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Institut für Weltwirtschaft an der Universität Kiel

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A SUPPLY AND DEMAND MODEL OF BILATERAL TRADE IN A MULTICOUNTRY FRAMEWORK

Abstract

This study develops a practical supply and demand model of bilateral trade flows. The model is constructed in two tiers. First, aggregate import demand and aggregate export supply are determined from aggregate economic relations that contain real income (output) and relative prices. Second, bilateral import demand and bilateral export supply are determined from theory-based allocation relations. By differentiating import prices from export prices, the analysis incorporates international transportation costs and tariffs. The result is a simultaneous system that determines bilateral trade flows and bilateral prices given country incomes, domestic price levels and international transmission factors.

The model in dynamic form is estimated from a panel of bilateral trade flows for five major OECD countries (United States, Japan, France, West Germany, United Kingdom) for the years 1958-1974. The model has many applications, e.g. in the analyses of the impacts on trade flows of differential economic growth rates and tariff policies. These policy aspects figure prominently in the current discussions among the major OECD countries.

A SUPPLY AND DEMAND MODEL OF BILATERAL TRADE IN A MULTICOUNTRY FRAMEWORK

1. Introduction

1.1. Objective. This study develops a supply and demand model of bilateral trade flows. Previous studies have tended to consider only the demand side. We generalize the analysis by incorporating the supply side and international transmission factors. Here "transmission factors" is a generic term that includes transport costs, tariffs, and trade preferences. The analysis provides a practical model for the joint determination of the supply and demand for bilateral trade, in which both bilateral quantities and bilateral prices are endogenous. The model is estimated from a panel of bilateral flows for five major OECD countries (the "Group of Five") over the years 1958-1974.

Policy aspects that figure prominently in the ongoing discussions among major industrial countries include the impact of differential economic growth rates, inflation rates, tariff policies, and exchange rates. Analysis of these aspects calls for a comprehensive model that includes demand, supply, and transmission factors. This call for a comprehensive model appears frequently in the trade literature (e.g. Rhomberg [1973]), but there is the usual caveat that practical difficulties thwart its construction.[1]

The theoretical analysis starts with the specification of bilateral demand and supply equations. In principle, such bilateral equations would contain income and output variables, respectively, together with all relevant bilateral prices. In the presence of transmission factors, export and import prices for identical goods will differ. A bilateral demand and supply system for aggregate trade among n countries would then require consideration of $2n^2$ price variables. Given this enormous number of variables, it seems hopeless to determine bilateral demand and supply in one direct step.

The few studies which have analyzed bilateral trade flows have done so only after introducing strong assumptions whose effect has been to either incorporate demand but disregard important supply factors, or, alternatively, to incorporate supply as well as demand, but disregard the effects of relative price changes on bilateral trade flows. The former studies were limited to the demand side of bilateral trade flows on the assumption that supply is infinitely elastic at the given prices. While this simplifies the analysis to a single demand equation in which prices are predetermined, it is a strong assumption. The second category contains constant-market-share models, which include supply as well as demand elements, but disregard the full effects of relative price changes by virtue of the constant-share assumption.[2] This approach also results in a single-equation model, but again at the cost of a strong assumption that precludes the analysis of many policy questions. The present study pursues the more appealing approach of specifying a complete bilateral demand and supply system in which both bilateral price and quantity are endogenous.[3]

In addition to the mentioned restrictions, the previous studies also abstract from international transmission factors, aside from making the necessary adjustments for c.i.f./f.o.b. differences. This specification omission further reduces the set of trade policy questions that can be addressed. That omission is filled here.

1.2. Demand Analysis. Armington [1969a] presents a theory of demand for individual *products* differentiated by place of production, which can be recast in terms of *import bundles* distinguished by country of origin; cf. Armington [1969b], Hickman [1973] and Hickman and Lau [1973]. Following Armington, the specification of bilateral import demand equations starts with a quantity index of imports for each country of the constant elasticity of substitution (CES) type:

$$(1)\qquad \tilde{m}_j = [\Sigma_{i=1}^{n} a_{ij} x_{ij}^{(\sigma_j-1)/\sigma_j}]^{\sigma_j/(\sigma_j-1)} \qquad (j = 1, 2, \ldots, n)$$

where x_{ij} = quantity of imports into country j from country i,

a_{ij} = aggregation weights,

σ_j = elasticity of substitution between the imports from any two countries in the jth market[4],

n = total number of countries,

$\tilde{m}_j$ = quantity index of the overall level of imports into j ("~" denotes CES aggregation).

The cost minimizing quantities of imports demanded for attaining a given level of $\tilde{m}_j$ are obtained from the allocation relation:

$$(2)\qquad x_{ij} = a_{ij}^{\sigma_j} \tilde{m}_j (p_{ij}/\tilde{p}_j)^{-\sigma_j}$$

in which p_{ij} is the price of imports into j from i (importer's valuation) and

$$(3)\qquad \tilde{p}_j = [\Sigma_{i=1}^{n} a_{ij}^{\sigma_j} p_{ij}^{(1-\sigma_j)}]^{1/(1-\sigma_j)} .$$

The CES price index $\tilde{p}_j$ has the property that its product with the CES quantity index equals the actual total value of the imports.

The essential assumptions leading to this allocation relation are these:

(a) Independence in Demand. The importing country's marginal rate of substitution between import bundles from any two countries is independent of the level of imports from any other country.

(b) Market Shares. Each import market share is unaffected by the size of the import market as long as relative prices in that market remain unchanged.

(c) Constant Elasticities. The elasticities of substitution between import bundles competing in any import market are constants--that is, they do not depend on market shares or price levels.

(d) Equal Elasticities. The elasticity of substitution between any two import bundles competing in any market is the same as that between any other pair of import bundles competing in the same market.

Hickman [1973] and Hickman and Lau [1973] apply Armington's demand theory to practice. Adopting a convenient normalization for the CES aggregation weights, they linearize (2) by a first-order Taylor's series expansion around base period prices. This produces a simple demand equation in which x_{ij} is a linear function of the total quantity of imports into j (assumed predetermined) and the difference between p_{ij} and an observed proxy for $\tilde{p}_j$ in (3). Hickman and Lau estimate dynamic versions of their equation for 27 countries from 1961-1969.

2. The Supply and Demand System

2.1. Prices. It is necessary to distinguish import prices from export prices. Let π_{ij} denote the price of exports from country i to country j (exporter's valuation). The relationship between import and export prices is posed as

$$(4) \quad p_{ij} = \pi_{ij} r_{ij}$$

in which r_{ij} is the transmission factor. The empirical work considers transport costs and tariffs, so that $r_{ij} = 1 + t_{ij} + z_{ij}$, where t_{ij} is the ad valorem transport cost rate and z_{ij} is the ad valorem tariff rate. Export prices π_{ij} and transmission factors r_{ij} will be measured directly, while import prices p_{ij} will be obtained from (4).

2.2. Demand. Following Armington we start with the demand function (2). At this point Hickman and Lau linearize (2), since they seek simply to allocate a predetermined $\tilde{m}_j$ among the n potential exporters. However, this study attempts the more difficult task of explaining jointly the level of aggregate imports $\tilde{m}_j$ and the individual bilateral flows. Following numerous trade studies, we assume that aggregate import demand is determined by

$$(5) \quad \tilde{m}_j = A_j Y_j^{\mu_j} (\tilde{p}_j / P_j)^{\eta_j}$$

where Y_j is the real income of country j, P_j is the price of goods produced in j, A_j is a scale parameter incorporating tastes, and μ_j and η_j are elasticities of demand. Substituting (5) into (2) produces

$$(6) \quad x^d_{ij} = a_{ij}^{\sigma_j} A_j Y_j^{\mu_j} P_j^{-\eta_j} p_{ij}^{-\sigma_j} \tilde{p}_j^{(\eta_j+\sigma_j)}$$

where the superscript "d" denotes demand.

Let $r^0_{ij} = r_{ij}$ for the base period ("0"), adopt the convenient normalization

$$\Sigma^n_{i=1} a_{ij}^{\sigma_j} r_{ij}^{0\,(1-\sigma_j)} \equiv 1,$$

and set all base period *export* prices to unity, i.e. $\pi^0_{ij} = 1$ for all i and j. The base period *import* prices are therefore $p^0_{ij} = r^0_{ij}$. This identifies the base period market share of the ith country as

$$\alpha^0_{ij} = r^0_{ij} x^0_{ij} / m^0_j = a_{ij}^{\sigma_j} r_{ij}^{0\,(1-\sigma_j)}$$

where x^0_{ij} is the quantity of imports into j from i in the base period and $m^0_j = \Sigma^n_{i=1} r^0_{ij} x^0_{ij}$.

Using this base period market share, (6) can be rewritten as

$$x^d_{ij} = (\alpha^0_{ij}/r^0_{ij})A_j Y_j^{\mu_j} P_j^{-\eta_j} p_{ij}^{-\sigma_j} [\Sigma^n_{k=1}\alpha^0_{kj} p_{kj}^{(1-\sigma_j)}]^{(\frac{\eta_j+\sigma_j}{1-\sigma_j})}$$

where $p_{ij} = P_{ij}/P^0_{ij}$ is the current import price relative to the base period import price. Finally, application of a log transformation to both sides of the equation and approximation by a first-order Taylor's series expansion around $p_{ij} = 1$ produces the convenient demand equation

$$(7) \quad ln x^d_{ij} = W^d_{ij} - \sigma_j ln(p_{ij}/\bar{p}_j) + \eta_j ln\bar{p}_j$$

where $W^d_{ij} = ln(\alpha^0_{ij}/r^0_{ij}) + lnA_j + \mu_j lnY_j - \eta_j lnP_j$ contains the predetermined variables and $ln\bar{p}_j = \Sigma^n_{k=1}\alpha^0_{kj} ln p_{kj}$ defines a new price index $\bar{p}_j$ for imports. (See Appendix A for details.) The loglinear specification is common in the empirical trade literature, so that (7) has intuitive appeal and wide potential use.[5]

2.3. Supply. Parallel to the CES framework, we model the supply side in terms of a constant elasticity of transformation (CET) framework. The CET function has been introduced in the context of multiple-output production processes, cf. Powell and Gruen [1968] and Hasenkamp [1976]. It is identical in analytic form to the CES function except that it has a parametric restriction that provides the convexity required for the economic tradeoff among exports. Consider the quantity index of exports for each country of the CET type:

$$\tilde{x}_i = [\Sigma^n_{j=1} b_{ij} x_{ij}^{s(\rho_i - 1)/\rho_i}]^{\rho_i/(\rho_i - 1)} \qquad (i = 1, 2, \ldots, n)$$

where x^s_{ij} = quantity of export supply from country i to country j (superscript "s" denotes supply),

b_{ij} = aggregation weights,

ρ_i = elasticity of transformation between the exports of country i to any two markets[6],

$\tilde{\tilde{x}}_i$ = quantity index of the overall level of exports by country i ("≈" denotes CET aggregation).

As shown in Appendix B, the revenue-maximizing quantities of exports supplied to provide a given level of $\tilde{\tilde{x}}_i$ are obtained from the allocation relation:

(8) $x^s_{ij} = b^{\rho_i}_{ij}\tilde{\tilde{x}}_i(\pi_{ij}/\tilde{\tilde{\pi}}_i)^{-\rho_i}$

in which

$$\tilde{\tilde{\pi}}_i = [\Sigma^n_{i=1} b^{\rho_i}_{ij}\pi^{(1-\rho_i)}_{ij}]^{1/(1-\rho_i)} \quad .$$

The CET price index $\tilde{\tilde{\pi}}_i$ has the property that its product with the CET quantity index equals the actual total value of the exports, cf. Green [1964, p. 25].

This supply hypothesis rests on the following assumptions paralleling those made for the demand side:

(a) Independence in Supply. The exporting country's marginal rate of transformation between export bundles to any two countries is independent of the level of exports to any other country.

(b) Export Shares. Each export supply share is unaffected by the level of the exporting country's total exports as long as relative export prices remain unchanged.

(c) Constant Elasticities. The elasticities of transformation between export bundles of a given exporting country are constants--that is, they do not depend on export supply shares or price levels.

(d) Equal Elasticities. The elasticity of transformation between any two export bundles of a given exporting country is the same as that between any other pair of export bundles supplied by that country.

Equation (2) represents the ex ante allocation of a given country's total imports among its trading partners; equation (8) represents the ex ante allocation of a given country's total exports among its trading partners. While the application of Armington's approach to import demand differentiates trade flows by origin, we differentiate trade flows by destination as well. Both differentiations are relevant when dealing with aggregate import or export bundles, since the commodity composition of trade is distinct for each ordered country pair (i,j). Differentiation by destination would only be questioned if one were dealing with homogeneous commodities, the case of pure microeconomic theory, and if price discrimination were absent.

To explain the level of aggregate exports $\tilde{x}_i$ as well as the individual bilateral flows, we assume that aggregate export supply is determined by

(9) $\tilde{x}_i = B_i Y_i^{\lambda_i}(\tilde{\pi}_i/\Pi_i)^{\epsilon_i}$

where Y_i is the final output of country i (a proxy for export capacity), Π_i is the price of goods sold in i, B_i is a scale parameter incorporating technology, and λ_i and ϵ_i are elasticities of supply. The size of the output elasticity λ_i depends on both the extent to which the export production function exhibits economies or diseconomies of scale and the extent to which the export sector tends to share in total resource growth at constant relative product prices, cf. Van Doorn Ooms [1967, pp. 129-130].

Adopting the convenient normalization rule

$$\Sigma_{j=1}^{n} b_{ij}^{\rho_i} \equiv 1$$

and setting all base period export prices to unity ($\pi_{ij}^0 = 1$) identifies the base period export share to the jth country as

$$\beta_{ij}^0 = x_{ij}^0/x_i^0 = b_{ij}^{\rho_i}$$

where x_{ij}^0 is the quantity of exports from i to j in period 0 and $x_i^0 = \Sigma_{j=1}^{n} x_{ij}^0$.

Using this base period export share, $\tilde{\tilde{x}}_i$ in (9) can be substituted into (8) and then the result rewritten to obtain

$$x^s_{ij} = \beta^0_{ij} B_i Y_i^{\lambda_i} \Pi_i^{-\varepsilon_i} \pi_{ij}^{-\rho_i} [\Sigma^n_{k=1} \beta^0_{ik} \pi_{ik}^{(1-\rho_i)}]^{(\frac{\varepsilon_i+\rho_i}{1-\rho})} .$$

Finally, application of a log transformation to both sides of the equation and approximation by a first-order Taylor's series expansion around $\pi_{ij} = 1$ produces the convenient supply equation

$$(10) \quad ln x^s_{ij} = W^s_{ij} - \rho_i ln(\pi_{ij}/\bar{\pi}_i) + \varepsilon_i ln\bar{\pi}_i$$

where $W^s_{ij} = ln\beta^0_{ij} + lnB_i + \lambda_i lnY_i - \varepsilon_i ln\Pi_i$ contains the predetermined variables and $ln\bar{\pi}_i = \Sigma^n_{k=1}\beta^0_{ik} ln\pi_{ik}$ defines a new price index for exports.

2.4. <u>Summary</u>. The complete demand and supply system is

$$(11a) \quad ln x^d_{ij} = ln(\alpha^0_{ij}/r^0_{ij}) + lnA_j + \mu_j lnY_j + \eta_j ln(\bar{p}_j/P_j) - \sigma_j ln(p_{ij}/\bar{p}_j),$$

$$(11b) \quad ln x^s_{ij} = ln\beta^0_{ij} + lnB_i + \lambda_i lnY_i + \varepsilon_i ln(\bar{\pi}_i/\Pi_i) - \rho_i ln(\pi_{ij}/\bar{\pi}_i),$$

$$(11c) \quad p_{ij} = p_{ij}/r^0_{ij} = \pi_{ij}(r_{ij}/r^0_{ij}),$$

$$(11d) \quad ln\bar{p}_j = \Sigma^n_{k=1}\alpha^0_{kj} lnp_{kj} ,$$

$$(11e) \quad ln\bar{\pi}_i = \Sigma^n_{k=1}\beta^0_{ik} ln\pi_{ik}.$$

On the equilibrium assumption $x^d_{ij} = x^s_{ij} = x^*_{ij}$, the system determines the desired bilateral quantities x^*_{ij} and prices π_{ij} given the country incomes Y_j and Y_i, the domestic price levels P_j and Π_i, the transmission factors r_{ij}, the base period market shares α^0_{ij}, and the base period export shares β^0_{ij}.

The model has been constructed in two tiers. First, aggregate import demand and aggregate export supply are determined from the aggregate economic relations (5) and (9) respectively. These relations explaining total import demand and export supply are basic to the subsequent determinations of bilateral import demand and export supply from the allocation relations (2) and (8) respectively. The two-tiered construction reflects a two-step maximization procedure in which the bilateral demands and supplies have to be consistent with the welfare maximizing total import and export levels. It falls short of a full general equilibrium specification, but it provides a practical model with relatively few unknown parameters, and it integrates previous work on aggregate trade and bilateral trade.[7] To the best of our knowledge, no one has estimated a multicountry supply and demand model of this kind.[8]

3. Empirical Specification

The static supply and demand system (11) determines desired bilateral trade flows. In this section a dynamic specification is proposed to relate actual to desired flows, after which the estimation procedure is described.

3.1. Dynamics. Actual trade flows can depart from desired flows for many reasons, including decision lags, production lags and delivery lags. A flow-adjustment model will be used to approximate these dynamics.[9] Let z^* denote the desired level of some variable, and let z denote the corresponding actual level. The flow-adjustment model assumes the continuous-time relationship:

$$\partial z/\partial \tau = \theta(z^* - z), \quad \theta > 0,$$

where τ denotes time and θ is the coefficient of adjustment. For our import demand relationship z equals $\ln x_{ij}$ (x_{ij} is the actual quantity), $z^* = \ln x^d_{ij}$, and equation (11a) determines the desired demand level. For the export supply relationship z equals $\ln x_{ij}$, $z^* = \ln x^s_{ij}$, and equation (11b) determines the desired supply level.

A full approach to the bilateral trade flow dynamics would specify an individual adjustment coefficient for each country pair. However, given a limited sample size, a less ambitious approach will be taken. For the import demand relationship a single aggregate adjustment coefficient (denoted θ_j) is posited for each importing country j; analogously, for the export supply relationship, a single aggregate adjustment coefficient (denoted ϕ_i) is posited for each exporting country.[10]

One weakness of the flow adjustment model is that it imposes the same lag structure on all the explanatory variables in a given relationship. It is especially bothersome to assume that trade flows respond with the same lag to income (output) changes as to price changes, the usual presumption being that the former lags are shorter. To allow different time responses for income and output, a *decomposition* is employed. The compound income term $[\mu_j^{\ell} ln Y_{j,t-1} + \mu_j^{c}(\Delta ln Y_{j,t})]$ replaces $\mu_j ln Y_{j,t}$ in (11a), where $\Delta ln Y_{j,t} = ln Y_{j,t} - ln Y_{j,t-1}$ is the approximate percentage change in Y_j; and the compound output term $[\lambda_i^{\ell} ln Y_{i,t-1} + \lambda_i^{c} \Delta ln Y_{i,t}]$ replaces $\lambda_i ln Y_{i,t}$ in (11b). The superscript "ℓ" denotes the "level" component, and "c" denotes the "change" component.

Combining the supply and demand system, flow-adjustment dynamics, and income (output) decomposition produces the final model for estimation:

$$
\begin{aligned}
\text{(12a)}\quad \Delta ln x_{ij,t} = {} & d_j ln A_j - d_j[ln x_{ij,t-1} - ln(\alpha_{ij}^{0}/r_{ij}^{0})] \\
& + (1/2)d_j[\mu_j^{\ell}(ln Y_{j,t-1} + ln Y_{j,t-2}) + \mu_j^{c}(\Delta ln Y_{j,t} + \Delta ln Y_{j,t-1}) \\
& + \eta_j(ln(\bar{p}_{j,t}/P_{j,t}) + ln(\bar{p}_{j,t-1}/P_{j,t-1})) \\
& - \sigma_j(ln(p_{ij,t}/\bar{p}_{j,t}) + ln(p_{ij,t-1}/\bar{p}_{j,t-1}))]
\end{aligned}
$$

$$(12b)\ \Delta ln x_{ij,t} = s_i ln B_i - s_i[ln x_{ij,t-1} - ln\beta^0_{ij}] + (1/2)s_i[\lambda^{\ell}_i(lnY_{i,t-1} + lnY_{i,t-2}) + \lambda^c_i(\Delta lnY_{i,t} + \Delta lnY_{i,t-1}) + \varepsilon_i(ln(\bar{\pi}_{i,t}/\Pi_{i,t}) + ln(\bar{\pi}_{i,t-1}/\Pi_{i,t-1})) - \rho_i(ln(\pi_{ij,t}/\bar{\pi}_{i,t}) + ln(\pi_{ij,t-1}/\bar{\pi}_{i,t-1}))],$$

where $d_j = 2\theta_j/(2 + \theta_j)$ and $s_i = 2\phi_i/(2 + \phi_i)$. For a given importer j, (12a) explains the annual percentage change in bilateral imports as a function of a constant, the cumulative percentage change in imports from the base period, and current and lagged incomes and prices.[11] Analogously, for a given exporter i, (12b) explains the percentage change in bilateral exports as a function of a constant, the cumulative percentage change in exports from the base period, and current and lagged outputs and prices.

As shown in Appendix C, the level-change decomposition of income (output) has a useful interpretation. In (12a) μ^{ℓ}_j is the long-run elasticity of import demand with respect to *trend income*, and $(\mu^c_j \cdot d_j)$ is the current impact on import demand of *transitory income*. Here "trend income" is an exponentially weighted moving average of past incomes, and "transitory income" is the difference between current income and trend income.[12] In (12b) λ^{ℓ}_i is the long-run elasticity of export supply with respect to trend output, and $(\lambda^c_i \cdot s_i)$ is the current impact on export supply of transitory output. This trend/transitory decomposition helps to analyze the cyclical behavior of trade.

3.2. Estimation Procedure. For the demand relationship (12a), the parameters for each importing country j are estimated by pooling the data over the four suppliers; this produces 4 x 17 = 68 observations.[13] Further, in pooling the data, three country-shift (dummy) variables are incorporated into the pooled equation. These three variables represent respectively the autonomous shifts in *lnx* associated with three of the supplying countries relative to a fourth country chosen as the base.[14] They are offered as crude proxies for bilateral *structural factors*, i.e. historical and other trade influences not captured in the observed movements of incomes and prices over time. A leading example is the EEC arrangement between France and Germany. Analogously, for the supply relationship (12b), the parameters for each exporting country i are estimated by pooling the data over the four markets, and again three country-shift variables are incorporated. In all there are ten pooled equations to estimate; each contains nine parameters (including the constant and three country-shift terms), and there are 68 observations for each equation.

The equations are each estimated by ordinary least squares (OLS) and instrumental variables (IV). For most parameters, the OLS and IV estimates are alike; Appendix D contains the comparison. Of 90 parameter estimates, in only 12 cases (indicated by an asterisk) does the IV estimate depart from the OLS estimate by a distance greater than one standard error of the OLS estimate.[15] Not surprisingly 7 of the 12 exceptions concern the price variables which are endogenous in the full supply and demand system. Of the 12 exceptions, nine are restricted to but two equations, the French import demand equation and the U.S. export supply equation.[16] For the remaining eight equations, the OLS estimates provide basically the same empirical inferences as the IV estimates do.

While IV estimates are consistent in principle and OLS estimates are not, our IV estimates are suspect because the relevant IV moment matrix turned out to be ill-conditioned in certain cases.[17] To overcome this difficulty with the IV strategy, future empirical work might seek additional bona fide instruments, e.g. input factor costs.[18] In any event doubts about the instrument set, the limited sample size, and the general similarity of the OLS to IV estimates ultimately led us to choose the OLS estimates for discussion in the paper, despite the well-known hazard of "simultaneous equations bias."[19] Recent finite-sample econometric theory provides some support for this choice of OLS in face of a deficient instrument set; cf. Hale, Mariano and Ramage [1978].

4. Empirical Results

The model is estimated for the aggregate bilateral trade among five major OECD countries--United States, Japan, France, West Germany, United Kingdom--for the years 1958 to 1974. The restrictions to aggregate bilateral trade flows, annual data, and only five countries were necessitated by severe problems in constructing bilateral price data. Given these restrictions, the present empirical work is intended only as a first application of the model.

4.1. Data. The demand and supply estimation requires information on bilateral prices. The absence of comprehensive bilateral price data is a formidable obstacle. As Richardson [1976, p. 179] states: "The principal problem in empirical work is the unsatisfactory nature of the data, inadequate even by comparison with other economic data. Most tormenting of all is the woefully unreliable or non-existent data on prices of internationally traded goods." Previous studies usually have assumed that import (export) prices do not differ by origin (destination); e.g. Hickman [1973, p. 29], Moriguchi [1973, p. 405] and Deppler and Ripley [1978, p. 61]. This assumes equality of average and bilateral prices. Because of the differences in the aggregate commodity composition of trade, this assumption has been rejected in the present study. Our alternative procedure is outlined in Appendix E. Briefly, one- and two-digit level export prices are weighted by a country-pair-specific standard commodity bundle to obtain the aggregate export price π_{ij}. Whenever possible, export price indices are employed instead of unit value indices. Finally, import prices are distinguished from export prices by tariffs and transport costs.[20] While this procedure does not produce a fully satisfactory set of bilateral prices, refinement would require an extraordinary data collection effort that was impossible in the present study. In any event the present price indices are proposed as an improvement over the traditional unit value indices.

The starting point for the construction of export and import prices is the bilateral export price π_{ij}. The import price p_{ij} is calculated from (11c), and the average export and import prices ($\bar{\pi}_i$ and $\bar{p}_j$) are then determined from (11d) and (11e). The domestic prices Π_i and P_j are wholesale prices. All price indices employ 1958 as the base year, and all are expressed in U.S. dollars. Trade flows are expressed in 1958 dollars as well. Income and output are Gross Domestic Products expressed in U.S. dollars and deflated by the domestic price index.

4.2. Import Demand Estimates. Table 1 presents the import demand estimates. The separation of trend and cyclical income effects and the inclusion of trade liberalization variables have been proposed by Magee [1975, pp. 188-192] as major ways to test for negative income elasticities (which "pure theory" allows). The present study recognizes both suggestions, but finds only significant positive elasticities on trend income, thereby supporting the usual empirical

Table 1. IMPORT DEMAND ESTIMATES[a, d]

	U.S.	Japan	France	Germany	U.K.
Adjustment Coefficient (θ)	.620 (.181)	1.106 (.291)	.124 (.083)	.116 (.073)	.339 (.151)
Trend-Income Elasticity (μ^{ℓ})	1.521 (.230)	.756 (.081)	1.193 (.552)	2.141 (.881)	2.384 (.356)
Cyclical-Income Effect ($\mu^c \cdot d$)	- .120 (.777)	.889 (.504)	- .553 (.519)	1.957 (.556)	.392 (.577)
Average-Price Elasticity (η)	-1.414 (.848)	- .554 (.484)	1.618 (3.819)	1.359 (2.714)	-1.590 (1.364)
Substitution Elasticity (σ)	1.032 (.320)	.230 (.225)	-2.314 (1.921)	2.771 (2.019)	.216 (.655)
Shift 2	- .456 (.139)	.281 (.078)	1.507 (.827)	1.889 (.843)	.202 (.194)
Shift 3	- .134 (.136)	- .013 (.085)	.350 (.415)	.677 (.429)	- .018 (.198)
Shift 4	- .559 (.120)	.188 (.072)	- .077 (.449)	.253 (.468)	.139 (.184)
Constant	-8.540 (2.063)	-1.453 (.456)	-3.514 (4.263)	-11.573 (6.271)	-12.332 (2.424)
R^2 [b]	.34	.43	.22	.37	.16
DW[c]	2.46	1.82	2.24	2.38	2.21

[a] The numbers in parentheses below the coefficients are the standard errors.

[b] R^2 is the coefficient of determination in fitting $\Delta \ln x$ (i.e. percentage change in exports) rather than $\ln x$, the basic dependent variable. Its meaning is therefore qualified.

[c] DW is the Durbin-Watson statistic. It is not really appropriate in the present pooling context. Here the observation vector is a stack of four different time series (one for each country), and lagged exports appears in the equation. This DW and the R^2 are reported for completeness, despite their limited meaning.

[d] Estimates were obtained by (nonlinear) ordinary least squares.

finding that imports grow with incomes in the long run. Interestingly, there is considerable variation across countries in the size of the trend-income elasticities, ranging from Japan with the low elasticity of .76 to U.K. with the high elasticity of 2.4. These results amplify previous studies, and the implications for the U.K. and Japanese trade balances have been discussed before, cf. Houthakker and Magee [1969].

The results on cyclical (transitory) income are mixed. The effects are positive for three cases and negative for two, and the relative standard errors are usually large. Since the test is limited by aggregation and the use of GDP to measure both trend and cycle, we offer only two tentative observations.[21] First, the wide variations in the cyclical effects across countries caution against uncritical applications of "Keynesian policies" to remedy balance-of-trade problems. Second, a transitory change in GDP has the most pronounced effects on the imports of Japan and Germany. While this has implications for their balance of trade, the implications for other countries are not obvious.

The two price elasticities usually have the expected signs ($\eta < 0$, $\sigma > 0$), but their relatively large standard errors preclude much reliance on these estimates. The average-price elasticity has unexpected signs for two countries (France and Germany), but the coefficients are highly insignificant. Of the three countries with expected signs, the U.K. and the U.S. have the high elasticities; Japan has the low one. The substitution elasticities have the expected signs, with the exception of the French case. A comparison with previous studies (Junz and Rhomberg [1965], Richardson [1972], Hickman and Lau [1973]) indicates that our substitution elasticity estimates are plausible, aside from the French case. However, this is only mild comfort, given the wide range of estimates across the studies.

A joint comparison of average-price and substitution elasticities indicates that U.S. import demand is elastic with respect to both the competition between imports and domestic goods and the competition among alternative suppliers. By contrast, Japanese import demand appears inelastic on both grounds, perhaps due to non-price factors and heavy dependence on imported raw materials and intermediate goods. Generally, the countries exhibit wide variations in price responsivity.

Many empirical studies (e.g. Junz and Rhomberg [1965, p. 242], Armington [1969b, p. 186]) have noted the presence of strong "structural effects" that accompany price and income effects. The coefficients on the three country-shift variables provide a crude measure. In the case of the U.S. import equation, the shift variables indicate the autonomous levels of French (Shift 2), German (Shift 3), and U.K. (Shift 4) exports relative to Japanese exports into the U.S. For the other import equations, the U.S. is the base of comparison instead of Japan. The shifts tend to be highly significant and indicate strong time-invariant effects. It should be noted that these structural effects are not necessarily of non-price origin, since they may reflect persistent comparative advantage from sustained differences in relative cost and price levels, in which case the observed marginal price changes may not affect the trade pattern in a major way.

Japan is a striking example. The strongly negative shift parameters (relative to Japan) in the U.S. import equation and the strongly positive shift parameters for Japan (relative to the U.S.) in the other import equations (Shift 2), which always dominate the shift parameters for other countries, indicate that observed income and price variations leave much of Japan's rapid export growth unexplained. Whether this growth was due to non-price factors, government policies, persistent comparative advantage, or other influences are hypotheses for future research.[22]

The adjustment coefficients vary widely across countries. Japan adjusts very quickly (but recall that the full Japanese response to income and price changes are among the smallest in size); the mean adjustment period is less than a year. For the U.S. and U.K. the mean adjustment periods are also relatively short, one and a half and three years respectively. In contrast for Germany and France, they are a long eight years.

4.3. Export Supply Estimates. Table 2 presents the export supply estimates. The trend-output elasticities of export supply are all positive and significant. In comparing the income and output elasticities for each country, the two are roughly equal for the U.S., France and the U.K., with the U.K. having the largest elasticities. For these countries the greater-than-unity output elasticities indicate "pro-trade-biased growth," cf. Johnson [1967, pp. 67-77] and Ooms [1967, pp. 129-134]. On the other hand, Japan's trend-output elasticity of export supply is nearly double her trend-income elasticity of import demand, which is consistent with her persistent trade surplus. Germany shows the reverse.

Cyclical output effects are mixed and generally insignificant. The U.S. and German export supplies respond negatively to transitory output changes. This result is not paradoxical. It conforms to previous findings (Steuer, Ball, and Eaton [1966], Mintz [1967], and Artus [1973]) which suggest that increases in domestic demand can have a negative effect on exports in certain commodity categories, especially raw materials and intermediate goods.

Table 2. EXPORT SUPPLY ESTIMATES[a, d]

	U.S.	Japan	France	Germany	U.K.
Adjustment Coefficient (ϕ)	.996 (.299)	.317 (.141)	.446 (.143)	.562 (.188)	.580 (.162)
Trend-Output Elasticity (λ^{ℓ})	1.776 (.345)	1.359 (.158)	1.068 (.282)	.904 (.254)	2.139 (.200)
Cyclical-Output Effect ($\lambda^{c} \cdot s$)	-1.267 (.660)	.120 (.434)	.795 (1.178)	- .225 (.579)	.473 (.483)
Average-Price Elasticity (ϵ)	11.937 (19.161)	5.994 (4.505)	- .340 (1.023)	4.390 (2.218)	- .529 (1.075)
Substitution Elasticity (ρ)	.635 (4.042)	.411 (4.354)	-2.805 (3.840)	1.568 (2.965)	- .789 (6.251)
Shift 2	- .358 (.086)	.796 (.216)	.710 (.238)	.231 (.166)	.736 (.116)
Shift 3	- .320 (.073)	.341 (.186)	.520 (.195)	.285 (.094)	.351 (.096)
Shift 4	- .408 (.073)	- .518 (.269)	.023 (.166)	- .081 (.112)	.105 (.095)
Constant	-10.997 (2.898)	-5.078 (1.032)	-4.237 (1.808)	-2.482 (1.796)	-11.077 (1.379)
R^2 [b]	.37	.24	.33	.26	.33
DW[c]	2.20	2.06	2.04	1.89	2.12

[a] The numbers in parentheses below the coefficients are the standard errors.

[b] R^2 is the coefficient of determination in fitting $\Delta ln x$ (i.e. percentage change in exports) rather than $ln x$, the basic dependent variable. Its meaning is therefore qualified.

[c] DW is the Durbin-Watson statistic. It is not really appropriate in the present pooling context. Here the observation vector is a stack of four different time series (one for each country), and lagged exports appears in the equation. This DW and the R^2 are reported for completeness, despite their limited meaning.

[d] Estimates were obtained by (nonlinear) ordinary least squares.

The estimates of the average-price elasticities have relatively large standard errors, so that interpretations must be made cautiously. Our average-price elasticity for the U.S. (11.9) is nearly identical to that (11.5) found by Magee [1970, p. 183], and the elasticities for Japan (6.0) and Germany (4.4) are comparable to those found by Goldstein and Khan [1978, p. 282]. Since there are scarcely any other studies on export supply, further comparisons are not attempted.

The elasticities of transformation are very insignificant. One explanation is that exporters do not switch from one export market to another in response to marginal price changes. This is plausible, given the start-up costs associated with new marketing efforts, physical distribution networks, and repair facilities. However, the present empirical work is too preliminary to draw any firm conclusions.

The supply shift parameters in the U.S. export equation express the U.S.'s autonomous exports to the various other countries (France, Germany, U.K.) relative to U.S. exports to Japan. For the other export equations, the U.S. is the base of comparison instead of Japan. Allowing for the output and price effects in the model, the supply shifts indicate relatively strong structural trade links among Japan, France, and Germany. From this partial perspective, the U.S. and the U.K. appear to be isolated markets.

The export supply adjustments tend to be more rapid and more uniform across countries than the import demand adjustments. For the U.S. the mean adjustment period is a year. For France, Germany, and the U.K. it is about two years, and for Japan it is three years.

5. Conclusion

The preceding empirical work used aggregate bilateral trade data for the five major OECD countries from 1958 to 1974. For import demand the broad findings were (a) significant, positive trend-income effects accompanied by mixed cyclical-income effects, (b) varied and generally insignificant price responses, (c) pronounced time-invariant structural effects, and (d) wide differences in adjustment speeds. For export supply the broad findings were (a) significant, positive trend-output effects accompanied by mixed cyclical-output effects, (b) varied and generally insignificant price responses, (c) pronounced time-invariant structural effects, and (d) relatively rapid and uniform adjustment speeds. Throughout, the estimates exhibited interesting variations across countries.

According to this first empirical application of the supply and demand model, the major industrial countries will find trade policies directed toward economic growth patterns and structural relationships more reliable than trade policies, such as tariff changes, directed toward prices. For a more incisive test of the role of prices in international trade, consonant with the microeconomic character of the present model, one should move on to disaggregated data.

APPENDIX A

Linearization of Demand Function

The exact demand function is

$$\text{(A.1)}\quad \ln x^d_{ij} = W^d_{ij} - \sigma_j \ln p_{ij} + \left(\frac{\eta_j + \sigma_j}{1 - \sigma_j}\right) \ln\left[\Sigma^n_{k=1} \alpha^0_{kj} p_{kj}^{(1-\sigma\ )}\right].$$

The first derivatives are

$$(h = i)\quad f_{hj} = (\partial \ln x^d_{ij})/(\partial \ln p_{hj}) = -\sigma_j + (\eta_j + \sigma_j)\alpha^0_{ij} p_{ij}^{(1-\sigma_j)}\left[\Sigma^n_{k=1}\alpha^0_{kj} p_{kj}^{(1-\sigma_j)}\right]^{-1}$$

$$(h \neq i)\quad f_{hj} = (\partial \ln x^d_{ij})/(\partial \ln p_{hj}) = (\eta_j + \sigma_j)\alpha^0_{hj} p_{hj}^{(1-\sigma_j)}\left[\Sigma^n_{k=1}\alpha^0_{kj} p_{kj}^{(1-\sigma_j)}\right]^{-1}.$$

(In deriving these the following fact was useful:

$$(\partial p_{ij}^{(1-\sigma_j)})/(\partial \ln p_{ij}) = (1 - \sigma_j) p_{ij}^{(1-\sigma_j)}.)$$

Evaluation of the first derivatives at $p_{ij} = 1$ yields

$$(h = i)\quad f^*_{hj} = -\sigma_j + (\eta_j + \sigma_j)\alpha^0_{ij}$$

$$(h \neq i)\quad f^*_{hj} = (\eta_j + \sigma_j)\alpha^0_{hj}.$$

The first-order approximation of (A.1) is thus

$$\text{(A.2)}\quad \ln x^d_{ij} = W^d_{ij} + [-\sigma_j + (\eta_j + \sigma_j)\alpha^0_{ij}] \ln p_{ij} + \Sigma^n_{\substack{k=1\\k\neq i}} (\eta_j + \sigma_j)\alpha^0_{kj} \ln p_{kj}$$

$$= W^d_{ij} - \sigma_j \ln p_{ij} + (\eta_j + \sigma_j)\Sigma^n_{k=1}\alpha^0_{kj} \ln p_{kj}.$$

Now define the geometric mean price index $\bar{p}_j$ such that $\ln \bar{p}_j = \Sigma^n_{k=1}\alpha^0_{kj} \ln p_{kj}$.

Then (A.2) can be rewritten as

$$\text{(A.3)}\quad \ln x^d_{ij} = W^d_{ij} - \sigma_j \ln p_{ij} + (\eta_j + \sigma_j) \ln \bar{p}_j.$$

This is rearranged as expression (7) in the text.

APPENDIX B

Derivation of Supply Allocation Equation

In deriving the supply allocation equation (8), it is useful to sketch a proof of Armington's demand allocation result (2). The quantity index of *imports* $\tilde{m}_j$ has the CES form. In the usual application of the CES function to single-output production theory, $\tilde{m}_j$ would be the output and each x_{ij} $(i = 1,\ldots,n)$ would be one of the multiple input factors. Thus determination of the bilateral demand x^d_{ij} in the present trade setting is fully analogous to determination of the derived demand function for an input factor in the usual production setting. Using the well-known results for the latter problem, cf. Nerlove [1967, pp. 100-104], (2) follows immediately. Armington [1969a] provides an alternative, more detailed proof.

The quantity index of *exports* $\tilde{x}_i$ has the CET form. In the usual application of the CET function to multiple-output production theory, $\tilde{x}_i$ would be total resource use and each x_{ij} $(j = 1,\ldots,n)$ would be one of the multiple outputs. Thus determination of the bilateral supply x^s_{ij} in the present trade setting is fully analogous to determination of the supply function for an output. Furthermore, since the CET function has the same analytic form as the CES function, the present problem of maximizing total export revenue yields the same kind of first-order conditions as does the previous problem of minimizing total import cost. Thus by a mere change of symbols in (2), we infer the bilateral supply equation (8).

APPENDIX C

Trend and Transitory Income (Output)

As discussed in Houthakker and Taylor [1970, pp. 27-29], the Bergstrom flow-adjustment model is given by

$$\partial z/\partial \tau = \theta(z^* - z), \qquad \theta > 0.$$

Assume z^* is determined as

$$z_t^* = bW_{t-1} + c\Delta W_t$$

in which $\Delta W_t = W_t - W_{t-1}$. Then, the estimating equation has the form

$$z_t = (1 - d)z_{t-1} + bd\bar{W}_{t-1} + cd\Delta\bar{W}_t$$

in which $d = 2\theta/(2 + \theta)$, $\bar{W}_{t-1} = (W_{t-1} + W_{t-2})/2$, and $\Delta\bar{W}_t = (\Delta W_t + \Delta W_{t-1})/2$.

Solving out lagged z, the final form is

$$\text{(D.1)} \quad z_t = bd\Sigma_{k=0}^{\infty}(1 - d)^k\bar{W}_{t-1-k} + cd\Sigma_{k=0}^{\infty}(1 - d)^k\Delta\bar{W}_{t-k}.$$

Further, it can be shown that

$$\text{(D.2)} \quad d\Sigma_{k=0}^{\infty}(1 - d)^k\Delta\bar{W}_{t-k} = d\bar{W}_t - d\Sigma_{k=0}^{\infty}d(1 - d)^k\bar{W}_{t-1-k}.$$

Now define "trend-W" as the familiar exponentially weighted moving average:

$$\bar{\bar{W}}_t = d\Sigma_{k=0}^{\infty}(1 - d)^k\bar{W}_{t-1-k},$$

and define "transitory-W" as $(\bar{W}_t - \bar{\bar{W}}_t)$. Finally, using these definitions and (D.2), z_t in (D.1) can be rewritten as

$$z_t = b\bar{\bar{W}}_t + cd(\bar{W}_t - \bar{\bar{W}}_t).$$

Current z has been expressed as a linear function of trend-W and transitory-W.

The following symbolic relationships link this result to (12a) and (12b):

$$b = \mu_j^{\ell}, \qquad c = \mu_j^{c}, \qquad d = d_j; \qquad \text{(12a)}$$

$$b = \lambda_i^{\ell}, \qquad c = \lambda_i^{c}, \qquad d = s_i. \qquad \text{(12b)}$$

APPENDIX D

Table D.1. Import Demand: Comparison of Ordinary Least Squares and Instrumental Variable Estimates[a]

		U.S.	Japan	France	Germany	U.K.
Adjustment Coefficient (θ)	OLS:	.620	1.106	.124	.116	.339
	IV:	.608	1.138	.079	.115	.320
Trend-Income Elasticity (μ^{ℓ})	OLS:	1.521	.756	1.193	2.141	2.384
	IV:	1.521	.742	1.289	2.054	2.282
Cyclical-Income Effect ($\mu^{c}\cdot d$)	OLS:	- .120	.889	- .553	1.957	.392
	IV:	.090	1.034	- .538	1.941	.320
Average-Price Elasticity (η)	OLS:	-1.414	- .554	1.618	1.359	-1.590
	IV:	-1.389	- .490	5.569*	1.371	-2.392
Substitution Elasticity (σ)	OLS:	1.032	.230	-2.314	2.771	.216
	IV:	1.007	- .013*	- .127*	1.727	- .547*
Shift 2	OLS:	- .456	.281	1.507	1.889	.202
	IV:	- .465	.234	2.646*	1.696	.101
Shift 3	OLS:	- .134	- .013	.350	.677	- .018
	IV:	- .142	- .073	.659	.555	- .147
Shift 4	OLS:	- .559	.188	- .077	.253	.139
	IV:	- .565	.155	.273	.070	.053
Constant	OLS:	-8.540	-1.453	-3.514	-11.573	-12.332
	IV:	-8.535	-1.364	-3.760	-10.890	-11.626

[a] The instrument set consists of the right-hand predetermined variables, current and once-lagged versions of income and domestic price level for the exporting country, the exchange rate, the transmission factor, and a dummy variable formed as the interaction of the country-shift variables and the natural log of time (which creates a time-varying shift with bilateral character).

Table D.2. Export Supply: Comparison of Ordinary Least Squares and Instrumental Variable Estimates[a]

		U.S.	Japan	France	Germany	U.K.
Adjustment Coefficient (ϕ)	OLS:	.996	.317	.446	.562	.580
	IV:	1.086	.387	.454	.495	.574
Trend-Output Elasticity (λ^{ℓ})	OLS:	1.776	1.359	1.068	.904	2.139
	IV:	1.463	1.349	1.142	1.109	2.119
Cyclical-Output Effect ($\lambda^{c}\cdot s$)	OLS:	-1.267	.120	.795	- .225	.473
	IV:	- .503*	.179	.228	.080	.451
Average-Price Elasticity (ϵ)	OLS:	11.937	5.994	- .340	4.390	- .529
	IV:	-8.328*	4.468	- .848	1.645*	- .285
Substitution Elasticity (ρ)	OLS:	.635	.411	-2.805	1.568	- .789
	IV:	22.098*	3.785	-4.306	.326	- .528
Shift 2	OLS:	- .358	.796	.710	.231	.736
	IV:	- .061*	.766	.633	.145	.735
Shift 3	OLS:	- .320	.341	.520	.285	.351
	IV:	- .163*	.349	.466	.267	.353
Shift 4	OLS:	- .408	- .518	.023	- .081	.105
	IV:	- .253*	- .365	- .011	- .125	.104
Constant	OLS:	-10.997	-5.078	-4.237	-2.482	-11.077
	IV:	-8.564	-5.173	-4.543	-3.823	-10.937

[a] The instrument set consists of the right-hand predetermined variables, current and once-lagged versions of output and domestic price level for the importing country, and a dummy variable formed as the interaction of the country-shift variables and the natural log of time (which creates a time-varying shift with bilateral character).

APPENDIX E

Data

The data sources for the respective variables are listed below:

1. Trade Flows (x_{ij}): OECD, *Overall Trade by Countries*, Series A, various issues. Missing data for Japan are from United Nations, *Yearbook of International Trade Statistics* for various years (1958-1968) and from *United Nations Commodity Trade Statistics* (1958-61). Figures are in millions of U.S. dollars for monthly averages of f.o.b. trade values. These figures were multiplied by twelve for conversion to yearly aggregate bilateral trade values and then deflated by the bilateral export price index (π_{ij}) to obtain a constant-dollar measure for yearly aggregate trade flows (x_{ij}).
2. GDP (Y_i, Y_j): OECD, *National Accounts of OECD Countries*, 1958-1969, and OECD, *Yearbook of National Account Statistics*, various issues. Figures were converted into U.S. dollars at official exchange rates. The GDP data were deflated by the domestic price index (Π_i).
3. Transmission Factors (r_{ij}): This is the sum of the *ad valorem* tariff rate and the international transport cost factor (the c.i.f./f.o.b. ratio of trade values). C.i.f. trade values came from the same sources as the f.o.b. trade values (above). Since the U.S. has until recently reported only f.o.b. values of imports, we assumed that transport costs on U.S. imports are symmetric to transport costs on U.S. exports. In constructing yearly tariff rates, simple means for 1958 were calculated from *Political and Economic Planning, Atlantic Tariffs and Trade*, George Allen & Unwin, London, 1962;

and for 1970 from GATT, *Basic Documentation for the Tariff Study*, Geneva, 1974. Tariffs for interim years were calculated by applying a 20% reduction in 1963 for the Dillon Round and a 40% total reduction over the five-year period 1968-1972 for the Kennedy Round. French-German tariffs were adjusted according to the EEC tariff timetable provided in L.B. Krause, *European Integration and the United States*, Washington, D.C.: The Brookings Institution, 1962. These rates conform to those used in various other studies.

4. Bilateral Export Prices (π_{ij}): There are no data sources which contain comprehensive series of bilateral export prices or bilateral export price indices. Therefore, it was necessary to construct our own bilateral price indices. Presumably aggregate bilateral prices for the exports of any country will differ over destination countries due to differences in (a) the commodity composition of aggregate bilateral exports, and (b) any market conditions in the importing countries which give rise to price discrimination on the part of exporters. Lacking a measure of exporters' price discrimination, if it exists, our procedure considers only the differences in the commodity composition of trade. The price construction proceeded as follows: export prices (π_i^k) were obtained for each exporting country i for as many individual commodity categories k as possible (i.e. for as many as there were matching SITC classes). Wherever possible unit values were avoided. The sources were the following official national statistical publications:

U.S.: U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, various issues; 14 commodity classes.

Japan: Bureau of Statistics, Office of the Prime Minister, *Japan Statistical Yearbook*, Tokyo, various issues; 9 commodity classes.

France: Institut National de la Statistique et des Études Économiques, *Annuaire Statistique de la France*, Paris, various issues; 20 commodity classes.

West Germany: Statistisches Bundesamt, *Statistisches Jahrbuch für die Bundesrepublik Deutschland*, Wiesbaden, various issues; 14 commodity classes.

U.K.: Central Statistical Office, *Annual Abstract of Statistics*, London, various issues; 11 commodity classes.

For France and the U.K. only unit values were available. For the U.S. the wholesale price index was used, and for Germany and Japan genuine export price indices were available. Since some countries update export price indices every five years or so, various index series were spliced to obtain indices for 1958-74. While this questions the homogeneity assumption for relative prices in the aggregate import and export equations, there seems little choice.

The commodity export prices (π_i^k) were then weighted by bilateral trade flows (x_{ij}^k) corresponding to the matching commodity classes k (mostly 1 and 2-digit SITC classes). Further disaggregation was ruled out by the unavailability of matching commodity price indices. The commodity-level bilateral export values appear in OECD, *Analytical Abstracts, Foreign Trade, Series B*, various issues.

Weighting each year's commodity price indices ($\pi^k_{i,t}$), t for time, by the corresponding trade flows ($x^k_{ij,t}$) would create a unit value index. To avoid this a standard commodity bundle was constructed as the geometric mean of the 17 yearly observations on each bilateral trade flow: $\bar{x}^k_{ij} = ln^{-1}[\frac{1}{17} \Sigma^{17}_{t=1} ln x^k_{ij,t}]$. (The estimation results were robust to experiments with the geometric means for both values and quantities.) Finally, the bilateral export price index for overall trade is the weighted average of the $\pi^k_{i,t}$:

$$\pi_{ij,t} = \frac{\Sigma_k \pi^k_{i,t} \bar{x}^k_{ij}}{\Sigma_k \bar{x}^k_{ij}} .$$

5. Domestic Prices (P_j, Π_i): International Monetary Fund, *International Financial Statistics*, May 1976.

6. Exchange Rates: International Monetary Fund, *International Financial Statistics*, May 1976; used for all conversions into U.S. dollars.

7. General: All value and price data are in U.S. dollars. The base year for all price indices is the beginning year 1958. Aside from the symmetry imposed in constructing the U.S. c.i.f./f.o.b. ratios (above), no adjustments to the data were made.

FOOTNOTES

[1] For example, Taplin [1975, p. 365] suggests that "another area deserving further study is the way in which import demand is distributed among supplying countries," but he adds: "Bilateral import equations . . . are cumbersome. There are too many prices if the equations are specified correctly, and it is not worth doing otherwise." Taplin then recommends consideration of the Armington [1969a] procedure, which is used in this study.

[2] For a survey and critique of such models, cf. Leamer and Stern [1970, Ch. 7] and Magee [1975].

[3] A third class of models are the so-called "gravity models," which incorporate demand, supply, and transmission factors, but suppress prices. These models are static cross-section models and therefore do not address the same questions as the bilateral demand and constant-market-share models do.

[4] The elasticity of substitution has the form

$$\sigma_j = -\frac{\partial(x_{ij}/x_{kj})}{\partial(p_{ij}/p_{kj})} \cdot \frac{p_{ij}/p_{kj}}{x_{ij}/x_{kj}}, \quad \sigma_j \geq 0, \qquad (i, k = 1, 2, \ldots, n;\ i \neq k)$$

where p_{ij} is the price of imports into j from i.

[5] Khan and Ross [1977] present empirical evidence that supports the log linear specification of import demand.

[6] The elasticity of transformation has the form

$$\rho_i = -\frac{\partial(x^s_{ij}/x^s_{ik})}{\partial(\pi_{ij}/\pi_{ik})} \cdot \frac{\pi_{ij}/\pi_{ik}}{x^s_{ij}/x^s_{ik}}, \quad \rho_i \leq 0 . \qquad (j, k = 1, 2, \ldots, n;\ j \neq k)$$

[7] The bilateral (own and cross) price elasticities of demand can be derived from (11a), cf. Armington [1969b], and the bilateral price elasticities of supply can be derived from (11b). These will not be considered in this paper.

[8] There are estimates of some related models. First, there have been numerous multicountry demand studies, cf. Stern, Francis and Schumacher [1976]; Houthakker and Magee [1969], Resnick and Truman [1973] and Johnson, Grennes and Thursby [1977] are noteworthy examples. Second, there have been several two-region supply and demand studies, cf. Magee [1975, pp. 181-184]. Third, Clements [1977, 1978a] presents a three-sector monetary model of an open economy, which contains a supply system based on a quadratic transformation function; and Clements [1978b] proposes a supply and demand model along "Rotterdam lines." Fourth, Goldstein and Khan [1978] examine the supply and demand for total exports in a simultaneous framework.

[9] This is the "Bergstrom model" in Houthakker and Taylor [1970, pp. 27-29].

[10] A similar aggregation strategy was pursued earlier in formulating the supply and demand parameters. There, the basic elasticities (e.g. the substitution elasticities) for a given country were assumed equal across trading partners. Magee [1975] discusses the limitations of such aggregations.

[11] The cumulative percentage change from the base period equals $[\ln x_{ij,t-1} - \ln(\alpha^0_{ij}/r^0_{ij})]$ for (12a), and it equals $[\ln x_{ij,t-1} - \ln\beta^0_{ij}]$ for (12b).

[12] This construction parallels the decomposition of income into "permanent" and "transitory" components in the consumption literature, cf. Muth [1960].

[13] Hickman and Lau [1973, p. 362] also employ this pooling strategy in their demand study.

[14] There are three shift variables, since there are four trading partners, and a constant term is included in the equation. Moriguchi [1973, p. 405] employs country shift variables to represent "geographical and historical characteristics of i-j bilateral trade relations."

[15] No formal statistical content is attached to this comparison. The standard errors of the OLS estimates appear in Tables 1 and 2 of the text below.

[16] A marked sensitivity of the IV estimates for these two equations to seemingly minor changes in the instrument set cast great doubt on the reliability of these IV estimates.

[17] This was manifested in small determinants, sensitivity of certain IV estimates (footnote 16), and convergence problems with a nonlinear instrumental-variables algorithm aimed at calculating standard errors of the IV estimates.

[18] Maccini [1978] presents a price expectations model of price determination which guides the choice of instruments. Unfortunately, while theory is available, the required international data are often not, cf. Richardson [1976].

[19] Another source of inconsistency for OLS is the inherent correlation between measurement errors in the dependent quantity variable and errors in the right-hand price variables, cf. Kemp [1962].

[20] In the absence of better data, nominal tariff rates were used, and the difference between c.i.f. and f.o.b. valuations was used to measure transport costs. See Geraci and Prewo [1977] and Prewo [1978] on the role of transport costs and tariffs as determinants of bilateral trade.

[21] Marston [1971], using a more elaborate specification of the cyclical component, found sharp cyclical-income effects for the U.K., with wide variations across commodities. Data limitations prohibited a test of the Marston specification.

[22] Aho and Carney [1978] provide some preliminary evidence and hypotheses on structural factors influencing comparative advantage for the U.S., Germany, and Japan.

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