of the standard normal distribution. Thus:

$$\Psi(e_t, \lambda) = 1 - \Phi_{tl} + (\Phi_{tu} - \Phi_{tl}) \Psi(e_{t-1}, \lambda) \ . \tag{11}$$

This non-linear difference equation can be solved numerically to obtain $\Psi(e_t, \lambda)$, for any set of parameter values and given an initial value for $\Psi(e_t, \lambda)$ at $t=0$. Thus, $\Psi(.)$ is a function of e_t and λ as well as all the past values of e_t.

Total exports at time t are equal to the number of active firms times exports by the average individual active firm:

$$x_t^S = (1 - \Psi(e_t, \lambda)) n x_t^* \ , \tag{12}$$

where n denotes the total number of potential exporters. Under the assumptions that n is constant over time and that the volume of export by each active firm, x_t^*, depends on the same variables as supply in model M_1, we have:

$$x_t^S = (1 - \Psi(e_t)) V(p_{st}, c_t, e_t) \ . \tag{13}$$

Note that by assuming that x_t^* is a function of other variables, rather than a fixed quantity, we are violating the assumptions behind the implicit optimization exercise that leads to the model described in (8). However, as

far as the empirical exercise is concerned, this assumption makes the model richer and more interesting.

Re-writing (13) in terms of p_{st},

$$p_{st} = g(\frac{x_t^s}{1 - \Psi(e_t, \lambda)}, c_t, e_t) \, . \tag{14}$$

It is clear from (14) that hysteresis in the form of changes in regime at the individual firm level is translated into non-linearities in the export function when aggregated across firms. This type of hysteresis would be supported empirically by the statistical significance of the parameters of $\Psi(.)$ and $x^s{}_t$. In this formulation, hysteresis in supply could co-exist with hysteresis resulting from insufficient exchange rate pass-through.

Using an error correction formulation and letting demand be determined as in model M_1, the econometric representation of the model when supply is set equal to demand (referred to as M_2), is:

$$\Delta p_{st} = \rho_1 \Delta p_{s,t-1} + \frac{\alpha_1 \Delta x_t}{1 - \Psi(\Delta e_t, \lambda)} + \alpha_2 \Delta c_t + \alpha_3 \Delta e_t +$$
$$\delta_1 (p_{s,t-1} - \beta_1 x_{t-1} - \beta_2 c_{t-1} - \beta_3 e_{t-1}) + v_{1t} \, , \tag{15}$$

$$\Delta x_t = \rho_2 \Delta x_{t-1} + \gamma_1 \Delta p_t + \gamma_2 \Delta y_t + \delta_2 (x_{t-1} - \omega_1 p_{t-1} - \omega_2 y_{t-1}) + v_{2t} \, , \tag{16}$$

$$\Psi(e_t, \lambda) = 1 - \Phi_{tl} + (\Phi_{tu} - \Phi_{tl}) \Psi(e_{t-1}, \lambda) \, , \tag{17}$$

where v_{it}, for i=1,2, is a normally distributed error term satisfying the standard assumptions, and Φ_{tl} and Φ_{tu} are defined as above. M_2 is different from M_1 in that it contains non-linearities that result from regime switches in supply. Although these are only present in the price equation, they clearly also affect quantities because of the simultaneous determination of prices and quantities. A priori it is not obvious how model M_2, in its error-correction form, may be specified as far as the presence of $\Psi(.)$ is concerned. The above specification assumes that regime switches affect only the short-run coefficients, and accordingly $\Psi(e_t, \lambda)$ is replaced by $\Psi(\Delta e_t, \lambda)$. This procedure is justified on the grounds that the nominal exchange rate is generally considered to contain unit roots, and thus Δe_t, the shock to the exchange rate, is more likely to follow a stationary distribution.[1]

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[1] A number of empirical tests reject the hypothesis of stationarity for exchange rates. See Giovannetti (1992) for a survey.

The likelihood function for model M_2 is as follows:

$$l_2(\theta_2) = \sum_{t=1}^{n} \log|J_t| - \frac{n}{2}\log(2\pi\sigma_{v1}^2\sigma_{v2}^2) - \frac{v_{1t}'v_{1t}}{2\sigma_{v1}^2} - \frac{v_{2t}'v_{2t}}{2\sigma_{v2}^2}, \tag{18}$$

where the Jacobin now is a function of e_t and is equal to

$$J_t = \begin{bmatrix} -1 & \dfrac{\beta_1}{1 - \Psi(\Delta e_t, \lambda)} \\ \beta_2 & -1 \end{bmatrix} \tag{19}$$

Unlike model M_1, the Jacobin for model M_2 is a function of the exchange rate and is therefore variable over time. Note that in maximizing the likelihood function for M_2, $\Psi(.)$ has to be calculated numerically for each set of parameter values during the optimization process.

IV. Estimation and Results

Models M_1 and M_2 were estimated using quarterly data on manufacturing exports for the United States, Japan, and Germany over the period 1975-93.[1] The estimation results are reported in Table 1 and can be summarized as follows:[2]

1. Exchange Rate Pass-Through

The coefficients of Δe_t and e_{t-1} (the error correction term) represent, respectively, the short-run (or impact) and long-run elasticities of local currency export prices with respect to the exchange rate. The numerical sizes of these coefficients, therefore, indicate the extent to which local currency export prices adjust to the exchange rate. The results suggest that firms in the United States pass on exchange rate changes entirely to their international prices: the coefficient of the exchange rate is not significant in the short or in the long run, indicating that local currency export prices are not influenced by the movement in the exchange rate. In

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[1]Data sources for manufacturing exports, export unit prices, and industrial countries' GDP and prices are the OECD. The latter two variables were aggregated using the *World Economic Outlook* PPP weights. The exchange rate data is from the *World Economic Outlook* database. All estimations are done by maximum-likelihood Gauss version 3.00.

[2]Attempting to estimate both λ and the variance of e_{ci} was unsuccessful so the latter was set equal to the variance of Δe_t and only the former was estimated freely.

Table 1. Maximum-Likelihood Estimates of the Parameters of the Export Models[1]

	United States (1975Q3-1993Q3)		Germany (1975Q3-1992Q2)		Japan (1975Q3-1993Q3)	
	M_1	M_2	M_1	M_2	M_1	M_2
Supply						
$\Delta p_{s,t-1}$	-0.04 (-0.33)	-0.02 (-0.019)	0.07 (0.55)	0.02 (0.15)	0.10 (1.25)	0.10 (1.19)
Δx_t	-0.04 (-1.33)	-0.00 (-2.10)	-0.10 (-2.30)	-0.00 (-4.05)	-2.33 (-2.52)	-0.17 (-3.39)
Δc_t	0.22 (2.41)	0.23 (2.59)	-0.06 (-0.85)	-0.04 (-0.56)	-0.08 (-0.89)	-0.07 (-0.82)
Δe_t	-0.01 (-0.38)	-0.01 (-0.38)	-0.17 (-2.31)	-0.18 (-2.55)	-0.46 (-8.66)	-0.47 (-9.03)
$\hat{\delta}_1$	-0.06 (-1.42)	-0.07 (-1.60)	-0.07 (-1.23)	-0.06 (-1.20)	-0.16 (-2.67)	-0.15 (-2.62)
x_{t-1}	-0.48 (-1.39)	-0.38 (-1.54)	-0.24 (-0.68)	-0.13 (-0.40)	-0.16 (-0.73)	-0.13 (-0.61)
c_{t-1}	0.45 (0.92)	0.60 (1.55)	-2.49 (-1.16)	-2.40 (-1.13)	-0.48 (-1.08)	-0.42 (-0.97)
e_{t-1}	-0.55 (-1.28)	-0.45 (-1.43)	0.66 (0.77)	0.46 (0.57)	-0.67 (-6.28)	-0.67 (-6.23)
$\hat{\lambda}$		0.01 (1.91)		0.00 (0.00)		0.10 (49.18)
$\hat{\sigma}_{u1}$	0.01	0.01	0.01	0.01	0.02	0.02
Demand						
Δx_{t-1}	-0.06 (-0.62)	-0.06 (-0.62)	-0.14 (-1.29)	-0.14 (-1.29)	0.01 (0.10)	0.01 (0.10)
Δp_{dt}	0.11 (1.13)	0.10 (1.11)	0.49 (2.06)	0.50 (2.33)	-0.13 (-0.88)	-0.15 (-1.12)
Δy_t	0.34 (1.54)	0.34 (1.52)	2.00 (3.32)	2.00 (3.32)	0.45 (0.76)	0.46 (0.78)
$\hat{\delta}_2$	-0.22 (-5.62)	-0.22 (-5.62)	0.42 (-3.95)	-0.42 (-4.07)	-0.09 (-2.30)	-0.09 (-2.30)
$p_{d,t-1}$	-0.89 (-7.84)	-0.89 (-7.84)	-0.66 (-2.04)	-0.66 (-2.08)	-2.14 (-1.75)	-2.19 (-1.78)
y_{t-1}	1.32 (8.59)	1.32 (8.58)	1.40 (18.85)	1.40 (19.16)	0.99 (2.03)	0.98 (2.00)
$\hat{\sigma}_{u2}$	0.03	0.03	0.03	0.03	0.03	0.03
ℓ	408.87	410.14	371.61	376.75	354.84	356.94

1/ M_1 refers to equations (4)-(5), and M_2 to (15)-(17) in the text. The dependent variables in the supply and demand equations are respectively the rate of change in local currency export prices, Δp_{st}, and the rate of change in export volumes, Δx_t; t-ratios are in parenthesis, and ℓ is the maximized value of the joint likelihood function. Other notation is as in the text.

Germany, prices respond to exchange rate movements in the short run but not in the long run. Japanese exporters, by contrast, appear to offset a large part of exchange rate fluctuations by adjusting local currency export prices, 67 percent in the long run and 46 percent in the short run, thus protecting their market shares.[1] Hence, hysteresis in the form of limited exchange rate pass-through appears to be present in the case of Japan, and to some degree Germany, but not in the case of the U.S.

2. Domestic Factors and Supply Elasticities

In the long run, prices do not seem to respond to supply. The coefficients on the export volume variable in the supply equation (price equation) are not significantly different from zero in any of the three countries. In the short run, export volumes have significant coefficients in the case of Germany and Japan, but with the wrong sign. Domestic cost conditions seem to affect prices only in the case of the United States, and only in the short run.

3. Hysteresis and Discontinuous Adjustment

Japan seems to be the only country where hysteresis in the form of regime-switches plays a role since the estimates of the hysteresis band and the coefficient of Δx_t are both significant. In Japan, therefore, not only is there a significant response of prices in local currency to exchange rate changes (i.e. hysteresis in the form of limited pass-through), there is also evidence of hysteresis in the form of regime switches. Furthermore, the results appear to suggest a hysteresis band of around 10 percent of the change in the exchange rate within a quarter. This suggests that only fluctuations of larger than 10 percent trigger exit or entry of Japanese firms from export markets.[2]

4. Demand Functions Estimates

The results suggest that demand for Japanese manufacturing exports is less responsive to prices and income than demand for the U.S. and German exports. Both variables have insignificant coefficients in the short run in the case of Japan. The long-run income elasticity for Japanese exports is significant and has a coefficient of almost unity, which seems in line with the existing estimates. For the United States and Germany, the estimated income elasticities are similar and significantly different from zero (1.32 and 1.40 in the long run), while the price elasticity is significant in the long run in the United States but not in Germany.

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[1]Giovannetti (1994) reports some empirical evidence on falling profits for Japanese firms and constant profits for US firms over the period 1985-89. See also Ohno (1990) and Dixit (1994).

[2]Note, of course, that the presence of non-linearities in Japanese export volume, although consistent with the hypothesis of hysteresis, could also have other causes.

In summary, the differences in the three countries, in particular between the United States and Japan, is striking. In the United States, there is no evidence of hysteresis either in the form of limited pass-through or of regime switches. U.S. firms pass exchange rate changes on to foreign currency export prices and are not characterized by the presence of a hysteresis band. Prices and quantities, furthermore, do not appear to be simultaneously determined (in the demand equation prices are significant only in the long run while in the price equation quantity is never significantly different from zero). In Japan there is evidence of hysteresis in both forms and the estimated hysteresis band is around 10 percent. Hence, Japanese firms appear to protect their market shares both by maintaining export prices independent of movements in the exchange rate, and by showing hysteresis in supply decisions. In Germany, there is evidence of limited pass-through in the short run, but not in the long run and no evidence of a hysteresis band.

V. Conclusions

In this paper we have tested for the presence of hysteresis in trade by looking at the behavior of aggregate exports when individual firms face sunk costs and may behave discontinuously. A novel implication of this approach, pioneered by Dixit (1989a), is that aggregate behavior reflects the history of the variable that drives the adjustment at the micro level (in our case the exchange rate) as well as its current value. When there is an exchange rate shock, different firms respond differently depending on their particular history, and depending on their entry and exit costs. They can enter or exit a new market or maintain the status quo. This has important implications for the macroeconomic aggregate export function. While this is determined by individual firms' behavior, it also depends on the number of firms entering/exiting a market and on the probability distribution of the thresholds. Hence, the estimated parameters of a traditional aggregate export function that do not take account of these factors may be unstable, since the estimated elasticities will be conditional on the history of the exchange rate. Moreover, persistence is not only, or not always, a question of unit roots, but also a result of discontinuous adjustment by optimizing firms.

Our empirical estimates for the United States, Japan, and Germany suggest that, in line with some existing descriptive analyses, only in Japan there is evidence of both pricing-to-market behavior and hysteresis. In the terminology used in the paper, there is evidence of hysteresis both in the form of limited exchange pass-though and discontinuous adjustment to exchange rate shocks. Obvious extensions of the analysis presented in the paper include the introduction of expectations formation, allowing the width of the band to vary over time, considering the influence of different processes driving the exchange rates, and incorporating other driving variables.

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