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THE EFFECT OF EXCHANGE RATE UNCERTAINTY ON THE PRICES AND VOLUME OF INTERNATIONAL TRADE

by

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I. Introduction

Since the floating of exchange rates in the Spring of 1973 there has been a considerable increase in the variation of bilateral exchange rates. For example, the dollar-mark rate has fluctuated by as much as 20 per cent within periods of several months or less. Such fluctuations raise important questions about how much the risks associated with international transactions have increased and what impact the increase in risk has had on those transactions.

In this paper we analyze the impact of exchange rate fluctuations on U.S. and German trade with each other and with other major industrial countries. We assume in our model that the only source of uncertainty for international traders is fluctuations in their future receipts or payments caused by variations in the future exchange rate, and we then determine what direct impact, if any, such uncertainty has had on the volume and prices of trade. To the extent that there are other sources of uncertainty in international markets that are to some degree offset by exchange rate fluctuations, our model overstates the effects of exchange rate uncertainty on international trade.1/ Finally, we address only the narrow question of the impact of uncertainty on trade and do not consider its broader welfare and policy implications.

Our theoretical structure is a model of the market for international trade, with the import demand and export supply sides of the market each specified explicitly. Importers and exporters are treated as utility maximizing firms who may bear foreign exchange risk. As such, our approach is distinguished from previous analyses of the effect of exchange uncertainty on trade (e.g., Clark (1973) and and Ethier (1973)) which considered only one side of the market, analyzed the effect only on the volume of trade,[2/] and did not allow for differences in risk aversion or risk bearing between importers and exporters. In our model the risk preferences of both importers and exporters, the proportion of risk born by each side of the market, and the proportion of forward hedging are instrumental in determining the impact of exchange rate uncertainty on the prices as well as the volume of trade. Moreover, we find that whereas exchange uncertainty should unambiguously lead to a reduction in the volume of trade, it can lead to either an increase or a decrease in the export price depending upon whether the exporter or the importer bears the greater burden of exchange risk.

Since the nature of our subject is empirical, we specify a model that is empirically estimable. While there has been considerable theoretical work in this area,[3/] very little empirical analysis has been undertaken. Clark and Haulk (1972) investigated the effects of exchange rate fluctuations on the volume of Canadian trade during the 1950's Canadian dollar float (finding no significant impact), and Makin

(1976) investigated the same question for multilateral import volumes of four major countries during the 1960's and early 1970's, using the variance in their bilateral dollar exchange rates as a proxy for exchange uncertainty (also finding negligible impact). In this paper we test for the effects of exchange uncertainty on U.S. and German multilateral and bilateral trade flows during a period that includes the exchange rate volatility of the 1970's.

In Section II we present the theoretical structure of the model and analyze the effects of exchange uncertainty on the price and volume of trade. Section III outlines the data and estimation procedure, and Sections IV and V present the results of our empirical tests and our summary and conclusions.

II. The Model

This section presents a model of market equilibrium for traded goods that includes both import demand and export supply. The demand and supply functions are derived for individual firms. These functions are then aggregated to derive market demand and supply in order to obtain reduced-form equations for market equilibrium price and quantity. Initially we assume that the proportions of the importer's and exporter's foreign exchange credits or debits hedged in the forward exchange market are invariant to the degree of risk associated with foreign exchange exposure. We also assume that contracts are invoiced only in the importer's and exporter's currencies. These assumptions are relaxed in Appendix A to allow for variance in hedging and for third-currency contracts are shown not to alter the reduced form of the model.

Import Demand

The demand for imports is a derived demand schedule, where imports are treated as inputs into the domestic production function.[4/] The importer is a firm facing a domestic demand schedule for its output (Q) which is an increasing function of domestic money income (Y) and the price of other goods in the domestic economy (PD), and a decreasing function of the price (P) and nonprice rationing (CU) of its own output:

$$Q = aP + bPD + cY + dCU \qquad (1)$$

where CU behaves as a price variable: as demand pressure and capacity utilization increase during cyclical upswings, available supply is rationed through such techniques as longer order-delivery lags and tighter customer credit conditions, thereby depressing demand.[5/]

We assume fixed input-output coefficients so that import demand is determined by the level of domestic output. To simplify the analysis we also assume a two-period framework: in the first period the firm receives orders for its domestic output and places orders for its imported inputs, and in the second period it receives and pays for the imported input and ships and is paid for its own output. Alternatively the firm could meet current domestic demand by running down its inventories of the imported input and replenishing its inventories in the next period. In either case the firm sets the level of its output so as to maximize its utility, which is an increasing function of its expected profits and a decreasing function of the standard deviation of those profits: 6/

$$\underset{Q}{\text{Maximize}} \qquad U = E\,\pi - \gamma\,(V(\pi))^{1/2} \qquad (2)$$

where E is the expected value operator, U is total utility, V is the variance operator, and γ is the relative measure of risk preference.

Assuming constant input-output coefficients, the importer's profits are:

$$\pi = Q\,P(Q) - UC \cdot Q - HP^{*}\,i\,Q \qquad (3)$$

where UC is the unit cost (unit labor plus unit material costs of production), P* is the foreign currency price of imports, i is the fixed ratio of imports to total output ($q = iQ$, where q is the quantity of imports needed to produce Q), and H is a weighted average of the cost of foreign exchange to the importer. H then depends on the currency in which the import contract is invoiced and the extent to which the contract is hedged in the forward market:

$$H = \beta(\alpha F + (1-\alpha)R_1) + (1-\beta)R \qquad (4)$$

We assume that on the date that the contract is made, some proportion β of the imports is denominated in the exporter's currency while some proportion $(1-\beta)$ is denominated in the importer's currency. 8/ The proportion denominated in the importer's currency costs $(1-\beta)\,RP^{*}\,q$ (in terms of importer's currency), where R is the current exchange rate in terms of the importer's currency per unit of the exporter's currency. 9/ Of the proportion denominated in foreign currency (β), the importer is assumed to hedge some constant proportion (α) in the forward exchange market at the forward exchange rate F, at a total cost of $\beta\alpha \; FP^*q$.[10/] The proportion of imports denominated in foreign exchange and not hedged in the forward market then costs $\beta(1-\alpha)R_1P^*q$, where R_1 is the spot exchange rate prevailing on the (future) date of payment. HP*iQ is then the total cost of imports. This cost would be known with certainty if: 1) all imports were denominated in the importer's currency ($\beta = 0$), or 2) all imports denominated in the exporter's currency were hedged in the forward market ($\alpha = 1$).

Uncertainty is introduced into the transaction on the importer's side when part of the contract is invoiced in the exporter's currency and when, whether for institutional reasons and/or by choice, not all of the importer's foreign currency obligation is covered forward. All variables except R_1 are assumed known with certainty on the contract date, and we assume that cov $(R_1, P) = 0$. Therefore, the variance in the importing firm's profits is:

$$V(\pi) = [P^*iQ \; \beta(1-\alpha)]^2\sigma^2_{R_1} \qquad (5)$$

where $\sigma^2_{R_1}$ is the variance of R_1.[11/]

With the elements of the firm's utility function (2) now defined, the firm's output and import demand can be determined from the first-order conditions. Substituting for $\frac{\partial P}{\partial Q}$ from (1), for π from (3), and for $V(\pi)$ from (5), assuming that the importer is a price taker in the import market, and differentiating (2) with respect to the control variable Q yields the first-order condition:

$$[\frac{Q}{a} + P - UC - P^{*}i\,(EH + \gamma\,\delta\,\sigma_{R_1})] = 0, \quad (6)$$

where $\delta = \beta(1-\alpha)$ (7)

Substituting for P from (1) and q/i for Q into (6), and solving for q yields the import demand function for an individual firm:

$$q = \frac{i}{2}(a\,UC + bPD + cY + dCU) + \frac{ai^2}{2}\,P^{*}(EH + \gamma\,\delta\,\sigma_{R_1}) \quad (8)$$

Export Supply

The exporter is assumed to sell some proportion (β) of his total output (q^*) at P^*, and some proportion ($1-\beta$) at RP^* denominated in the importers' currency, facing a known downward sloping market demand curve aggregated over n identical competitive importers' demand functions: 12/

$$q^* = nq = \frac{ni}{2}(aUC + bPD + cY + dCU) + \frac{nai^2}{2}\,P^{*}(EH + \gamma \cdot \delta\,\sigma_{R_1}) \quad (8)'$$

We assume that the exporter maximizes his utility, which is an increasing function of expected profits (π^*) and a decreasing function of the standard deviation of profits:

$$\underset{q^*}{\text{Maximize}} \quad U^* = E\pi^* - \gamma^*(V(\pi^*))^{1/2} \quad (9)$$

where γ^* is a measure of the exporter's relative aversion to risk.

The exporter's profit function is analogous to the importer's, except that the exporter is assumed not to use imported inputs in production:

$$\pi^* = q^*\,P^*\,H^* - q^*\,UC^* \quad (10)$$

where UC* is the exporter's domestic unit cost of production, and H* is defined:

$$H^* = \beta + (1-\beta)R\left(\frac{\alpha^*}{F} + \frac{(1-\alpha^*)}{R_1}\right) \qquad (11)$$

This expression (H*) represents the adjustment to the exporter's own-currency receipts due to: a) the effect on his uncovered position of changes in the spot exchange rate during the contract period, and b) the cost of hedging, as measured by the difference between the current spot and forward rates.13/

The exporter is assumed to hedge a constant proportion α^* of his foreign exchange exposure by selling forward exchange at the rate F. The remaining portion must be converted to local currency at the spot exchange rate (R_1) prevailing on the date of payment.

With all variables except R_1 known with certainty on the contract date, the variance in the exporter's profits is:

$$V(\pi^*) = [P^* q^*(1-\beta)(1-\alpha^*)R]^2 \sigma^2_{1/R_1} \qquad (12)$$

where σ^2_{1/R_1} is the variance of the exchange rate $1/R_1$.

The exporter's quantity supplied is derived by substituting for π^* from (10), for $V(\pi^*)$ from (12), and differentiating (9) with respect to the quantity of output q*, to obtain the first-order condition:

$$[(EH^* - \gamma^* \delta^* \sigma_{1/R_1})(P^* + q^* \frac{\partial P^*}{\partial q^*}) - UC^*] = 0 \qquad (13)$$

where $$\delta^* = (1-\beta)(1-\alpha^*) R \qquad (14)$$

Solving (13) for q* we have the utility maximizing level of output:

$$q^* = (1/\frac{\partial P^*}{\partial q^*})\left(\frac{UC^*}{EH^* - \gamma^* \delta^* \sigma_{1/R_1}} - P^*\right) \qquad (15)$$

Market Equilibrium Price and Quantity

Solving the import demand function (8)' for P* and differentiating with respect to q* yields:

$$\partial P^*/\partial q^* = \frac{2}{ai^2 \; n(EH + \gamma \; \delta \; \sigma_{R_1})} \qquad (16)$$

Substituting (16) into (15), and solving (15) and (8)' for P* yields the reduced-form price equation:

$$P^* = \frac{UC^*}{2(EH^* - \gamma^* \; \delta^* \; \sigma_{1/R_1})} - \frac{aUC + bPD + cY + dCU}{2nai(EH + \gamma\delta \; \sigma_{R_1})} \qquad (17)$$

Substituting for P* from (17) into (8)' then yields the reduced-form quantity equation:

$$q^* = \frac{ni}{4}(a \; UC + bPD + cY + dCU) + \frac{nai^2}{4} \; \frac{UC^* \; (EH + \gamma \; \delta \; \sigma_{R_1})}{(EH^* - \gamma^* \delta^* \; \sigma_{1/R_1})} \qquad (18)$$

Equations (17) and (18) reflect the fact that the equilibrium price and quantity are affected by the degree of exchange risk faced by exporters and importers.

Changes in Risk, Risk Preferences, and Contract Currency

We can use the reduced-form equations to analyze the effects of increases in the variance of the exchange rate and changes in tastes for risk-bearing. Using a Taylor-series expansion to approximate σ_{1/R_1} by $\sigma_{R_1} \; R_1^{-2}$, differentiating (17) and (18) with respect to σ_{R_1}, and assuming risk aversion yields:

$$\frac{\partial P^*}{\partial \sigma_{R_1}} = \frac{UC^* \gamma^* \delta^* R_1^{-2})}{2(EH^* - \gamma^* \delta^* \sigma_{R_1} R_1^{-2})^2} + \frac{\gamma\delta(aUC + bPD + cY + dCU)}{2nai(EH + \gamma\delta\sigma_{R_1})^2} \lesseqgtr 0 \tag{19}$$

$$\frac{\partial q^*}{\partial \sigma_{R_1}} = \left(\frac{nai^2 UC^*}{4(EH^* - \gamma^*\delta^* R_1^{-2} \sigma_{R_1})}\right)\left(\gamma\delta + \frac{(EH + \gamma\delta\sigma_{R_1})\gamma^*\delta^* R_1^{-2}}{EH^* - \gamma^*\delta^* R_1^{-2}\sigma_{R_1}}\right) < 0 \tag{20}$$

That is, if exporters and importers are risk averse ($\gamma, \gamma^* > 0$), an increase in exchange rate variability will reduce the volume of trade and have an ambiguous effect on price. The first term on the right hand side of (19) implies that if risk-averse exporters' preferences dominate, increases in exchange variability will induce a price increase, whereas the export price will fall with increased variability if risk-averse importers' preferences dominate. With risk-neutrality ($\gamma, \gamma^* = 0$) there is no effect on either q^* or P^*, and in the case of risk-loving importers and exporters, $\frac{\partial q^*}{\partial \sigma_{R_1}} > 0$. Note that the more elastic is the demand for the importers' output (i.e., the larger is a) the more elastic is the importers' demand for tradable goods and the greater is the impact of exchange risk on quantity and the lesser on price. Alternatively, the more inelastic is the demand for tradables the greater will be the effect of exchange risk on price and the lesser on quantity.

Differentiating (17) and (18) with respect to the importers' and exporters' risk preferences reinforces these results:

$$\frac{\partial P^*}{\partial \gamma} = \left(\frac{(a\,UC + bPD + cY + dCU)}{2nai\,(EH + \gamma\delta\,\sigma_{R_1})^2}\right)\sigma_{R_1} < 0 \tag{21}$$

$$\frac{\partial q^*}{\partial \gamma} = \frac{nai^2\,UC^*\delta\,\sigma_{R_1}}{4(EH^* - \gamma^*\delta^*\,\sigma_{1/R_1})} < 0 \tag{22}$$

$$\frac{\partial P^*}{\partial \gamma^*} = \frac{UC^*\;\delta^*\;\sigma_{1/R_1}}{2(EH^* - \gamma^*\delta^*\,\sigma_{1/R_1})^2} > 0 \tag{23}$$

$$\frac{\partial q^*}{\partial \gamma^*} = \frac{nai^2\;UC^*\;(EH + \gamma\delta\;\sigma_{R_1})}{4(EH^* - \gamma^*\delta^*\,\sigma_{1/R_1})^2}\,(\delta^*\,\sigma_{1/R_1}) < 0 \tag{24}$$

That is, increased risk aversion places two distinct and opposing forces on the price. The more risk averse are the importers the less imports they will buy, decreasing demand and shifting the foreign currency price downward. Similarly, increased risk aversion on the part of exporters will cause them to reduce their supply and charge a higher price as a risk premium. On the other hand, increased risk aversion on the part of either importers or exporters will reduce the volume of trade.

III. Estimation Procedures and Data

In this section, we present the general form of the estimation equations and define the variables and data employed. The reduced-form price and volume equations are specified explicitly in complex nonlinear functional forms, requiring nonlinear estimation techniques. In addition, we have estimated linear approximations to these equations. The nonlinear estimation forms of the price and quantity equations are written explicitly:

$$P^* = \frac{a_1 \; UC^*}{EH^* + a_2 \; \delta^* \; \sigma_{1/R_1}} + \frac{a_3 UC + a_4 PD + a_5 Y + a_6 CU}{EH + a_7 \; \delta \; \sigma_{R_1}} \tag{17}$$

$$q^* = b_1 \; UC + b_2 PD + b_3 \; Y + b_4 CU + \frac{b_5 \; UC^* \; (EH + b_6 \; \delta \; \sigma_{R_1})}{EH^* + b_7 \; \delta^* \; \sigma_{1/R_1}} \tag{18}$$

where

$$EH = \beta(\alpha F + (1-\alpha) \; ER_1) + (1-\beta)R \tag{4}$$

$$EH^* = \beta + (1-\beta) \; R(\alpha^*/F + (1-\alpha^*)/ER_1) \tag{11}$$

$$\delta = \beta(1-\alpha) \tag{7}$$

$$\delta^* = (1-\beta)(1-\alpha^*)R \tag{14}$$

Our priors on the coefficients in (17) and (18) for risk averse importers and exporters are:

$a_1 = 1/2 > 0$

$a_2 = - \gamma^* < 0$

$a_3 = -1/2ni < 0$

$a_4 = -b/2nai > 0$

$a_5 = -c/2nai > 0$

$a_6 = -d/2nai < 0$

$a_7 = \gamma > 0$

$b_1 = nai/4 < 0$

$b_2 = nbi/4 > 0$

$b_3 = nci/4 > 0$

$b_4 = ndi/4 < 0$

$b_5 = nai^2/4 < 0$

$b_6 = \gamma > 0$

$b_7 = -\gamma^* < 0$

The system is overidentified, as estimates of the risk aversion factors γ and γ^* can be obtained from a_7 or b_6, and a_2 or b_7 respectively.

The linear approximations used for the reduced-form equations are:

$$P^* = c_0 + c_1 UC^* + c_2 UC + c_3 PD + c_4 Y + c_5 CU + c_6 EH^* + c_7 EH + c_8 \delta^* \sigma_{1/R_1} + c_9 \delta \sigma_{R_1} \quad (25)$$

$$q^* = d_0 + d_1 UC^* + d_2 UC + d_3 PD + d_4 Y + d_5 CU + d_6 EH^* + d_7 EH + d_8 \delta^* \sigma_{1/R_1} + d_9 \delta \sigma_{R_1} \quad (26)$$

where we expect c_1, c_3, c_4, c_8, d_3, d_4 and d_6 to be positive, c_0 and d_0 to be either positive or negative, and all other coefficients to be negative.

Definition of Variables and Data Employed

The data employed for each variable are briefly summarized here; a more detailed description of the data, their sources, and specific weighting procedures is given in the Data Appendix.

P^* = price of exports (imports) in the exporting country's currency. Bilateral export price data are not available, so that data had to be generated by calculating weighted averages of commodity-disaggregated export price data using current commodity-disaggregated bilateral export value shares as weights (see the Data Appendix).

q^* = export quantity, approximated by deflating the dollar value of each export flow by the local currency export price times the dollar value of the exporters' currency.

UC^* = Unit costs of production in the exporting country.

UC = Unit costs of production in the importing country.

(For foreign countries unit labor costs were employed, and for the United States a weighted average of unit labor costs and the price of industrial materials -- using 1967 input-output shares as weights -- was used.)

PD = Domestic price index in the importing country. The GNP deflator was used for the United States while the wholesale price index for manufactured goods was used for all other countries.

Y = Nominal GNP in the importing country.

CU = Manufacturing capacity utilization in the importing country.

F = Forward exchange rate, in importers' currency per unit of exporters' currency. Quarterly averages of end of month 90-day forward rates were used.

R = Spot exchange rate (importers' currency per unit of exporters' currency). Quarterly averages of end-of-month spot rates were used.

ER_1 = Traders' expectations about the value of next period's spot rate. To greatly simplify our empirical analysis we assumed that both importers' and exporters' expectations are realized, so that the next period's actual spot rate could be used in our model.[14]

σ_{R_1}, σ_{1/R_1} = Exchange risk for the importing and exporting firms respectively. Several exchange risk expectations formation hypotheses were tested. We assumed that firms assess the degree of exchange risk in the future on the basis of one of the following: a) the volatility (as measured by the standard deviation over thirteen weekly observations within the quarter) of the current spot exchange rate, b) the volatility of the current forward exchange rate (as suggested by Clark (1973)), and c) the average (over thirteen weeks) absolute difference between the previous forward and the current spot rate (as suggested by Ethier (1973)).

Our "best guesses" for the values of α and α^*, the proportion of hedging by importers and exporters, and β, the proportion of contracts invoiced in the exporters' currency, are listed below. The priors for α and α^* are purely judgemental, while those for β are based on analyses of contract currency denomination by Grassman (1973, 1976) and Magee (1974). These priors provided us with first-round estimates; we also tested the sensitivity of our results to variations in these estimates for selected bilateral trading cases.

Prior Values for α, α^*, and β.

Trade Flows	α	α^*	β
U.S. Exports to Canada	.2	.2	.85
All Other U.S. Exports	.4	.2	.85
U.S. Imports from Canada	.2	.2	.65
U.S. Imports from Japan	.2	.4	.4
All Other U.S. Imports	.2	.4	.65
All Other German Exports & Imports	.4	.4	.7

Dock Strike Adjustment

The U.S. import and export volume equations include an adjustment factor for the effects of dock strike disruptions on trade flows. The dock strike factors, calculated by Isard (1975), are estimates of the deviation of actual U.S. multilateral trade from "normal" trade that would have occurred in the absence of the strikes.

Lag Structures

Our theoretical model is based on a two-period time framework: firms are assumed to place their orders for imports in one period and to receive the goods and make payment in the next. Each equation was estimated with a one-quarter lag on the explanatory variables. We also estimated the equations with no lag on some of the explanatory variables, testing for the possibility that firms anticipate market demand and costs of production one period ahead. We did not test for longer lags for several reasons. First, the focus of our analysis is on the effect of exchange rate uncertainty on trade flows, and obtaining the best possible equation fit in terms of lag structures was of secondary concern. Because we were interested in applying our model empirically to a fairly large number of cases, a detailed search for lengthy distributed lags on each of the explanatory variables for each case was beyond our means. Moreover, recent empirical work on lag structures in international trade suggest that our results may not have been significantly affected by any misspecification involved in working with a one-quarter time horizon.

In a survey of invoices of U.S. imports from Germany and Japan in 1971 and 1973, Magee (1974) found that the average combined transportation and order-delivery lag was about ninety days. Also, Wilson and Takacs (1976) have recently estimated distributed lag structures for the price and exchange rate determinants of multilateral imports and exports for each of six major industrial countries. Their results suggest that while distributed lags on prices and exchange rates average about seven quarters in length, in most cases the current and one-quarter lag coefficients were the largest and in many cases they dominated the rest of the lag structure. Hooper (1976) found the same result after searching extensively for lag patterns on the determinants of U.S. multilateral imports and exports.

IV. Results

Nonlinear Estimation

In a first round of estimation we utilized a nonlinear estimation program package available at the Federal Reserve Board. The results were disappointing and are not reported here because they provided no consistent evidence on the hypotheses we were testing. Coefficients and t-ratios on similar variables across different equations ranged from extremely high to low values, often with the wrong sign, and with no apparent explanation. We concluded that the nonlinear estimation program must be very sensitive to certain statistical difficulties, most importantly collinearity among variables, and decided therefore to concentrate on estimating the linear approximations to the model.

Linear Estimation

In the next round of estimation we estimated the linear reduced-form price and volume equations (25) and (26) for each of sixteen cases involving German and U.S. trade with major industrial countries. The equations were estimated twice, first with a one-quarter lag on all of the explanatory variables, and second with no lag.

The one quarter lag proved generally more significant than no lag in almost all cases, suggesting that there is at least a one quarter order-delivery lag on average (as suggested by Magee (1974)) and that firms do no anticipate the determinants of their supply and demand with perfect foresight.

The linear results were significantly better than those obtained in nonlinear estimation. However, there was fairly strong evidence of collinearity among the various cost, price, and income variables in each equation, and between the importers' and exporters' risk variables. Many of the coefficients on these variables either had the wrong sign or were statistically insignificant, and they fluctuated considerably when related variables were dropped from the equation. Indeed, testing for the relationship between the importers' and exporters' risk variables, we found correlation coefficients ranging from .99 to a low of .96. The effects of multicollinearity made the initial round of linear estimation results difficult to interpret.

In the next round of estimation we dropped from the equations those cost, price, and income variables that had insignificant or wrong-signed coefficients and that we suspected of being a source of multicollinearity. We also dropped the exporters' risk variable from each equation, reasoning that, because of the very high collinearity between the two risk-variables, the importers' risk variable alone would capture in a reduced-form fashion the total effect of exchange risk on the dependent variable.

The resulting estimates for the reduced-form price and quantity equations are presented in Tables 1 and 2 respectively. The left-hand column indicates the particular trade flow, and succeeding columns give the estimation coefficients and t-ratios for each of the explanatory variables (refer to pages 13-15 for definitions of the variables) and the summary statistics for the equations. Thus, the first row in Table 1 lists the estimated equation explaining the price of German exports to France. The summary statistics include the autocorrelation coefficient (presented when it was necessary to use the Cochran-Orcutt technique as a result of evidence of serial correlation in the residual), R^2 corrected for degrees of freedom, and the standard error of the regression.

Income, Price, and Cost Variables

The exporting country's cost variable, UC* and the importing country's income variable, Y, dominated the other variables in both the price and volume equations; they were statistically significant (at a 95% level of confidence) in about three-fourths of the cases. However, we cannot conclude that the importing country's production costs, domestic prices and nonprice rationing were relatively unimportant as much of their explanatory power could have been captured by the two dominant variables as a result of the collinearity among these variables. With respect to the nonprice rationing variable (CU) we have found coefficients with positive as well as negative signs, contrary to our specification that the sign be negative. The theoretical model specified that an increase in the importing firm's nonprice rationing to its domestic customers would depress domestic demand and hence import demand. Unfortunately, we do not have data on importing firms' nonprice rationing, and the proxy used, total manufacturing capacity utilization in the importing country, may represent nonprice rationing on the part of domestic competitors (rather than importers) in which case the expected sign is positive. This alternative hypothesis would seem to apply in most cases as indicated in Tables 1 and 2.

<u>Exchange Rate Variables and Contract Currency Denomination</u>

The importers' weighted average exchange rate, EH, had coefficients with the expected sign in most cases and statistically significant in eleven out of thirty-two cases. At the same time, however, none of the coefficients on the exporters' exchange rate adjustment factor, EH*, were significant and only about half had the expected sign. This result is not altogether surprising in view of Grassman's (1973) findings that trade tends to be invoiced largely in the exporter's currency. As can be seen from equation (11) on page 17, the larger is β (the proportion of contracts invoiced in the exporter's currency), the smaller is the variable part (hence the variance) of EH*, or in other words, the less important are exchange rate considerations to the exporter. Meanwhile, the size of β does not necessarily affect the variance of EH.

We tested these results for their sensitivity to the values selected for β, by reestimating the equations with β alternatively set equal to .95 and .2. With β set at .2, the coefficient on EH* became significant in three cases, but in each case the overall equation fit (as measured by the standard error of the regression) worsened. Meanwhile, EH proved insensitive to changes in β in all cases.

Exchange Risk Variables

As we noted in Section III, several alternative variables were tested as proxies for traders' assessment of future risk in foreign exchange markets. Of the three variables tested, we expected that the average absolute difference between this periods' spot exchange rate and last periods' forward rate would be the best indicator of risk, and our empirical results confirm this expectation.[15/] That variable yielded both more significant coefficients on the risk variable and better overall equation fits than the standard deviation of either the current spot or the current forward rate.

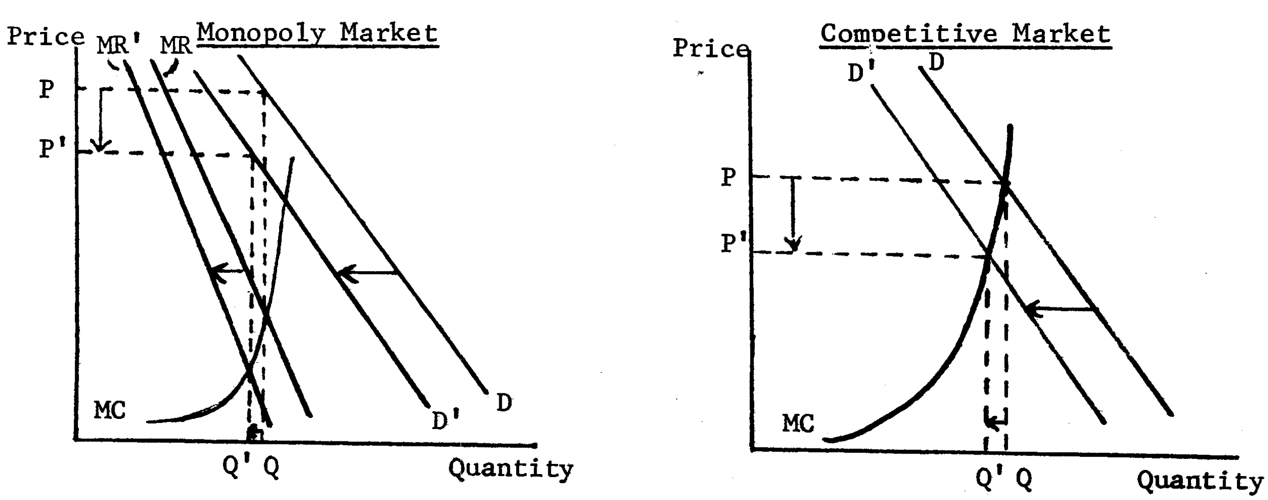
In the price equations for U.S. exports and German exports and imports, this risk proxy had negative coefficients in nine out of eleven cases, and was significantly negative at the 90 per cent level in six cases. This result suggests that the impact of exchange risk was dominant on the importers' side of the market, implying that increased exchange risk depressed import demand and caused a fall in the market price. On the other hand, in four of the five U.S. import cases, risk had a positive impact on price and in two cases statistically significant positive coefficients were obtained. Positive coefficients in those cases support Grassman's (1973) results that U.S. imports tend to be an exception to the rule that trade is denominated in the exporter's currency. Hence, with U.S. imports largely invoiced in dollars, most of the risk is faced by the exporter, and an increase in risk induces a rise in the export price. Magee (1974) on the other hand found that not all U.S. imports are invoiced predominantly in dollars. Notably, he found that while imports from Japan were predominantly dollar denominated those from Germany were largely Mark denominated. These findings are reflected in the risk coefficients obtained in the price equations--in the Japanese case the coefficient is significantly positive, while in the German cases it is negative, though insignificant.

Whereas risk appeared to have a significant impact on the price of traded goods, we found no significant impact on the volume. The impact was negative as expected in half the cases, but it was never significantly negative. We made considerable effort to find a significantly negative impact of exchange risk on trade volume--we tried all three risk variables alternatively, with no lag, with a one quarter lag, and with a two-quarter moving average, lagged and not lagged, and with different values for α, α^*, and β. We also tried estimating volume as a structural import demand equation (equation (8)) in a two-stage procedure using export price fitted in a first-stage reduced form equation. This structural approach was tried with both linear and nonlinear estimation techniques for each of the risk variables, and again, in not a single case did we find a significantly negative impact of exchange risk on the volume of trade.

At first glance the volume equation results may seem at odds with the price equation results--our model suggests that the impact of risk on price is negative through its negative impact on import demand and positive through its effect on export supply, so that in either case we would expect to find some effect on quantity. This apparent discrepancy of a price effect in the absence of a statistically significant quantity effect could be explained by the presence of price-inelastic export supply in the case of a fall in price and inelastic import demand in the case of a price increase.

We illustrate the case of risk-bearing importers facing inelastic supply in both monopolistic and competitive market situations in the two diagrams below. With an inelastic supply (marginal cost) curve, a shift to the left of aggregate import demand (and thus marginal revenue)

Effect of an Increase in Exchange Risk on Risk-Bearing Import Demand and Equilibrium Price



caused by an increase in exchange risk to the importer, will result in a relatively large drop in price and a relatively small drop in quantity. Similarly, if exporters bear the risk and face inelastic demand for their output, an increase in exchange risk will shift their supply downward, and induce a relatively large increase in price and a small decrease in quantity.

V. Summary and Conclusions

We have constructed a theoretical model for analyzing the impact of exchange risk on trade prices and volumes and we have tested it empirically for various U.S. and German trade flow cases for 1965-1975. We have modeled equilibrium in a market for traded goods that includes both export supply and import demand functions, enabling us to analyze the impact of exchange risk on trade prices as well as volumes and to simultaneously consider both importers' and exporters' attitudes toward exchange risk. We found that if traders are risk averse, an increase in exchange risk will unambiguously reduce the volume of trade whether the risk is born by importers or exporters. However, we also found that the effect of an increase in exchange risk on the price of traded goods could be in either direction, depending upon who bears the risk. If importers bear the risk, the price will fall as import demand falls, whereas if exporters bear the risk, the price will rise as exporters charge an increasingly higher risk premium. Finally, we assumed that all determinants of export demand and supply except for next period's exchange rate are known with certainty, so that exchange risk is the only source of risk in the system. If however, other price changes are uncertain and are offset by exchange rate changes, our results have overstated the impact of exchange risk on the system.

In our empirical tests of the model we estimated the reduced-form price and quantity equations for sixteen U.S. and German trade flow cases. Available nonlinear estimation techniques proved too crude to yield meaningful results, forcing us to concentrate on a linear form of the model. We found that exchange risk, as measured by the average absolute weekly difference between the forward and subsequent spot exchange rate over the quarter, had a significantly negative impact on the market price in cases where importers were likely to have faced the bulk of exchange risk. That is, as exchange risk increases, import demand is depressed *ceteris paribus*, and market price is reduced. We also found a significantly positive impact on export price in cases where the exporter was most likely to have born the risk, most notably exports to the United States, implying that these transactions are largely denominated in dollars. However, we found absolutely no significant effect of exchange risk on the volume of trade, despite considerable effort and experimentation with alternative risk proxies and alternative functional forms of the quantity equation.

Appendix A: Extensions of The Model

1. Alternative Hedging Motivations

Our discussion of trade speculation assumed that importers and exporters hedge a constant proportion (α and α^* respectively) of their foreign exchange exposure. This implies traders' activities in the forward market are not at all responsive to changing uncertainties in the foreign exchange market or to the relative cost of forward exchange. Alternatively, we could assume that the proportion of importables denominated in foreign currency that is hedged forward is an increasing function of exchange rate uncertainty and the difference between the expected future spot rate and the current forward rate:

$$\alpha = \alpha_1(ER_1-F) + \alpha_2\,\sigma_R \tag{27}$$

where α_1 and α_2 are normalized so that $0<\alpha<1$ over the relevant sample period.

The weighted average of the importers' exchange rate is then:

$$H' = \beta\,[F(\alpha_1(R_1-F)+\alpha_2\,\sigma_R)+R_1(1-\alpha_1(R_1-F)-\alpha_2\,\sigma_R)]+(1-\beta)R \tag{28}$$

and

$$V(\pi)' = P^{*2}\,q^{*2}\,\beta^2\,\Psi^2 \tag{29}$$

where

$$\Psi^2 = (1+2\alpha_1F-\alpha_2\sigma_R)^2\sigma^2_{R_1}+\alpha_1^2\sigma^2_{R_1^2} - 2\alpha_1(1+2\alpha_1F-\alpha_2\sigma_R)\mathrm{cov}(R_1,R_1^2) \tag{30}$$

Analogously:

$$\alpha^* = \alpha_1^*\,(\frac{1}{F}-\frac{1}{R_1}) + \alpha_2^*\,\sigma_{1/R_1} \tag{31}$$

$$V(\pi^*)' = P^{*2}\,q^{*2}(1-\beta)^2\,R^2\,\Psi^{*2} \tag{32}$$

where

$$\Psi^{*2} = (1-\alpha_2^*\,\sigma_{1/R} - \frac{2\alpha_1^*}{F})^2\,\sigma^2_{1/R_1} + \alpha_1^{*2}\,\sigma^2_{1/R_1^2} + 2\alpha_1^*(1-\alpha_2^*\,\sigma_{1/R} - \frac{2\alpha_1^*}{F})\,\mathrm{cov}(\frac{1}{R_1},\frac{1}{R_1^2}) \tag{33}$$

It follows that in the case where the proportion of risky trade covered is a function of exchange uncertainty and the relative cost of forward exchange, the reduced-form solution to the model becomes:

$$P^* = \frac{UC^*}{2(EH^{*\prime}-\gamma^*\delta^{*\prime})} - \frac{aUC+bPD+cY+dCU}{2nai(EH^{\prime}+\gamma\ \delta^{\prime})} \qquad (17)'$$

$$q^* = \frac{ni}{4}(aUC+bPD+cY+dCU)+\frac{nai^2}{4}\left(\frac{UC^*(EH^{\prime}+\gamma\ \delta^{\prime})}{(EH^{*\prime}-\gamma^*\delta^{*\prime})}\right) \qquad (18)'$$

where $\delta' = \beta\ \Psi$ (33)

$$\delta^{*\prime} = (1-\beta)R\ \Psi^* \qquad (34)$$

Thus, the basic structure of the reduced-form price and quantity equations are unchanged by this specification, except that the weighted-average exchange rate term (H,H*) and the risk variables are much more complicated than in the original model. These terms now include the variances and covariances as well as the levels of the current and the square of the future spot rate.

2. Third Country Currencies

We assumed that international contracts can be denominated only in the currency of either the importer or the exporter. Now we introduce the possibility that some proportion β_3 can be denominated in a third currency, so that the average cost of foreign exchange for the importer becomes:

$$H'' = \beta(\alpha F^{12}+(1-\alpha)R_1^{12}+\beta_3 R^{32}(\alpha_3 F^{13}+(1-\alpha_3)R_1^{13})+(1-\beta-\beta_3)R^{12} \qquad (35)$$

where R^{ij} and F^{ij} are the spot rate and forward rate respectively of the jth currency in terms of the ith currency (where 1, 2, and 3 refer to the importers', exporters', and third country's currencies respectively).

The variance of importers' profits is then:

$$V(\pi)'' = P^{*2} q^{*2}\ \phi^2 \qquad (36)$$

where

$$\phi^2 = \beta^2(1-\alpha)^2\sigma^2_{R_1^{12}} + \beta_3^2(R^{32})^2(1-\alpha_3)^2\sigma^2_{R_1^{13}} + 2\beta\beta_3 R^{32}(1-\alpha)(1-\alpha_3)\mathrm{cov}(R_1^{12},\ R_1^{13}) \qquad (37)$$

Analogously:

$$H^{*''} = \beta + (1-\beta-\beta_3)R^{12}\left(\frac{\alpha^*}{F^{12}} + \frac{(1-\alpha^*)}{R_1^{12}}\right) + \beta_3 R^{32}\left(\frac{\alpha_3^*}{F^{32}} + \frac{(1-\alpha_3^*)}{R_1^{32}}\right) \qquad (38)$$

$$V(\pi^*)'' = P^{*2}\ q^{*2}\ \phi^{*2} \qquad (39)$$

where

$$\phi^{*2} = (1-\beta-\beta_3)^2(R^{12})^2(1-\alpha^*)^2\sigma^2_{1/R_1^{12}} + \beta_3^2(R^{32})^2(1-\alpha_3^*)^2\sigma^2_{1/R_1^{32}} \qquad (40)$$

$$+2\beta_3(1-\beta-\beta_3)(1-\alpha^*)(1-\alpha_3^*)R^{12}\ \mathrm{cov}\left(\frac{1}{R_1^{12}},\ \frac{1}{R_1^{32}}\right)$$

Finally, the reduced-form price and quantity equations become:

$$P^* = \frac{UC^*}{2(EH^{*''} - \phi^*\gamma^*)} - \frac{aUC + bPD + cY + dCU}{2nai(EH'' + \phi\gamma)} \qquad (17)''$$

$$q^* = \frac{ni}{4}(aUC + bPD + cY + dCU) + \frac{nai^2}{4}\ \frac{UC^*(EH'' + \phi\gamma)}{(EH^{*''} - \phi^*\gamma^*)} \qquad (18)''$$

The introduction of a third currency does not alter the basic structure of the reduced-form equations, but it does change the way in which we measure the expected costs and risks associated with foreign exchange. Specifically, the variance of the third currency in terms of each of the other two currencies ($\sigma^2_{R_1^{13}}$, $\sigma^2_{1/R_1^{32}}$) and the covariance of both the importers' and exporters' currencies against each of the other two currencies ($\mathrm{cov}(R_1^{12}, R_1^{13})$, $\mathrm{cov}\left(\frac{1}{R_1^{12}}, \frac{1}{R_1^{32}}\right)$) are now included in the risk variable.

Assuming risk aversion, the greater is the variance of the third currency in terms of the importers' currency the lower will be both the export price and the volume of trade. Analogously, the greater is the variance of the third currency in terms of the exporters' currency the higher will be the export price and the lower will be the volume of trade. The less positively or more negatively correlated are the importers' currency value of both the third currency and the exporters' currency, the lower is the risk to the importer and the higher are both the export price and quantity. Analogously, the more positively or less negatively correlated are the exporters' currency values of the importers' currency and the third currency the higher will be the export price and the lower will be the volume.

Appendix B: Data

In this appendix we describe the construction of bilateral export price indexes and the aggregation of data across countries for the multilateral equations. We also list the sources of the data used in our empirical analysis.

Export Price Data

Since bilateral export price data are not available we had to generate approximations to these data by reweighting available commodity-disaggregated price data. Assuming that each exporter charges the same price (in his own currency) for a given commodity in all markets, an aggregate bilateral price index can be defined:

$$P_{ijt} = \sum_k \frac{x^k_{ijk}}{\sum_k x^k_{ijt}} P^k_{it} \qquad (41)$$

where P_{ijt} = the aggregate price index for country i's exports to country j in period t.

P^k_{it} = the price index of country i's export commodity k in period t

x^k_{ij} = the quantity of commodity k exported from country i to country j in period t.

Thus, P_{ij} is a bilateral quantity-trade-share weighted average of country i's commodity-disaggregated export price indexes.

Since commodity-disaggregated bilateral trade data are not available in quantity terms, equation (41) was approximated using available trade value shares as weights instead of quantity shares. Kresge (1969) has shown that when value or nonimal weights are substituted for quantity or real weights, a harmonic mean weighting procedure should be used instead of an arithmatic mean procedure, so that (41) is rewritten:

$$P_{ijt} = (\sum_k X^k_{ijt}) / \sum_k (X^k_{itt} / P^k_{it}) \qquad (42)$$

where X^k_{ijt} is the value of exports of k from country i to j in period t.

Equation (42) was calculated for each of the fourteen bilateral trade cases. The commodity price data were generally disaggregated into between five and ten major commodity groups, using the End-Use breakdown for U.S. export prices (unit values) and a one to two-digit level SITC breakdown for foreign export prices. The current trade value weights were compiled on a consistent commodity break-down. A detailed description of the commodity classes employed can be obtained from the authors upon request.

The results of the bilateral trade share reweighting of export price indexes are illustrated in Charts 1 and 2 for the U.S. and German cases. In Chart 1 the price of U.S. exports to Japan rose much more sharply in 1972-74 and then dropped off more steeply in 1975 than the price of U.S. exports to Canada. This pattern reflects the relatively larger share of primary commodities in U.S. exports to Japan, the prices of which were much more volatile during this period than the prices of finished goods which dominated U.S. exports to Canada.

Aggregation of Foreign Data

In the U.S. multilateral export and import equations, foreign data were aggregated over the five (four in the case of imports) foreign countries included in the analysis. The aggregation was done with current trade value shares, using the harmonic mean weighting procedure discussed above. Thus, for example the multilateral foreign (f) export price to the United States (us) was calculated as:

$$PX_{f,us} = \sum_i X_{i,us} / \sum_i (X_{i,us}/PX_i), \qquad (43)$$

where $X_{i,us}$ is the value of country i's total exports to the United States.

Data Sources

A complete listing of data sources is given at the end of this appendix. The sources of individual data series are listed in the following table with source numbers corresponding to the list that follows.

Table A1. Data Sources By Variable and Country

Variable:	Canada	France	Germany	Japan	UK	US
	Country and Source Number:[a]					
Export Price (by commodity).....	6	--	11	12, 13	15	3
Export Value						
a) Total Bilateral	22	22	22	22	22	22
b) Bilateral by commodity	20	20	20	20	20	2, 3
GNP Deflator	--	--	--	--	--	1
Wholesale Price Index, manufactures	5	9	10	12	16	--
Wholesale Price Index, industrial materials	--	--	--	--	--	1
Unit labor cost[b]	18	18	10, 18	18	16, 18	21
GNP	7	--	10	14	16	1
Industrial production	--	19	--	--	--	
Manufacturing Capacity Utilization....	24	24	24	24	24	4
Spot Exchange Rate						
a) Monthly	17	17	17	17	17	17
b) Weekly	23	23	23	23	23	23
Forward Exchange Rate						
a) Monthly	17	17	17	17	17	17
b) Weekly	23	23	23	23	23	23

a/ Sources listed on next two pages, numbers correspond to numbers of sources listed.
b/ Where not available, these data were constructed from compensation or wages and salaries per manhour divided by output per manhour.

Statistical Sources

Source No.	United States
1	U.S. Department of Commerce, Survey of Current Business.
2	U.S. Department of Commerce, Highlights of U.S. Export and Import Trade, FT990
3	U.S. Department of Commerce, Bureau of International Commerce, trade tapes.
4	Federal Reserve Board, Federal Reserve Bulletin.
	Canada
5	Dominion Bureau of Statistics, Canadian Statistical Review and Annual Supplement to Section 1.
6	Statistics Canada, Summary of External Trade, Summary of Exports, Trade of Canada: Exports by Commodity
7	Statistics Canada, National Income/Expenditure Statistics
8	Bank of Canada, Bank of Canada Review
	France
9	Institute National de Statistiques et Etudes Economiques, Bulletin Mensuel de Statistique
	Germany
10	Bundesbank, Statistiche Beihefte zu den Monatscherichten der Deutschen Bundesbank, Reihe 4
11	Statistiche Bundesmat Wiesbaden, Wirtschaft und Statistiche
	Japan
12	Bank of Japan, Monthly Economic Statistics
13	Bank of Japan, Price Indexes Annual

Statistical Sources (Continued)

Source No.	Japan
14	Bank of Japan, Basic Data for Economic Analysis, April 1975
15	Central Statistical Office, Monthly Digest of Statistics
16	Central Statistical Office, Economic Trends
	International
17	IMF International Financial Statistics, and IMF taxes.
18	OECD Main Economic Indicators
19	OECD Industrial Production
20	OECD Statistics of Foreign Trade, Series B and C
	Other Sources
21	Federal Reserve Board Macrodata library
22	John Wilson and Wendy Takacs
23	Harris Bank
24	Wharton School

TABLE 1 REDUCED-FORM EXPORT PRICE EQUATIONS--LINEAR APPROXIMATIONS, 1965I - 1975IV

Trade Flow:		Explanatory Variables and Expected Signs of Coefficients (t-ratios in parentheses):											
Exporting Country	Importing Country	Constant (+, -)	UC* (+)	UC (-)	PD (+)	Y (+)	CU (-, +)	EH* (-)	EH (-)	σ_{R_1} (+, -)	ρ	$\bar{R}^2$	SER
Germany	France	48.5 (2.04)	.73 (7.04)	--	.23 (3.40)	.01 (.24)	--	-36.1 (-1.82)	-9.69 (-1.47)	-20.3 (-1.86)	.87 (11.68)	.9961	1.11
Germany	Japan	36.6 (1.13)	.26 (2.31)	--	.20 (2.81)	.002 (4.59)	--	20.1 (.63)	-20.2 (-2.24)	-.49 (-2.78)	.76 (7.50)	.9955	.953
Germany	U.K.	32.5 .83)	.84c (6.45)	-.22c (-2.73)	--	.002c (2.59)	-.31c (-2.51)	16.8 (.54)	-1.29 (-.19)	-201. (-1.20)	.87 (11.44)	.9939	1.17
Germany	USA	2.93 (.86)	.60 (4.07)	--	--	.04 (4.29)	.06 (.53)	-19.6 (-.72)	-10.3 (-1.60)	-40.8 (-.65)	.76 (7.68)	.9921	1.39
Japan	Germany	176. 1.98)	.72 4.30)	-.38 -2.07)	.20 (.68)	--	--	-100. (-1.46)	-29.4 (-1.16)	-11374. (-2.54)	.87 (11.57)	.9803	2.26
U.K.	Germany	83.0 1.80	.87 (9.81)	-.22 (-1.49)	--	.01 (4.32)	--	-67.7 (-1.86)	-32.2 (-2.47)	-5.88 (-1.69)	.96 (23.74)	.9981	1.69
USA	Germany	95.7 (1.63)	1.24 (14.9)	--	--	--	--	-83.8 (-1.53)	-38.9 (-3.04)	-17.5 (-1.90)	.91 (14.16)	.9970	1.87
USA	Canada	-114. (-.48)	.74 (5.70)	--	--	.003 (3.65)	--	91.1 (.40)	25.1 (.97)	-88.6 (-1.63)	.69 (6.23)	.9962	.172
USA	France	250. (3.19)	.90 (6.48)	--	.38 (6.48)	--	--	-249. (-3.23)	-24.6 (-3.65)	2.18 (.35)	.22 (1.47)	.9957	2.02
USA	Japan	180. (1.01)	1.21 (6.17)	--	--	.003 (2.15)	--	-156. (-1.50)	-25.4 (-1.24)	-.21 (-1.58)	.96 (23.23)	.9967	2.10
USA	U.K.	82.3 (1.10)	1.12 (8.65)	--	--	.001 (1.08)	--	-101. (-1.34)	-2.60 (-.23)	62.1 (.95)	.80 (7.81)	.9969	1.70
USA	All (5)	223. (1.58)	.87 (4.40)	--	.45 (2.04)	--	--	-244. (-1.74)	-8.13 (-.44)	-168. (-1.99)	.76 (7.58)	.9977	1.50
Canada	USA	28.9 (.32)	.83 (5.10)	--	.25 (1.86)	--	.22 (2.32)	-29.89 (-.34)	-29.79 (-1.72)	46.6 (.69)	.60 (4.90)	.9958	1.49
Japan	USA	-82.8 (-2.89)	.52 (6.84)	--	--	.03 (3.56)	.33 (3.33)	117. (4.28)	-46.1 (-4.73)	51345. (3.87)	.76 (7.69)	.9913	1.42
U.K.	USA	5.57 (.14)	.80 (10.49)	--	--	.04 (2.87)	--	-17.4 (-.52)	-7.01 (-.67)	11.16 (1.30)	.93 (15.94)	.9980	1.49
All (4)	USA	8.85 (.19)	1.01 (29.11)	--	--	--	.2 (3.86)	-10.1 (-.23)	-23.3 (-2.24)	4301. (2.84)	.82 (9.33)	.9980	.90

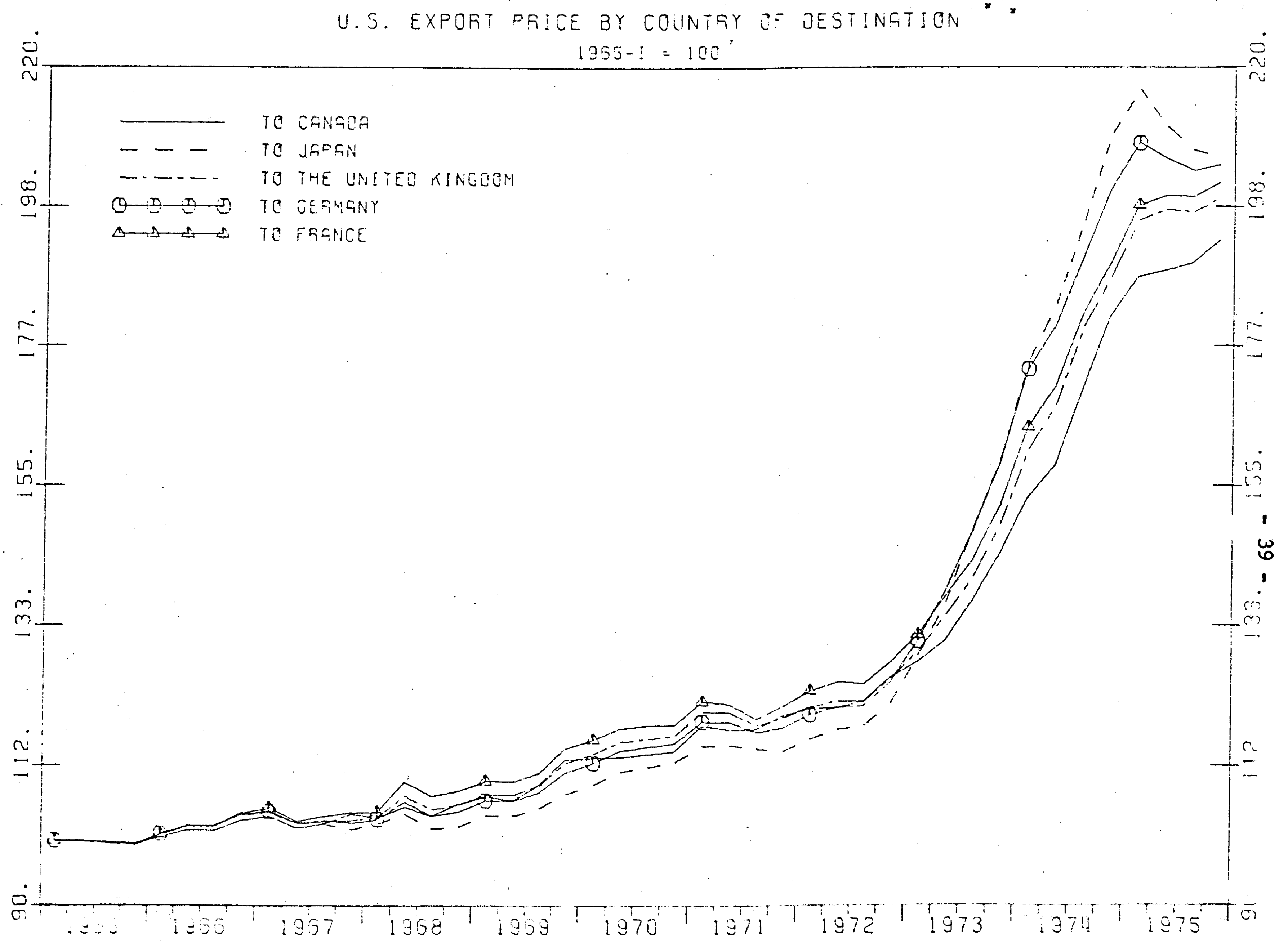
c/ Variable concurrent with dependent variable; all other variables are lagged one quarter.

Table 2 REDUCED-FORM EXPORT VOLUME EQUATIONS--LINEAR APPROXIMATIONS, 1965I - 1975IV

Trade Flow: Exporting Country	Importing Country	Explanatory Vairables and Expected Signs of Coefficients (t-ratios in parentheses): Constant (+, -)	UC* (-)	UC (-)	PD (+)	Y (+)	CU (-, +)	EH* (-)	EH (-)	$E\sigma_R$ (-) 1	Dock Strike	ρ	$\bar{R}^2$	SER
Germany	France	2.99 (.21)	-.12 (-2.40)	--	.02 (.78)	.24 (6.49)	.22 (4.63)	16.6 (1.35)	-1.67 (-.47)	-7.29 (-1.01)	--	.52 (3.94)	.9413	.628
Germany	Japan	1.52 (.46)	-.03 (-2.30)	--	--	.001 (2.29)		1.55 (.47)	.35 (.37)	-.01 (-.76)	--	.90 (13.34)	.9143	.103
Germany	U.K.	-7.37 (-1.09)	--	--	--	.001[c] (1.20)	.50[c] (2.50)	5.38 (.90)	.34 (.24)	9.07 (.29)	--	.93 (16.70)	.9585	.241
Germany	USA	33.8 (2.65)	-.14 (-3.04)	--	--	.02 (5.33)	--	-20.9 (-1.64)	-5.27 (-1.82)	2.82 (.10)	1.03 (3.79)	.61 (4.95)	.8278	.630
Japan	Germany	.14 (.03)	-.01 (-1.94)	--	--	.004 (8.30)	--	-1.63 (-.39)	.28 (.22)	149.7 (.55)	--	.53 (4.05)	.9677	.130
U.K.	Germany	4.95 (1.13)	-.005 (-2.42)	--	--	.001 (2.11)	--	-.17 (-.04)	-2.44 (-4.32)	-.97 (-.03)	--	--	.9466	.156
USA	Germany	-6.83 (-.48)	-.03[c] (-1.43)	--	--	.007 (2.33)	--	7.17 (.55)	1.30 (.42)	.73 (.33)	1.26 (4.42)	.68 (5.99)	.8815	.407
USA	Canada	151. (1.23)	-.24 (-3.67)	--	--	.002 (5.61)	--	-97.8 (-.82)	-26.5 (-2.07)	-39.6 (-1.39)	--	.65 (5.67)	.9709	.889
USA	France	2.94 (.35)	-.01 (-1.42)	--	.02 (2.98)	.03 (6.58)	--	-2.21 (-.26)	-.94 (-1.42)	-.49 (-.68)	1.44 (3.66)	--	.8952	.228
USA	Japan	-27.7 (-.89)	--	--	--	.003 (4.92)	.17 (7.88)	31.8 (1.05)	-13.8 (-4.25)	-.02 (-.44)	.78 (3.43)	.55 (4.25)	.9713	.531
USA	U.K.	-25.8 (-1.28)	.04[c] (1.20)	-.05 (-1.89)	--	.003 (.89)	-.002 (-.45)	28.7 (1.46)	3.05 (1.10)	-31.9 (-1.86)	1.08 (3.98)	.68 (6.03)	.7659	.424
USA	All (5)	-2.73 (-1.48)	-.46[c] (-2.13)	.27 (1.87)	.46 (2.12)	.02 (6.17)	.78 (3.58)	1.91 (1.07)	2.55 (.17)	48.28 (.43)	.57 (3.85)	.30 (2.03)	.9778	1.583
Canada	USA	-82.2 (-1.38)	-.32 (-4.93)	--	--	.05 (7.19)[c]	.08 (1.26)	73.5 (1.30)	13.1 (.78)	-41.3 (-.91)	--	.64 (5.43)	.9776	1.005
Japan	USA	22.1 (1.30)	--	-.16 (-4.31)	--	.02 (2.47)	--	27.0 (2.16)	-20.6 (-4.36)	4425. (.75)	--	.97 (26.05)	.9753	.703
U.K.	USA	19.1 (1.71)	-.04 (-4.08)	-.03 (-1.41)	--	.008 (8.43)	--	-10.4 (-.96)	-3.33 (-2.46)	4.24 (1.42)	.73 (2.36)	--	.8386	.398
All (4)	USA	165. (1.40)	-.49[c] (-2.24)	--	--	.08 (3.17)	--	-114. (-1.01)	-23.0 (-.71)	8276. (2.15)	.22 (1.91)	.93 (16.50)	.9801	2.407

c/ Variable concurrent with dependent variable; all other variables are lagged one quarter.

CHART 1



U.S. EXPORT PRICE BY COUNTRY OF DESTINATION
1965-I = 100
TO CANADA
TO JAPAN
TO THE UNITED KINGDOM
TO GERMANY
TO FRANCE
220.
198.
177.
155.
133.
112.
90.
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975

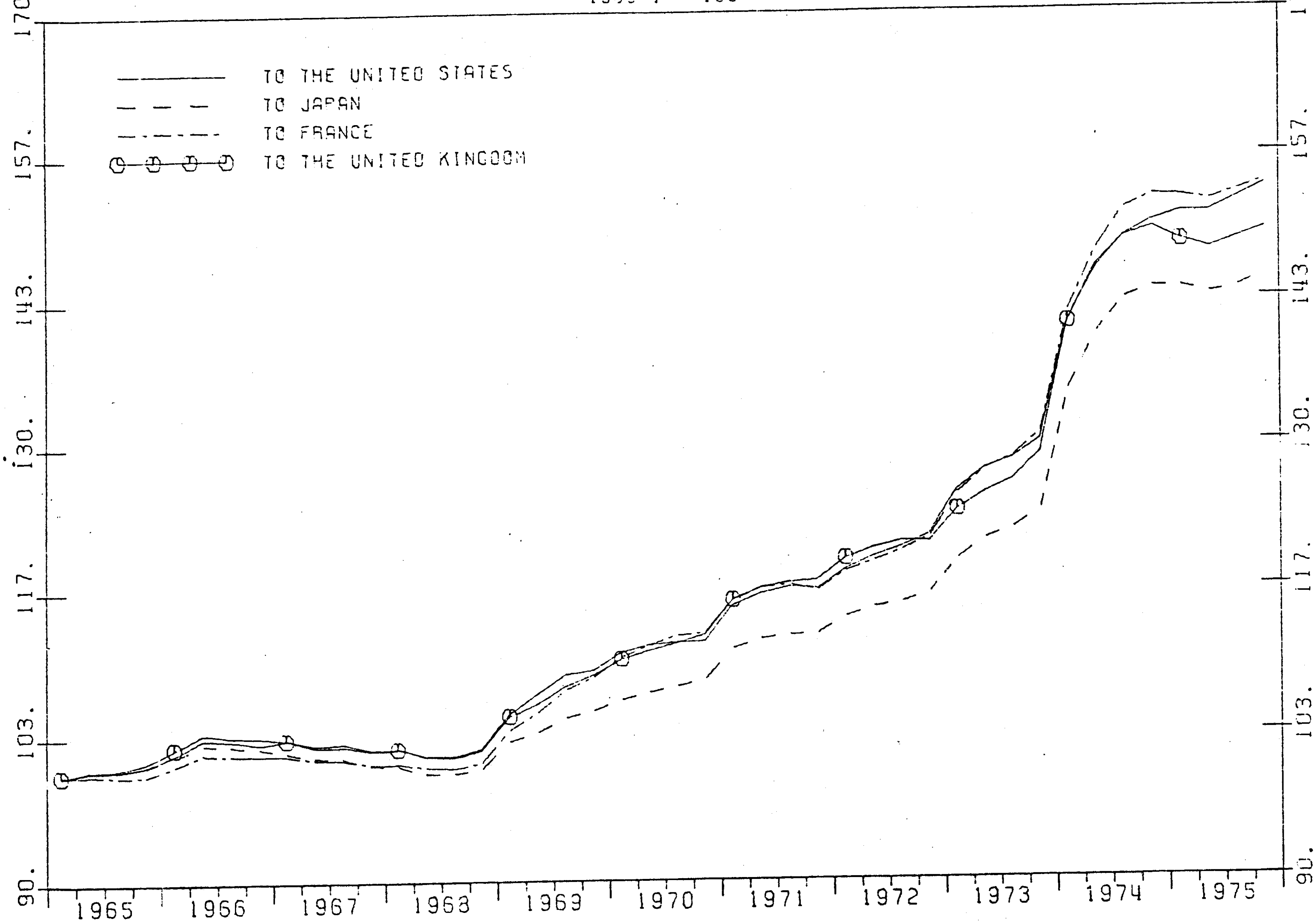
- 39 -

- 66 -

CHART2

GERMAN EXPORT PRICE BY COUNTRY OF DESTINATION

1965-I = 100



Footnotes

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1/ For discussion of the extent to which exchange rate changes are negatively correlated with other price changes, see Clark (1973), Ethier (1973), and Pigott, Sweeney, and Willett (1976).

2/ In a more recent paper Baron (1976) does analyse the effects of exchange rate fluctuations on the export price, but he assumes that prices are set in one period and orders placed and payments made in another, thus leaving importers with no exchange risk. Whereas his results on export prices are similar to ours, his methodology and focus of analysis and the implications of his model concerning the volume of trade are quite different.

3/ See for example, Clark (1973) and Ethier (1973) and Baron (1976) for theoretical analyses of the effect of uncertainty on international trade, and Leland (1972), Sandmo (1971) and Holthausen (1976) for more general analyses of the effect of uncertainty on the theory of the firm.

4/ This specification of import demand differs from the usual treatment of imports as a final demand which ignores the intermediate demand aspects of import determination. In our own treatment, imported goods may range from material inputs to finished goods, where domestic value added may amount to as little as a wholesale or retail distribution service. For simplicity we assume that the importing firm sells all of its output domestically. Analogously, we assume below that the exporting firm sells all of its output abroad.

5/ For a discussion on nonprice rationing and its proxies see Gregory (1971).

6/ This utility function has indifference curves that are linear in mean and standard deviation space which implies that there is not sufficient risk aversion for an interior solution to a simple portfolio problem. This drawback is not relevant in our case since the firm is not faced with the problem of allocating its wealth over a set of risky and riskless assets. More complicated functional forms of utility functions are not without their own undesirable characteristics and do not yield easily interpretable or econometrically estimable reduced-form equations for our problem.

7/ The condition $\gamma>0$ implies risk aversion, $\gamma=0$ risk neutrality, and $\gamma<0$ risk loving.

8/ While it is unlikely that an individual contract will be invoiced in more than one currency, we use this convention for expositional convenience to simplify our later transition from the single-firm, single-contract case to the multi-firm, multi-contract aggregate trade case that we analyze empirically. Magee (1974) and Grassman (1973) have shown that aggregate bilateral imports and exports are denominated in more than one currency.

9/ Note that P* is the price denominated in the exporter's currency while P* R is the price quoted in the importer's currency. An alternative assumption is that the exporter charges P*F or P*(ER_1) when he denominates in the importer's currency. In either case, the specification of H (and H*, δ, and δ* below) is slightly altered, but there are no substantive changes in the analysis.

10/In this paper we treat β and α (and α^* below) as constants rather than as control variables. The choice of invoice currency is probably dependent upon tradition and institutional factors and unlikely to vary much in the short run (Magee (1974) and Grassman (1973, 1976)). Because we assume that risk preferences (γ and γ^* below), and the cost of foreign exchange (R and F) are constant at any point in time, treating α as a control variable would yield the result that the firm should hedge either all or none of its exchange risk depending on whether the expected future spot rate ER_1 is greater or less than the forward rate F. Aggregating over firms and assuming that different firms have different expectations, α would measure the proportion of total imports purchased by firms for whom ER_1 was greater than F, a proportion which in any case could not be identifiable in our empirical work.

11/ As noted earlier, to the extent that exchange rate changes are caused by past domestic price changes or induce domestic price changes in the case where the importers sells his output at an unknown future price, exchange risk will be at least partially offset and the variance of profits will be less than that in (5), and our measure of risk will overstate the effects of foreign exchange risk on international trade. Also note that our treatment of risk assumes that traders have a relatively short term planning horizon (see Clark (1973)), so that all variables except next period's exchange rate are known with certainty. A more general treatment would be to assume uncertainty about all future prices and (spot and forward) exchange rates over all future transactions. This would complicate the structure of our model considerably, but would not alter our conclusions with respect to exchange risk. The degree of impact of exchange risk on trade would then depend upon the covariance of that variable with the other sources of risk.

12/ For expositional simplicity we have assumed that the export supply side of the market consists of one firm with some control over its market price. Relaxing this assumption to allow for more than one firm does not materially affect our results -- so long as each firm has some monopoly power.

13/ If $\beta \neq 1$, H^*-1 will be more positive (negative) the more the forward and future spot rates are greater (less) than the current spot rate.

14/ It is important to note that we do not assume that firms have perfect foresight concerning exchange rates, rather, we assume that their uncertain expectations are realized.

15/ The major advantage of this proxy, compared with the standard deviation of either the spot or the forward rate, is that under fixed exchange rates, it would indicate the market's assessment of exchange risk during the period leading up to a parity change, whereas the standard deviation of the spot exchange rate and possibly the forward rate would not.

Bibliography

Baron, David P., 1976, "Fluctuating Exchange Rates and the Pricing of Exports," Economic Inquiry, September, pp. 425-438.

Clark, Peter B., 1973, "Uncertainty, Exchange Risk, and the Level of International Trade," Western Economic Journal, September, pp. 302-313.

_________, and Charles J. Haulk, 1972, "Flexible Exchange Rates and the Level of Trade: A Preliminary Analysis of the Canadian Experience," unpublished manuscript, Federal Reserve Board.

Ethier, Wilfred, 1973, "International Trade and the Forward Exchange Market," American Economic Review, June, pp. 494-503.

Grassman, Sven, 1973, "A Fundamental Symmetry in International Payment Patterns," Journal of International Economics, May, pp. 105-116.

_________, 1976, "Currency Distribution and Forward Cover in Foreign Trade: Sweden revisited, 1973," Journal of International Economics, May, pp. 215-222.

Gregory, R.G., 1971, "United States Imports and Internal Pressure of Demand: 1948-1968," American Economic Review, March.

Holthausen, Duncan M., 1976, "Input Choices and Uncertain Demand," American Economic Review, March, pp. 94-103.

Hooper, Peter, 1976, "A Quarterly Forecasting Model of U.S. Nonagricultural Export and Nonfuel Import Prices and Volumes, 1956I-1975IV," unpublished manuscript, Federal Reserve Board.

Isard, Peter, 1975, "Dock Strike Adjustment Factors for Major Categories of U.S. Imports and Exports, 1958-1974," February, International Finance Discussion Paper No. 60, Federal Reserve Board.

Kresge, David T., 1969, "Price and Output Conversion: A Modified Approach," in The Brookings Model: Some Further Results (Duesenberry et.al., eds.), Chicago: Rand McNally and Co.

Bibliography (Continued)

Leland, Hayne E., 1972, "Theory of the Firm Facing Uncertain Demand," American Economic Review, June, pp. 278-291.

Magee, Stephen P., 1974, "U.S. Import Prices in the Currency-Contract Period," Brookings Papers on Economic Activity, I, pp. 117-164.

Makin, John H., 1976, "The Impact of Exchange Rate Variability Upon Trade Flows in Four Industrial Countries," in Eurocurrencies and the International Monetary System, American Enterprise Institute, Washington, D.C.

Pigott, Charles, Richard J. Sweeney, and Thomas D. Willett, 1976, "Uncertainty Effects of Exchange Rate Changes," mimeo, U.S. Treasury, February.

Sandmo, Agnar, 1971, "On the Theory of the Competitive Firm Under Price Uncertainty," American Economic Review, March, pp. 65-73.

Wilson, John F. and Wendy E. Takacs, 1976, "Differential Response Lags to Price and Exchange Rate Changes in the Foreign Trade of Selected Industrial Countries," unpublished manuscript, Federal Reserve Board.