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General Equilibrium Analysis of US-EEC-Japanese Trade and Trade Distorting Policies: A Model and Some Preliminary Findings

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GENERAL EQUILIBRIUM ANALYSIS OF US-EEC-JAPANESE TRADE AND TRADE DISTORTING POLICIES: A MODEL AND SOME PRELIMINARY FINDINGS

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General Equilibrium Analysis of US-EEC-Japanese Trade and Trade Distorting Policies: A Model and Some Preliminary Findings[1]

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Abstract

This paper describes a large scale general equilibrium trading model of the U.S., Japan and the (9 member) EEC and reports some preliminary results obtained on the trade restricting impacts of tariff and selected non-tariff barriers to world trade. 33 commodities in each trading bloc are considered along with domestic production and demand patterns; tariff and non-tariff barriers enter as ad valorem charges on imported products. The approach allows the effects of tariff and non-tariff barriers (including domestic taxation and subsidy policies) to be analyzed not only on trading patterns, but, also on the allocation of productive factors by industry, welfare levels of consuming groups, and domestic income distributions. The numerical solution of the model uses recently developed computational techniques which determine competitive equilibria for international trade general equilibrium models.

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[1]This paper is a progress report on the project 'A Computational Appraisal of the Economic Impact of Selected Barriers to Trade Among Major World Trading Blocs' to be delivered at the Ford Foundation Seminar on International Economic Order, Madison Wisconsin, November 11-12, 1977. I am grateful to Mary Flannigan, Jon Fuller, John Piggott, Dale Turton, Hon Po Wong, and Bernard Yeung for research and programming assistance.

I. Introduction

Current policy analysis of tariff and non-tariff barriers continues to rely on calculations of ad valorem rates to provide measures of trade interference. This form of analysis persists even though it is agreed that it is not the rates themselves which are at issue but their effects on prices and quantities of traded products in protecting domestic producers and changing a country's terms of trade. A general equilibrium approach to trade policy evaluation seems called for and yet remains predominantly a theoretical rather than a practical technique.[1]

In this paper a large dimensional general equilibrium trading model of the US, Japan, and (9 member) EEC is outlined whose solution utilizes recently developed general equilibrium computational techniques. This model incorporates estimates of tariff and non-tariff barriers along with specifications of domestic activity and demand patterns in each of the trade blocs. This offers the capability of assessing impacts of trade policy variations not only on trade by commodity by area; but also on domestic production levels and factor use by industry, income distributions, and welfare levels of consuming groups. Some preliminary findings are discussed in a final section to the paper.

While, at the current stage of development, it is misleading to suggest that precise general equilibrium estimates of impacts of policy variations can be easily obtained, the operationality of the approach seems to be established.

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[1] Perhaps the best known of earlier attempts at quantitative general equilibrium analysis is the work of Evans [1972] on Australian tariff policy. Important as this work is, Evan's model and structure is more restricted in scope than the approach outlined here because of the differences in the nature of the computational devices employed to numerically solve the general equilibrium model considered. A more recent model due to Waelbroeck and Ginsburg [1976a,b,c] also analyzes international trade in a general equilibrium manner although from a forecasting rather than detailed policy analysis perspective.

Many difficulties remain, not the least of which is the problem of obtaining reliable estimates of the policies themselves in model equivalent form. The exploration of properties of the model, the search for more reliable data sources, and the inevitable arithmetic checking of data manipulations remains an ongoing task.

II. A Model of US-EEC-Japanese Trade and Trade Policies

The model of US-EEC-Japanese trade and domestic economic activity used is a conventional Walrasian general equilibrium model and is outlined[1] in Figure 1. As in all general equilibrium models, the central point of focus is the price system, and the set of equilibrium market prices. The present model differs from purely theoretical analysis in that a specific structure has been chosen and decisions made not only on parameter values for particular functions but also the type of functions used and to what they relate. A list of commodities has been drawn up along with the characteristics of consumer groups considered, and preferences and production technologies specified in terms of functional forms. A list and quantitative specification of the trade policy interventions considered by each bloc has also been obtained.

The structure of the model therefore reflects a balance of judgment between features of detail whose inclusion is indicated by interest in particular policies, and the constraints imposed by data availability and the mechanics of model solution.[2] Each of these specifics is discussed in this section in descriptive terms outlining the considerations influencing model design. An algebraic representation of the complete model in formal terms is given in Appendix A.

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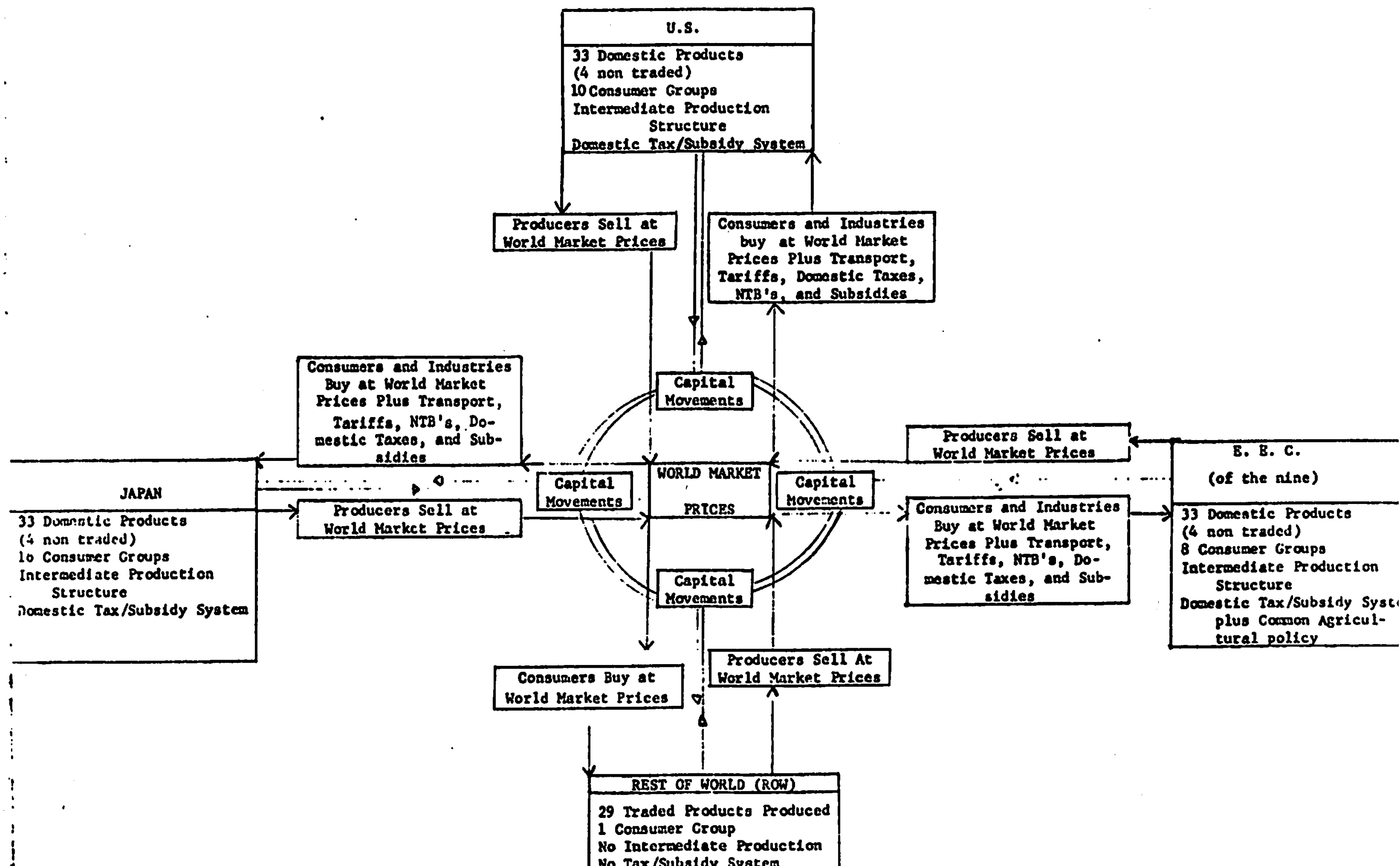
[1] This structure is a specific form of a general class of international trade general equilibrium models described by Shoven and Whalley [1974], who also discuss computation of equilibria for such models.

[2] The solution of large scale general equilibrium models is a relatively recent innovation and the restrictions of computational speed and size and storage facilities of machines are substantially extended by the present model.

FIGURE 1

A GENERAL EQUILIBRIUM MODEL OF US-EEC-JAPANESE TRADE - A STRUCTURAL OUTLINE



World General Equilibrium

A set of world market prices such that

(1) Demand equals supply for all goods and factors.

(2) No industry make positive profits, with those in operation breaking even.

(3) Each trading bloc is in zero trade balance (including capital movements).

The Treatment of Trading Blocs

Three trading blocs, the US, the 9 member EEC, and Japan, are considered in the model along with a residual 'rest of the world'. In the case of the US, the EEC, and Japan, their trade policies and their interacting effects are the object of the model construction and are treated in some detail. The representation of the rest of the world is schematic and no trading policies or detailed features of economic structure are considered.

This choice reflects an attempt to select those trading blocs whose policies provide the major focus for trade liberalization negotiations and who also account for a large portion of world trade. The coverage of world trade is complete and explains why the rest of the world is also considered. Given the commodity listing chosen for the model,[1] consideration of more trading blocs would result in a model size outside the limits of reasonable machine availability for program debugging and solution. The data problems in any such extensions would also be substantial.

The 'national' groupings of US, EEC, and Japan have been chosen instead of the 'continental' groupings of North America, Europe, and Pacific coast Asia because statistical information is only available in a usable form for the model for the national groups. Furthermore, the national groups correspond to the spheres of power of major decision makers in trade liberalization negotiations.

The level of world trade which the model analyzes is dependent on the number and type of trading blocs considered as no internal trade among countries of the bloc is included. Any projections obtained as to the effect of elimination or reduction of trade restricting policies on the level of world trade must therefore be interpreted as lower bound estimates especially as trade between EEC countries, and between rest of the world countries is ignored.

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[1] This list is described below in Figure 3.

Although major trading blocs are identified in the model, each has trading relations with additional areas which, although important for the bloc concerned, are not for the others. These trading 'satellites' are included with the rest of the world, and trade preferences to or restrictions on imports from these countries by their major trading partners are not separately considered.[1] In a regime of differential trade policies freed of the MFN provisions of GATT treaties, trade policies to these satellites would be major issues for each of the trading blocs.

Figure 2 gives a broad picture of the trading linkages between these major trading blocs along with the role of other important trading partners considered here in the rest of the world.

Commodities Considered

The commodities considered in the model are listed in Figure 3 which also gives the SITC division numbers of the commodity classification used. The size of the list fits within the overall dimensionality of model which can be satisfactorily handled with existing computational methods, and is the type of disaggregation for which national accounts and other data on domestic activity are available,[2] althouth this is by no means universally true.[3] Within this set of overall restrictions, individual items have been identified as far as possible in line with the importance of trade distorting policies.

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[1]The countries who fill this satellite role are Canada for the US, non-EEC European countries for the EEC, and Taiwan, Korea and Malaysia for Japan. The percentage figures of imports and exports by major trading blocs with these countries are given in Figure 1.

[2]Foreign trade data are available for a much more detailed level of aggregation than domestic production data.

[3]The discussion of data sources and adjustments in Appendix B highlights those areas where particular difficulty is encountered obtaining data consistent with this classification.

Figure 2

Characteristics of 1973 Merchandise Trade of USA, EEC, and Japan[1]

	U.S.A. %		EEC %		JAPAN %	
	IMPORTS	EXPORTS	IMPORTS	EXPORTS	IMPORTS	EXPORTS
A. TRADE CATEGORY AS % OF GDP	5.4	5.4	8.8	9.4	8.3	8.9
B. TRADE PERCENTAGE WITH TRADING BLOCS						
U.S.A.	-	-	17.3	15.5	23.7	25.8
E.E.C.	22.4	23.3	-	-	8.2	11.9
JAPAN	13.6	11.6	4.5	2.7	-	-
C. TRADE PERCENTAGES WITH OTHER BLOCS						
CANADA	24.4	21.1	3.2	2.3	5.2	2.7
E.F.T.A.	3.4	3.1	18.9	25.6	2.0	3.5
MIDDLE EAST	1.8	3.1	11.3	5.4	14.6	4.3
ASIA	9.9	9.3	5.6	5.0	20.3	24.1
AFRICA	3.1	2.1	11.9	9.4	2.9	6.7
L.A.F.T.A.	10.8	10.8	5.8	4.8	3.6	4.3
D. 1973 CURRENT PRICE GDP AT MARKET PRICES IN $ BILLION	1297.5		1046.3		409.3	

[1] Trade statistics from United Nations, YEARBOOK OF INTERNATIONAL TRADE STATISTICS, 1974. Volume 1, pp. 24-25.

Figure 3

COMMODITIES CONSIDERED IN THE MODEL

COMMODITIES CONSIDERED	SITC DIVISIONS
Agriculture	
(1) Meats and Dairy Products	Div 00, Div 02, Div 94, 011, 012
(2) Cereals	Div 04-045
(3) Other Agricultural Products Fruits, Vegetables, Oil Seeds, Nuts, Animal Feed, Crude Animal and Vegetable Materials. Silk Wool, Cotton, Jute and Vegetable Fibres.	Div 05-051, 054, Div 22, Div 29, Div 08, 261, 262, 263, 264, 265
(4) Forestry and Fisheries	031
Mining	
(5) Coal	321.4
(6) Oil, Natural Gas	331, Div 34
(7) Metallic, Non-Metallic and Other	Div 27, 281, 285, 286, 283
Manufacturing	
Non-Durable Goods	
(8) Tea, Sugar, Coffee, Spices, Cocoa	Div 06, Div 07
(9) Alcoholic Drinks	112
(10) Other Foods Animal and Vegetable Oils and Fats, Misc. foods Prep. fruits and veg., Prep. cereals, Beverages, Prep. meat and fish.	Div 09, Div 41, Div 42, Div 43,111, 048, 052, 053, 055, 013, 032, 046, 047
(11) Tobacco	Div 12
(12) Apparel and Textile Products	266, 267, Div 65, Div 84, Div 21, Div 61, Div 85
(13) Paper, Printing, Publishing	Div 25, Div 64
(14) Pharmaceuticals and Toiletries	Div 54, Div 55
(15) Other Chemical and Allied Products	Div 51, Div 52, Div 53, Div 56, Div 57, Div 59
(16) Petroleum and Coal Products	Div 32 less 321.4, 332
(17) Rubber and Plastics	Div 23, Div 58, Div 62
Durable Goods	
(18) Lumber, Wood and Furniture	Div 24, Div 63, Div 82
(19) Primary and Fabricated Metals, Stone Glass	Div 66, Div 67, Div 68, Div 69, 282, 284
(20) Machinery Except Electrical	Div 71
(21) Electrical Machinery	Div 72
(22) Transport Vehicles	Div 73
(23) Scientific and Precision Instruments	Div 86, Div 95, Div 96
(24) Miscellaneous Manufacturing	Div 83, Div 89, Div 93
Construction	
(25) Construction	
Services	
(26) Water Transportation	
(27) Other Transportation and Communications	Div 91
(28) Housing Services	
(29) Electricity, Gas and Water Services	Div 35, Div 81
(30) Wholesale and Retail Trade	
(31) Finance, Insurance and Real Estate	
(32) Other Services	
(33) Government Services	

Thus, agricultural products are divided into four subgroups even though domestic data on agricultural activity is not uniformly available on this basis, because of the desire to analyze the foreign trade role of CAP in the EEC, the importance of US-EEC and US-Japan cereals trade, the trade effects of domestic subsidies to rice production in Japan, and other trade issues with agricultural products. Tea, sugar, coffee, spices and cocoa are identified from other food products, while tobacco and alcoholic drinks are identified because of the trade role of domestic taxation policies. Textiles, pharmaceuticals, and vehicles, all of which provide examples of trade restricting policies in one or more blocs are also separately identified. Service items are less finely divided due to the relative absence of direct trade distorting policies.

An important characteristic of the model is that for any trading bloc, domestically produced and imported commodities with similar physical characteristics are considered to be qualitatively different. Domestically produced and imported goods are treated as heterogeneous, even though they are close substitutes in demand. This treatment follows that of Armington [1969, 1970] and is adopted because empirical work with foreign trade data, even at a fairly aggregated level, has to contend with countries both importing and exporting 'identical' products. An appealing rationalization for this phenomenon is qualitative difference in products depending on country of origin. An important implication of this treatment is that it results in larger dimensional general equilibrium problems than if homogeneity were assumed.

The overall dimensionality for the model is 128 commodities, which breaks down into 33 US products, 33 EEC products, 33 Japanese products, and 29 rest of world products. As the rest of the world is treated schematically, the 4 products from the list of 33 that are non-traded are not considered by the model.

Trade Restricting Policies

The trade restricting policies considered are classified under three broad headings: tariffs, non-tariff barriers, and domestic taxation and subsidy policies.

Tariffs are considered to apply in ad valorem form to imports of products for both final and intermediate uses valued at f.o.b. prices.[1] Tariff collections become part of the general government revenues for financing government expenditures. As is well known there is substantial difficulty in obtaining average tariff rates in ad valorem form for aggregated classifications of the form presented in Figure 3. The procedure used has been to adopt the 1974 GATT study averaged rates for manufactured and mining products which use 1973 MFN tariff schedules. The GATT averaging procedure of using world imports for 1970 and 1971 has been extended in arriving at estimates consistent with the classification in Figure 3. Estimates for agricultural and food items are taken from Yeats [1976, 1977]. The broad pattern of tariffs rates is given in Figure 4 where average rates for five broad categories are reported by trading bloc.

Non-tariff barriers include an assortment of policies which either deliberately or coincidently affect trading patterns in addition to those effects induced through tariff policy. In recent years they have attracted attention due to the view of many people that in practice they serve as a more severe impediment to trade than conventional tariff policy. A number of studies (Baldwin [1970], Walter [1972], UNCTAD [1969, 1970]) have attempted to classify and describe these barriers, although numerical estimates as to their importance are somewhat sparse. A recent study by Roningen and Yeats [1976] drawing on UNCTAD documentation provides estimates for France, Japan, Sweden, and the US, and a related study by Yeats [1976] contains estimates of the role of non-tariff barriers on agricultural products in the EEC. A descriptive list of non-tariff barriers would include government purchasing policies, quotas,

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[1] This approximates the customs clearance basis in the US; in Japan and the EEC tariffs apply to valuations much closer to a c.i.f. price.

Figure 4

Summary of Average 1973 Tariff Rates[1] By Broad Category and By Trading Bloc[2]

	Category	Items in Fig. 3 Included	Percentage Rate on U.S. Imports	Percentage Rate on EEC Imports	Percentage Rate on Japanese Imports
1.	Agriculture and Food Products	1, 2, 3, 4, 8, 9,10,11	5.37	19.34	21.92
2.	Raw Materials	5, 6, 7	3.20	0.45	8.02
3.	Semi Manufactures	15,16,17,18,19	5.87	7.35	7.61
4.	Finished Manufactures	12,13,14,20,21,22, 23,24	7.99	9.71	11.84
5.	Service Items and Other Goods	25,26,27,28,29,30, 31,32,33	0	0	0
6.	Average over all Products		5.23	8.78	9.38

[1]All rates are calculated to apply to imports valued on an f.o.b. basis; this involves data adjustments for the EEC and Japan.

[2]The sources used are GATT [1974], Yeats [1976, 1977], and author's own calculations.

seasonal restrictions, specific licensing regulations, valuation procedures for tariff purposes, voluntary export restraints, special import charges (including such items as variable levies in the European Community Agricultural Policy), and health and sanitary regulations. Clearly, some of these are more important than others and some can be quantified more satisfactorily than others.

The nature of the major non-tariff barriers by trading blocs and by broad category are outlined in Figure 5 which also reports ad valorem equivalents for certain of these barriers. These have been primarily derived from estimates reported by Roningen and Yeats [1976], although other sources including Baldwin [1970] have been used. The difficulties of documenting non-tariff barriers and obtaining reasonable estimates of their effect in terms of an ad valorem equivalent tariff are revealed in Figure 4. For a range of products no estimates are available, and for those where estimates exist, only a limited amount of confidence can be attached to them. They are used here as the best available, but their potential unreliability must be made clear.

A number of features of taxation and subsidy policies which affect trade patterns enter the model. Many of these have appeared in trade policy disputes, even though these policies have internal rather than external objectives. In the area of indirect taxation, the administration of the value-added tax in the EEC on a destination basis has long been objected to by the Americans, who more recently have objected to a similar basis being used for the commodity tax in Japan. High specific taxes on drink, tobacco, and hydrocarbon oil also have an influence on trade patterns although their role has not been the subject of such extensive dispute between the trading blocs as the broadly based indirect taxes. There are also other less obvious trade influences of taxation and subsidy policies. Service items and in particular the non-traded housing services tend to be lightly taxed. This feature has been analyzed in the UK context by Piggott and Whalley [1976]

Figure 5

Summary[1] of Major Non-Tariff Barriers by Broad Category and By Trading Bloc[2]

	Category	Items in Fig. 3 Included	Non-Tariff Barriers on US Imports: Description	Non-Tariff Barriers on US Imports: Ad valorem Equivalent	Non-Tariff Barriers on Japanese Imports: Description	Non-Tariff Barriers on Japanese Imports: Ad valorem Equivalent	Non-Tariff Barriers on EEC Imports: Description	Non-Tariff Barriers on EEC Imports: Ad valorem Equivalent
1.	Agricultural and Food Products	1,2,3,4,8, 9,10,11	Quotas on Meat and Dairy Products International Agreements on Coffee, Sugar, Cocoa	31.87	Health and Sanitary Restrictions Subsidies (primarily to rice producers) International Agreements on Coffee, Sugar, Cocoa State trading in Alcohol and Tobacco	96.95	Common Agricultural Policy (Meat, Dairy, and Grains) International Agreements on Coffee, Sugar, Cocoa	45.37
2.	Raw Materials	5,6,7	Licence fee system on Petroleum Imports Quotas (Petroleum, and Metallic and non-metallic ores) Depletion Allowances	No estimates Available ; Outside of Depletion Allowances Effects Small	Subsidies to Coal Quotas on Petroleum, Natural Gas	65.64	Subsidies to Coal, Quotas on Coal State Trading in Coal, Petroleum, Natural Gas	88.60
3.	Semi-Manufactures	15,16,17, 18,19	Quotas on Petroleum and Oil Products, Steel	No estimates Available ; Effects smaller than for finished manufactures	Quotas on Chemical and Petroleum Products	No estimates Available - Effects smaller than for finished manufactures	Quotas on Chemical Products, Petroleum and Coal Products, Rubber, Steel	No Estimates Available - Effects smaller than for finished manufactures
4.	Finished Manufactures	12,13,14, 20,21,22, 23,24	Textile Quotas Subsidies via Government Research expenditures	8.13	Quotas (Computers, transistors, communications equipment) subsidies (shipbuilding)	9.04	Quotas (Textiles, electrical machinery, transport equipment) Subsidies Restrictive Standards	16.80
5.	Service Items and Other Goods	25,26,27, 28,29,30, 31,32,33	Merchant Marine Flag Discrimination	No Estimates Available - Assumed Small		No Estimates Available - Assumed Small		No Estimates Available - Assumed Small
6.	General Non-tariff Barriers		Government Procurement Policies		'Buy National' Policies Voluntary Export Restraints		'Buy National' Policies	

[1]Summary and rates apply as far as possible to the period immediately prior to 1973 and take no account of subsequent changes in policies, especially to raw materials since the events of late 1973.

[2]Sources; for description; various GATT and UNCTAD documents, U.S. Tariff Commission Reports [1974]; for estimates of rates, Yeats and Roningen [1976], Baldwin [1970].

who were able to show a significant effect of the UK tax system on the commodity terms of trade for the economy through this feature. Differences in the size of public sector are also important in that relative burdens of direct taxes which contribute to factor cost vary substantially across trading blocs. A striking feature is the small size of the public sector in Japan which in terms of the ratio of real expenditures to GDP is approximately one half that of EEC countries. Income as a return to capital is considerably more lightly taxed than labour in Japan compared to either the US or the EEC which substantially aides capital intensive Japanese industries.

The model explicitly incorporates the domestic taxation and subsidy systems of each of the trading blocs. Although the tax systems vary in structure, the broad approach is to treat corporate and property taxes as taxes on profit type returns by industry, social security taxes on labor use by industry, value-added and sales taxes as production type taxes, specific excises as consumption taxes, and income taxes as charges on income receipts by consumer groups. The data sources for these tax rates are described in Appendix B.

Modelling Quotas and Other Non-Tariff Barriers as Ad Valorem Equivalents

Quotas and other non-tariff barriers are represented in the model in *ad valorem* equivalent form rather than as restrictions on quantities imported. A distinguishing characteristic of both quotas and non-tariff barriers is that they generate no tax revenue for the government. This is accommodated by returning receipts from these charges in lump sum form to consumer groups; the lump sum payments being determined by ratios of consumer incomes in basic data.

The effects of quotas are more realistically captured in a general equilibrium model not as equivalent *ad valorem* charges but directly as quantity restrictions. From a computational point of view it is straightforward to incorporate quantity restrictions implied by quotas by considering an additional fictitious commodity which must be purchased when the good involved is imported. The endowment of this commodity is equal to the value of the quota involved and is owned by the recipient of the rents which quotas create. If a quota is not binding in equilibrium, the corresponding artificial commodity will have a zero price.

While this approach can be implemented in small dimensions, the extra dimensions created by the quotas to be examined for the present model raise serious computational difficulties which are avoided by considering quotas in equivalent *ad valorem* form.

Production Structures

In each trading bloc technological possibilities for transforming commodities (factors) into other commodities (goods) are specified for each industry. There are as many industries as there are goods in the model, joint production being excluded. Each industry in each trading bloc is treated as using in its production process two substitutable primary factors, capital and labour services (described by a CES production function) and also requiring other domestically produced and imported products besides those it produces. This latter part of the production possibilities is represented by an intermediate requirement matrix of fixed coefficient form.[1]

Each industry is assumed to be operated by profit maximizing producers each of whom faces a constant return to scale set of production opportunities. They receive a single ex-works price for their product independently of whether it is sold domestically or abroad. Foreign consumers pay a higher price which reflects transport costs and the effects of any trade policies which may operate.

Data on production function parameters come partly from a recent survey of elasticity values by Caddy [1976] and partly from the model specification procedures to be described in the next section. Data on the fixed coefficient intermediate requirements matrices come from updated versions of the 1970 US Input-Output tables, the 1970 Japanese tables, and the 1970 tables for major EEC countries consolidated onto an EEC basis. All of these tables are aggregated onto the classification given in Figure 3.

Demand Patterns and Consumer Groups

For each of the trading blocs considered, a number of groups of consuming agents are included in the model. In the private sector of each trading bloc a number of consumer types are considered, stratified by income range in the case of the US and Japan, and by individual country in the case of the EEC. These groups are represented in Figure 6. The objective of identifying these groups in this way is to enable the impacts of alterations in tariff and non-tariff trade policies to be assessed on the personal distribution of income. Each of these groups also has different

1. The absence of substitutability between imported intermediate products and those produced domestically is a feature of the model to be relaxed in future extensions. The difficulties are in coping with the increased execution times involved for model solution.

Figure 6

Consumer Groups Identified in Each Trading Bloc

US

A. Government Sector
1 Agent

B. Corporate Sector
1 Agent

C. Household Sector

10 Households stratified by the following net of tax household income ranges as given in the 1960-61 CES data.[1]

< $1,000

$1,000 - $1,999
$2,000 - $2,999
$3,000 - $3,999
$4,000 - $4,999
$5,000 - $5,999
$6,000 - $7,499
$7,500 - $9,999
$10,000 - $14,999
$15,000 +

EEC

A. Government Sector
1 Agent

B. Corporate Sector
1 Agent

C. Household Sector

1 Agent considered for each of France, West Germany, U.K., Italy, Ireland, Denmark, Belgium and Luxembourg, Netherlands.

Japan

A. Government Sector
1 Agent

B. Corporate Sector
1 Agent

C. Household Sector

16 Households stratified by the following net of the household income ranges as given in the 1973 Japanese Family Income and Expenditure Survey.

< 400 thous. ¥

400 - 600 thous. ¥
600 - 800 thous. ¥
800 - 1,000 thous. ¥
1,000 - 1,200 thous. ¥
1,200 - 1,400 thous. ¥
1,400 - 1,600 thous. ¥
1,600 - 1,800 thous. ¥
1,800 - 2,000 thous. ¥
2,000 - 2,500 thous. ¥
2,500 - 3,000 thous. ¥
3,000 - 3,500 thous. ¥
3,500 - 4,000 thous. ¥
4,000 - 4,500 thous. ¥
4,500 - 5,000 thous. ¥
5,000+ thous. ¥

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[1]Survey of Consumer Expenditures 1960-1961, Bureau of Labor Statistics. At the present time this is the most recent complete set of consumer income and expenditure data for the US. Data for 1973 has been collected by the BLS but is not yet available.

preference patterns over the commodities purchased and the influence of these is also taken into account in the model.

A distribution of initial ownership of factors of any country is specified among the consuming groups located there. The value of these at any set of prices, along with transfers received and taxes payable, determines disposable incomes for each consuming group. This, in turn, provides the income level which appears in the budget constraint of each consuming group. Ownership patterns, transfers received, and taxes payable for each of the consuming groups in each trading bloc are determined from income distribution data.

Demand patterns (or preferences) for each of the consuming groups are also specified. In aggregate, the total (worldwide) demand functions are assumed to satisfy Walras Law (the condition that the value of demands equals total incomes at any vector of prices). The model utilizes three level, staged CES utility functions for each consuming group. The three levels of nesting allow for higher degrees of substitutability among some goods than others. Thus, high degrees of substitutability between domestically produced and imported goods are assumed. Intermediate degrees of substitutability prevail between components of the broad categories listed in Figures 3 and 4, and lowest degrees of substitutability between the broad categories themselves.

The personal sector alone does not account for all the final purchases in the economies considered, and demand patterns of the corporate and government sectors are also represented in the model. Government expenditures are financed by net tax receipts less transfers, and corporate expenditures (primarily on capital goods) by retentions plus new borrowings.

The preferences for all these groups are parameterized using expenditure data by type of product by agent and the way in which these data are used is discussed later.

Equilibrium Solutions

Equilibrium of both international trade and domestic activity is given in the model by a set of world prices for all commodities and factors such that (i) quantities demanded equal quantities supplied for all commodities and factors; (ii) in no industry in any of the trading blocs are there any opportunities for positive profits; and (iii) each country is in zero trade balance in terms of its trade with the rest of the world. For the general class of models considered by Shoven and Whalley [1974], such equilibria have been shown to exist and to be computable. A property of such equilibria is that government budgets are balanced (including tariff receipts). The use of such a model therefore allows alternative equilibrium states to be generated under various policy interventions and yields the basis for assessment of policy impacts. A potential difficulty with the use of any general equilibrium model is the possibility of multiplicity of equilibria. If more than one equilibrium exists for the present model, the equilibrium which is calculated may not be the one to which the trading blocs will move in the event of a policy change. In complex empirical models it is impossible to rule out multiplicity of equilibria on a priori grounds and resort must be made to a process of testing for uniqueness by repeatedly approaching equilibria at different speeds and from different directions. This form of testing has been done with general equilibrium models constructed for analysis of domestic taxation/subsidy policy and in no cases examined has multiplicity of equilibria been revealed. Limited testing has been done for the present international trading model, and until extensive testing is done multiplicity of equilibria for this model cannot be totally excluded as a possibility.

A further difficulty is that the ability to compute equilibria does not resolve the problem of which characteristics of equilibria are to be compared and

and on which basis. Solving the model for a new world competitive equilibrium under a different policy regime generates all new prices and quantities associated with that equilibrium. To draw conclusions on overall impacts of the policy change, summary statistics must be used, and many alternative indices are available and equilibria can be compared on different bases.[1] The particular results reported on later are in summary form and these will be made clear when the calculations are discussed.

The Treatment of Capital Movements

A significant portion of the international transactions involving the US, the EEC, and Japan is accounted for by capital movements. The model examines competitive equilibria for which zero trade balance for each country's external trade prevails, and ignoring capital movements is unsatisfactory in that trade imbalances are implied in the unadjusted data. Moreover, some response in capital movements may be anticipated as trade policies vary.

Capital movements and external asset transactions are therefore accommodated in the model through the demand patterns of agents. Income accruing from ownership of foreign assets enters the budget constraints of domestic capital owners, and purchases of foreign capital assets enter the investment demand patterns of the corporate sector. This treatment in the model differs substantially from the organizational scheme followed in balance of payments accounts, and adjustments to these data are therefore necessary. These are discussed in appendix B.

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[1] An as example, when there is a change in domestic taxation/subsidy policy it is conventional to contemplate a replacement broadly based consumption tax which preserves the total yield of the tax system. In these cases, a decision must be made as to whether the tax is to be administered on a destination or an origin basis.

Transport Costs

Transport costs of shipping items between trading blocs are explicitly incorporated into the model. The market price for any product which is considered in the model is the production cost in the country of origin. Transportation costs are considered to operate in a fixed coefficient manner for each transshipment route for each product. There is therefore a different transport inclusive price in the country of destination; only the production price (f.o.b.) is received by the domestic producer. Data on transportation costs by product by shipping route are not available in a form which is easy to use. The procedure followed has been to assume that the total transportation costs incurred on any route are given by the differential between c.i.f. and f.o.b. import values. This total is then distributed by broad category using estimates reported by Roningen and Yeats [1976] and items within these broad categories are assumed to have similar percentage transport costs for that transshipment route.

Dating the Model

The model is parameterized by using data for the year 1973. This choice of a single year is part of a broad approach to model parameterization that a set of data be assembled which satisfies the equilibrium conditions for the model and used to obtain parameter values for the functions used in the model.

The data set involved is large, and at the current stage of development it is impractical to consider using more than one year's data although some averaging across years would be desirable were it feasible. 1973 has been chosen as it is the most recent year for which sufficient data are available for the construction of the data set to proceed. It represents a reasonably full employment year in all the trading blocs included, and for the major part of the year the disruptions caused by the Middle East war played no role. Inflation rates were also lower in 1973 than in the two following years in all the trading blocs involved.

III. The Numerical Specification and Solution of the Model

This section describes the procedures of model specification and solution.

Model Specification

The approach which has been adopted to model specification broadly follows that used by Piggott and Whalley [1976, 1977] in their general equilibrium analysis of the U.K. economy and tax/subsidy system. The equilibrium solution concept of the model is used as an identifying restriction on the model and the equilibrium conditions are solved for parameter values for the underlying functions.

For the model described in Section II, once elasticity values in production and demand functions are specified the other parameters of these functions can be obtained directly from the equilibrium conditions. A literature search is used to provide estimates of elasticity values for production functions.[1] No econometric literature exists which provides values of substitution elasticities for demand functions, and in this case, resort is made to a range of best guess values with an approximate checking of point estimates of price elasticities of market demand functions against literature estimates.

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[1] The recent survey by Caddy [1976] provides the main source for these estimates.

The adoption of this overall approach implies the need to construct a benchmark equilibrium data set involving both the domestic and trading activity of each of the trading blocs. Such a data set is needed whatever techniques are used to assess the effects of policy changes relative to some currently operating policy regime, and an important feature of the model is the assembly of such a data set which can be used in other studies. Many divergent source materials need to be assembled and converted onto consistent classifications and definitions, and even when this is complete, further adjustments are necessary to mutually adjust the data so that the equilibrium conditions of the model are satisfied.

By any standards, this is a substantial undertaking and needs to be done with care and attention to detail. The data set which has been assembled thus far can only be considered as a first approximation to an ideal data set for the model. There are problems of inconsistent classifications and definitions, gaps in data availability, and differences in the dates of data sources. In addition, a considerable amount of careful arithmetic checking of data adjustments and data calculations needs to be made. The steady improvement of this data set is a task could easily preoccupy many years, and the results with this first assembled data set may indeed be substantially modified by such improvements if and when they are made.

The requirement of replicating a benchmark equilibrium state imposes a substantial amount of discipline on the programming of the whole model. A general equilibrium problem is to be solved to which the answer is known ex ante, and the ability to reproduce this answer gives increased confidence in the accuracy of programming. However, the possibility of nonuniqueness of equilibrium in these models (mentioned earlier) poses potential difficulties for this approach. The inability to replicate an equilibrium need not rule out a given specification if more than one equilibrium from the model is possible. The circumstantial evidence in favour of uniqueness is, in the author's opinion, strong but no proof of uniqueness can be offered.

Data Sources for the Benchmark Equilibrium Data Set

Constructing the benchmark equilibrium data set involves a number of diverse data sources to which adjustments are made to correct for differences in definition and coverage. A complete list of these data sources is given in Appendix B, together with an indication of the adjustments which have been made to these data.

In broad terms the overall data set can be decomposed into data relating to trading patterns and data relating to domestic activity in each economy. Under the former heading would appear data on foreign trade, capital movements, tariffs, and non-tariff data. Under the latter would appear data on value-added by component by industry, intermediate usage of both domestically produced and imported products by industry, final demand patterns by sector and by consumer type within the household sector, and data on domestic taxes and subsidies.

(i) Data relating to trading patterns.

Merchandise Trade - Data are taken from OECD Trade Statistics Series B January to December 1973. As the model uses one single set of trade data to represent the trade flows along any transshipment route, f.o.b. export values reported by the exporting country are used.

Capital Movements and Receipts of Investment Income - Data are taken from Balance of Payments accounts reported by each of the major trading blocs. As with the foreign trade data two reportings of the same transactions appear and some judgement is used to select a single figure. U.S. balance of payments data are heavily used but are supplemented by Japanese and EEC data where these are available on a gross basis (as against the net US basis). The features of these data sources are taken up in Appendix B.

Tariff data - Average tariff rates on manufactured products and raw materials are taken from the data in the GATT study [1974]. In this study eight different tariff rates are given for each product reported, four different averaging schemes being applied to the basic data and two procedures adopted of considering all imports in a category (whether dutiable or not) and only dutiable imports. Averaged MFN rates on all imports using world imports as weights are converted onto the classification of Figure 2 by extending the same averaging procedure. These data are complemented with tariff data on agricultural and food products using the estimates reported by Yeats [1976, 1977].

Non-Tariff Barriers - As indicated already, quantitative information on non-tariff barriers is sparse, and in some cases even qualitative information is difficult to obtain. Many of the major non-tariff barriers are considered by Baldwin [1970] where approximate ad valorem equivalent estimates are presented. The more recent work by Roningen and Yeats [1976] provides estimates by a residual method of the combined effects of non-tariff barriers in ad valorem form for some 26 product items for France, Japan, the U.S. and Sweden for 1973. The residual method does not directly allow for transport costs in their estimates for all product groups, which they estimate on average as equivalent to a trade barrier of 8 to 12 percentage points (with a high of 40 percentage points for mineral fuel imports into Japan) and an approximate correction for this is made in the figures used here. These two sources provide the main data on non-tariff barriers outside of agricultural products in the EEC. In this case, additional information is available on the trade effects of the Common Agricultural Policy.[1]

(ii) Data relating to domestic activity.

Value added by industry: Data on value added by industry by component provide estimates of capital and labour services used in each industry. Data of this form appear in the input-output tables for Japan and the EEC countries, but not for the U.S. These data, however, are not satisfactory for use in the model as there are also substantial differences in the concepts used beyond the differences in dates between the input-output data and the benchmark data set. Rather than begin with the input-output data and make adjustments for all these features, national accounts data have been used directly to construct the estimates required. Where the National Accounts data are not sufficiently disaggregated for use here, input-output and other data have been used as a basis for disaggregation.

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[1]The structure of the EEC common agricultural policy is such that a target price (taken as a price at Duisberg, W. Germany) is announced annually for a number of separate commodities more detailed than those specified in the model. The Community stands ready to buy at an intervention price (approximately 5% below the target price) and imports from outside the Community are charged a levy to bring their price up to the target price if world prices are below target prices (as is typically the case). The agricultural commodities appearing in Figure 3 cover those important (and contentious) aspects of this policy which can adequately be captured by the model given the restrictions on the total number of commodities and statistical availability of information in domestic production statistics. The importance of these levies for world trade clearly varies from year to year as world prices change and target prices are reset. The most complete recent set of estimates of <u>ad valorem</u> equivalents implied by the operation of levies are obtained by Yeats [1976] from UNCTAD data. Yeats also concludes from the UNCTAD data that quota and other restrictions on agricultural products are of minor importance in the EEC, although this is not so in the U.S., and estimates of the extent of these interventions are provided by Wipf [1971].

Input-Output Data: These data come from the published input-output tables for the U.S., Japan, and major EEC countries for 1970. No overall EEC table is available for this year and the tables for the U.K., Netherlands, West Germany, Belgium, Italy, and France are used to construct an aggregated EEC table which is scaled in such a way that total value added appearing in the tables reflects that given in EEC national accounts. In the cases of the EEC and Japanese tables, use of imported products by type by industry of use is separately reported. This is not the case for the U.S. input-output tables and a complex procedure using the basic source materials involved in the construction of the original tables is used to identify these imports.

Expenditure data by type by household: For the U.S. and Japan these data come from the latest available family expenditure survey data. For the U.S. this is the 1960-61 Consumer Expenditure Survey, for Japan the 1973 Family Expenditure Survey. Each of these sources reports expenditures of households stratified by income range by type of expenditure and a concordance is used between classifications of commodities in these sources and that reported in Figure 3.. No distinction is made in these sources between imported and domestically produced commodities and it is assumed that expenditures on these reflect the aggregate composition of traded and domestically produced commodities. In the case of the EEC, expenditures by the household sector of each economy by type appear in EEC national accounts and these figures are broken down by imported and domestically produced commodities in a similar manner to that for the Japanese and EEC data.

Taxation, subsidy, and government expenditure data: All of the major domestic taxes are considered in model equivalent form and data are collected on payments by the corresponding agents. Corporate and property taxes are treated as *ad valorem* taxes on the use of capital services by industry. Social security taxes are treated as *ad valorem* taxes on hirings of labor services by industry. Indirect taxes (sales and excise taxes in the U.S., VAT and excise taxes in EEC, commodity tax and excise taxes in Japan) are treated as taxes paid by domestic consumers on both imported and domestically produced goods with exports exempt. Income taxes are paid at different marginal rates by each of the consumer groups identified. Subsidies to particular industries appear as *ad valorem* production subsidies. Government expenditures by commodity appear as a component of final demands.

Consistency Adjustments to the Data Set

A number of consistency adjustments must be made to the overall data set so that the equilibrium conditions of the model will be satisfied by the data. Demands must equal supplies for all commodities; for each industry total costs should equal total sales; for each consumer group the value of purchases should equal that group's disposable income; the endowments of a given factor should equal its total usage in all industries; each government's budget should be balanced; the value of final demands in any trading bloc should equal the sum of value added originating there; and each trading bloc should be in zero overall trade balance.

Achieving this set of conditions in the benchmark equilibrium data set involves adjustments to all of the components of the data set. Most of these conditions will be satisfied in basic data sources, and are violated because of subsequent adjustments to the data. For instance, balance of payments accounts will satisfy the zero trade balance condition, but the use of a different set of merchandise trade statistics in the model from those used to construct the balance of payments accounts will cause the violation of these conditions. In input-output tables, the sum of value added equals the value of final demands and costs equal sales for each industry, but the use of different value added data in the model will violate equilibrium conditions in basic data.

A number of adjustments are therefore necessary to basic data some of which are small and others which are more substantial. The systematic adjustments which are used follow the procedures described in Piggott and Whalley [1977]. More detail on the specifics of these adjustments is given in Appendix B.

Completing the Model Specification--Substitution Elasticities

For the model considered here, it is not sufficient to provide a benchmark equilibrium data set in order to parameterize the model, for the functional forms considered elasticity values must also be specified.

These are critical parameters and ideally are the object of extensive investigations as to the effects of variations in parameter values on model predictions. The procedure followed is to select ranges of values from a literature search for production function elasticities, and to use ranges of plausible values for utility function elasticities. The implications of particular demand side values can be assessed in the aggregate by linking combinations of values to implied point estimates of price elasticities at the benchmark equilibrium. The recent survey by Caddy [1976] provides the production function elasticity values. An independent literature survey has been conducted to determine price elasticity estimates.

Numerical Solution of the Model

Numerical determination of competitive equilibria for the model involves a systematic search for an equilibrium set of prices and quantities which meet the conditions of a competitive equilibrium. The search used focuses on candidate price vectors; and due to the homogeneity property of demand functions prices can be normalized to sum to a constant. The search is therefore restricted to a unit price simplex. As tariffs and taxes operate in the economies considered, the price simplex must be augmented to include an additional dimension for the total taxation revenue collected by each trading bloc.

There are two types of search procedures which can be used for the model; Newton methods and simplicial subdivision mthods. In each of these, a search procedure across the augmented simplex is followed. In the case of Newton methods the search procedure involves a movement across the simplex in directions indicated by the local behaviour of excess demand functions at any point under consideration. Steps can be large or small and there is no guarantee that the search procedure will terminate with an equilibrium solution. With simplicial subdivision methods the search procedure involves the partition of the simplex into a finite number of pieces (sub-simplices). Instead of taking steps of variable size across the simplex, movements across the simplex are made to neighbouring pieces. The finiteness of the number of pieces of the simplex guarantees that an approximation to an equilibrium solution will eventually be found. This approximation becomes exact as the number of subsimplices considered becomes large, although the amount of computational time required to find a solution will also rise.

With the original simplicial subdivision methods developed by Scarf [1967, 1973], a particular difficulty was that the degree of approximation for the solution needed to be pre-set. If a fine approximation was desired a large amount of execution time was necessary to examine many small subsimplices, but a quicker solution yielding a crude approximation could not be easily refined without a repetition of the whole solution procedure. For this reason, the original uses of Scarf-type procedures were supplemented by a Newton termination method to improve the sense of the approximation. Over time, it became apparent that for many of the problems to which Scarf procedures were applied, Newton methods could be used in their own right as solution procedures without reliance on a prior Scarf-type calculation. At the same time recent advances in simplicial subdivision methods due to Eaves [1972] and Merrill [1971] allow continual refinement of the sense of approximation without a complete recalculation, and these techniques have resulted in a substantial improvement in the performance of simplicial subdivision methods.

For the present study, there is therefore a choice between these solution methods. While simplicial subdivision methods have an ex ante convergence argument in their favour, this argument is not of great importance provided solutions are in practice rapidly found. The choice between these two methods has therefore been made on grounds of speed of solution. Newton methods have proven to be quicker than simplicial subdivision methods and have shown themselves to be reliable in finding solutions in that no convergence difficulties have been encountered.

Newton's method is a technique for the numerical solution of a set of non-linear equations of the form

$$f(x) = 0$$

where f is a differentiable function. The method is based on the approximation that in the neighbourhood of a point x_o, a set of linearized functions serve as a good approximation to f

$$f(x) \doteq f(x_o) + f'(x_o)(x - x_o)$$

and that linear equation systems are easier to solve than non-linear.

The solution procedure is to start with some initial guess, x_o, and solve the linearized function for a value of x for which the function is zero, if such a solution exists. If not, a solution which minimizes the function can be obtained. At this solution, the function values for the non-linear equations can be obtained and a decision made as to whether to continue the procedure. If continuation proceeds, a new guess is obtained by modifying x_o on the basis of the solution values to the linearized equations. For many problems, convergence has been found to be extremely fast and this experience accounts for the extensive use of the method.[1] A criterion, ϵ,

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[1] An exposition of these convergence conditions appears in Robinson [1975]. An important property is that frequently labelled 'quadratic convergence'. Formally stated, if f satisfies a Lipschitz continuity condition in the neighbourhood of a value $\hat{x}$ for which $f(\hat{x})= 0$, then there is a neighbourhood of $\hat{x}$ such that for any initial point x_o the sequence $\{x_k\}$ exists and converges quadratically to $\hat{x}$. This is implies that there are constants α and γ, where $0 < \gamma < 1$, such that forall k $\|x_k - \hat{x}\| \leq \alpha\gamma(2^k)$.

is usually set as a stopping rule, such that x^* is accepted as a sufficiently close approximation to a solution if

$$\| f(x^*) \| \leq \epsilon$$

The two major difficulties in the implementation of Newton's method are the choice of an initial starting value x_o, and the repeated solution of the system of linear equations.

The choice of initial value of x_o, in this study is the 'benchmark equilibrium' represented by the consistent benchmark equilibrium data set. It is known that with starting values that are too far away from x^* to satisfy theoretical requirements for convergence properties, rapid convergence is nonetheless usually obtained. This has been the experience in this case, although no general proof of convergence is available for this particular model.

The major difficulty in solving the linear equation system is in the computation of the matrix $f'(x)$. While complicated partial derivatives can be calculated using analytical differentiation programmes, a more satisfactory way of coping with the problem in the present study is to avoid computing $f'(x)$ and use an approximation based on function evaluations of $f(x)$. These procedures are sometimes referred to as secant methods.

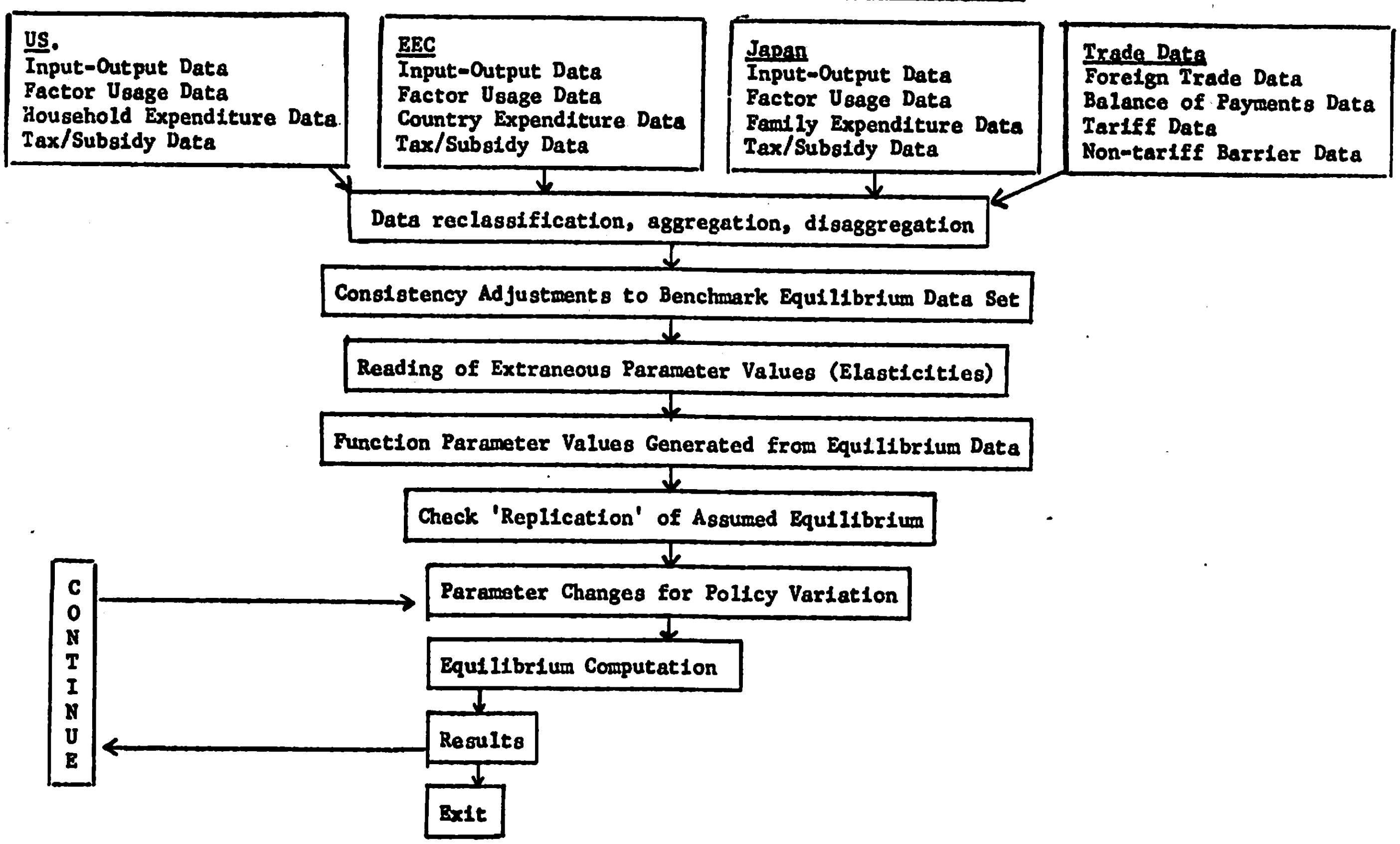
The experience with these methods here has been satisfactory; and from what comparisons are possible, it appears the Newton methods give faster execution than simplicial subdivision procedures. More details of the procedures used appear in Appendix C.

Computational Characteristics of the Model

The structure of the computer programmes is outlined in Figure 7 along with some of their machine characteristics. An important practical feature that the construction and use of this model has revealed thus far is that accommodating

Figure 7

Structure of Computer Programs and Machine Characteristics



Machine and Program Features

Machine: Cyber 73

Program Length in number of statements: (approx.) equilibrium computation 4,000; data classification and adjustments 3,000; parameter value generation 2,000; print format and results 3,000

Execution Time: depending on parameter values and nature of policy change in the region of 3 1/2 hours.

Compilation Time: approx. 40-50 seconds for each bloc of code

Space requirement: main frame (49K), plus most of an extended core facility (88K) plus 250K of a mass storage device (K denotes thousand words; The Cyber 73 uses a 60 bit word).

Data Requirements: "crude" data usage around 60,000 numbers; "model" data requirement 20,000 parametric values

Behavioral function evaluations: To calculate on excess demand correspondence for a given price vector requires evaluation of around 5,000 derived demand functions (by product and agent). A run of 3 1/2 hours would evaluate 240-300 excess demand correspondences.

the realism which the present model seeks makes substantial demands on space and speed of even fairly advanced computer technology.

Space is a difficulty which stems from the size of the model which has around 20,000 parameter values and uses some 60,000 basic pieces of informational data. Space, however, is the more minor of the problems as with repeated writing and re-reading from disk these problems can be overcome. The more difficult machine problem is the amount of execution time required.

Even with substantial amounts of optimization of code, and with the use of simplification devices in the solution of the model, execution times in the range of 3 1/2 hours - 4 hours have been experienced on the University of Western Ontario Cyber 73 system. Even though this machine is somewhat slower than many later generation machines (perhaps 15 times slower than a CDC 7600, and 6-8 times slower than an IBM 370/168) these are still large amounts of execution time. Debugging is inevitably slow, and execution runs have to be chosen with considerable care and advanced planning. These large execution times stem directly from the problem of 'dimensionality'.

Dimensionality in its crudest terms can be thought of as the overall size of the model, but in practice there are more specific features which can be identified as critical.

Two features of the dimensionality of the present model are

(i) The Dimensionality of Function Evaluation:

This is the dimensionality in which calculations underlying market demand and supply functions must be made. On the demand side of the economy the critical dimensions are the number of consumers and the number of commodities. In the present model this is a dimension of 41 by 128. On the supply side the dimensions involved are those of the number of industries and the number of inputs. As intermediate production enters the model this is a dimension of 128 by 136 although the treatment of the primary factors is more complex from a functional point of view than the other products.

Although these dimensions are critical (especially those on the demand side of the economy), the complexity of the functions involved must also be considered and simple relationships between 'size' (e.g., number of commodities) and execution time requirements cannot easily be claimed.

(ii) The Dimensionality of Search:

The dimensionality within which function evaluation takes place is typically larger than that involved for the search procedure over a simplex. The dimensionality of this simplex is crucial in determining the number of steps which must be made across the simplex in the search for an equilibrium. In the case of the model used here, simplifying devices reduce the dimension of simplicial search to 12 from the full price-revenue simplex of 140. From a computational point of view, this reduced dimension is a major factor making the computational approach operational for this model.

Of the execution time usage, experience suggests that the majority of that time is spent in function evaluation, particularly in evaluating the market demands for commodities at candidate price vectors. This suggests that execution times will be sensitive to the functional forms which are used to describe demand patterns and this seems to be borne out by experience.[1]

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[1]For instance, changing the structure of utility functions in the Piggott-Whalley model of the UK economy to a three level nesting structure rather than a two level structure increased execution time by around 25%.

Specifying the Rest of the World

The discussion in this section has neglected the specification of, and generation of data for,the rest of the world. It is an impossible task to specify a realistic data set for such an amorphous group, and the procedure followed here has been to specify the rest of the world crudely by ignoring most of the detailed features which are modelled for the US, Japan, and the EEC. There is no intermediate production, no taxes or subsidies, no tariff policy and only a single consuming unit. Numbers for factor endowments in this bloc are used which are large relative to the rest of the model. This means that the US, EEC, and Japan are price takers on world trade markets for the rest of world products and actions of the trading blocs cannot affect world prices for these products. While this may not be wholly accurate it helps to isolate the features arising from trade policy variations in these economies from other effects which may be induced by an artificial variation in the rest of the world prices.

IV. Some Preliminary Findings from the Model

Policy Variations Considered

The model described is ultimately intended to provide a general capability of analysis of alternative trade policy regimes. Thus far, only a limited number of solutions have been obtained for a model which is still incomplete in certain respects. Also a complete check both of basic data calculations on worksheets and of the correctness of data entry has not been made. The results reported must therefore be treated as preliminary findings which may be subsequently modified.

Three variations in trade policies are considered here in which all three trading blocs separately abolish their tariff barriers, their non-tariff barriers, and the combination of the two. In none of the cases considered is there a replacement tax for the foregone tariff revenue, and so in two of the three cases there is a small reduction in the size of the public sector in each trading bloc. While the variations considered are in no way a reflection of proposals currently under consideration, they provide an overall quantitative indication of the restrictive impact of trade barriers. Further variations in trade policies will be considered as the model is more extensively used.

No investigation has been made of the sensitivity of findings reported with respect to substitution elasticity parameters. Such investigations will, of course, be eventually undertaken. On the production side, as previously mentioned, central tendency estimates of production function substitution elasticities by industry are taken from Caddy [1976]. The same estimates are used by industry for each trading bloc. These estimates are systematically below one, with a mean value of approximately 0.85. These estimates come from a pooled sample of cross section and time series estimates. As is well known, cross section estimates differ from time series estimates by an approximate order of magnitude of 2. The use of cross section central tendency estimates, which some would consider more reasonable, would change the findings somewhat. On the demand side, a two rather than three level nested structure of preference functions has been used. For all consumer groups a value of 3.0 is taken for the substitution elasticities between 'identical' domestically produced and imported products, and a value of 0.75 for the substitution elasticity between broad groups of products. These values can be crudely justified by relating them to comparable estimates of (uncompensated) price elasticities. If the budget share of any consumer on any good is small, then in the neighbourhood of the benchmark equilibrium with prices of unity the corresponding (uncompensated) price elasticities will approximately equal these substitution elasticities. The Almon-Buckler [1974] estimates of US price elasticities for products differentiated by point of origin are not, on average, dissimilar to the assumed value of 3.0. Estimates of uncompensated price elasticities by product type are usually in the range of 0.5 to 1.25 with lower values for manufactured items, food, and housing, and higher values for services.

The model remains at this stage incomplete in the following respects.

(i) The consumer expenditure data for the household sector of each of the trading blocs has not been incorporated into the programming, even though much of the basic data work on reclassification has been done. Thus, for the model as presently constituted, no internal distributional impacts of trade policy variations are incorporated.

(ii) The treatment of transport does not conform to that specified in Appendix B. The fixed coefficient transport requirements of each product on each transshipment route has not been incorporated, although transport appears as a product entering both intermediate production and final demands. Some transportation services will therefore be demanded along with imported goods but not in the fixed coefficient transshipment route manner ultimately intended.

(iii) The level of nesting in the utility functions has been kept to two rather than three (with similar items produced in each trading bloc within a nest).

(iv) The consistency of the benchmark equilibrium data set has not been achieved in the more satisfactory way described in Piggott and Whalley [1977] which uses national accounting totals for value added and consumption expenditures by product. Thus no consistency adjustments have been applied to input-output data to allow for classification and other differences between basic data sources and the model.

(v) Some domestic taxation parameters, in particular the domestic output taxes of both a specific and a broadly based kind, remain to be specified.

(vi) The use made of the implied point estimates of price elasticities of demand functions for parametric choice of the model is crude. These elasticity values are of substantial importance for the results obtained and will be thoroughly investigated.

(vii) Where data are not available for non-tariff barrier ad valorem equivalents (chiefly semi-manufactured items) a zero rate has been assumed.

In interpreting findings it must be re-emphasized that a large volume of data is involved in using this model. Extensive checking of all data manipulations and calculations is needed and while never complete only a limited amount been done at this stage.

<u>Results and Implications for Trade Liberalization</u>

For each of the policy variations considered, three sets of summary statistics are reported; the impact of the policy changes on the volume and pattern of world trade, movements in the terms of trade for each trading bloc, and the pattern of domestic production in each case.

Figure 8 reports the world trade impacts. The trade flows in each equilibrium are valued at the equilibrium prices associated with the benchmark equilibrium, and so Laspeyeres indices of trade quantities are reported. Results using Paasche indices are substantially the same. Trade included is merchandise trade plus service items appearing in the balance of payments accounts. Capital movements and investment income flows are excluded.

Figure 8 suggests that the abolition of tariff and non-tariff barriers in the U.S. EEC and Japan would increase the 1973 value of world trade by approximately U.S.$35 bill. This is about an 8% increase in the volume of world trade, or put another way, the increase in the value of world trade is less than 1% of 1973 world GNP. Abolition of tariff barriers alone would increase world trade by U.S.$10 bill. while abolishing non-tariff barriers would increase trade by U.S.$20 bill. The two sets of policies thus have a compounding effect on the level of world trade. The effects of these two areas of

Figure 8

TRADE LIBERALIZATION AND THE VALUE OF TRADE (EXCLUDING CAPITAL MOVEMENTS)

(Bill 1973 $ US)

Imports by

		EEC	US	Japan	R.O.W.	Total
A. Original Trade						
From	EEC	0.0	21.6	4.5	83.5	109.6
	US	20.2	0.0	11.7	55.0	86.9
	Japan	5.2	12.1	0.0	25.2	42.5
	ROW	73.4	53.9	29.3	0.0	156.6
	Total	98.8	87.6	45.5	163.7	395.6
B. Abolition of Tariffs and Non-tariff Barriers						
From	EEC	0.0	22.9	4.6	88.0	115.5
	US	22.0	0.0	13.2	59.8	95.5
	Japan	5.6	14.1	0.0	30.0	49.7
	ROW	80.4	56.5	32.1	0.0	169.0
	Total	108.0	93.5	49.9	177.8	429.7
C. Abolition of Tariffs						
From	EEC	0.0	22.3	4.6	83.9	110.8
	US	21.1	0.0	12.8	56.7	90.6
	Japan	5.4	13.0	0.0	26.5	44.9
	ROW	74.7	55.1	29.8	0.0	159.6
	Total	101.2	90.4	47.2	167.1	405.9
D. Abolition of Non-tariff Barriers						
From	EEC	0.0	22.1	4.4	87.2	113.7
	US	21.0	0.0	12.2	57.4	90.6
	Japan	5.4	12.9	0.0	28.3	46.6
	ROW	78.7	55.1	31.4	0.0	165.2
	Total	105.1	90.1	48.0	172.9	416.1

policy appear unequally balanced and suggests the stress being placed on non-tariff barriers in the current Tokyo round negotiations is well founded. Abolition of both tariff and non-tariff barriers reduce the trade surplus position of the EEC slightly, changes a small deficit into a surplus for the U.S., brings a $3 bill. deficit for Japan into approximate balance and worsens the deficit position of the rest of the world. The impacts of trade liberalization on aggregate world GNP are less than 0.2%, an almost negligible amount.

Figure 9 reports the terms of trade effects which abolition of trade barriers produce. The abolition of all trade barriers results in a rise in import prices relative to domestic prices in each of the three trading blocs (and a fall in the rest of the world). If tariffs and non-tariff barriers are separately removed the terms of trade worsen in the EEC. The surprising feature of Figure 9 is the differential strength of these effects across trading blocs. In the Japanese case, import prices rise by 7% whereas for the US a 1.5% rise occurs. For the EEC a rise of 0.2% occurs. In addition to the differential strength of terms of trade effects the relative sizes of the effects in the US and EEC is a little surprising. Many people would probably characterize the EEC as more protectionist than the US though this turns out not to be the case. The inclusion of all domestic taxation and subsidy effects in this calculation, however, may alter this conclusion.

In Figure 10 the percentage changes in levels of production for each domestic industry are reported. The largest variation is the expansion in the tobacco industry in the US following abolition of tariff barriers. The majority of this response derives from the abolition of high tariffs in Japan and the EEC. In Japan, especially, there are limited excise taxes on tobacco products but instead a high tariff, and the increased derived

Figure 9

Trade Liberalization and Terms of Trade Movements

RATIO OF IMPORT PRICES TO DOMESTIC PRODUCT PRICES[1]

	Original Situation	Abolition of Tariff and Non-Tariff Barriers	Abolition of Tariffs	Abolition of Non-Tariff Barriers
E.E.C.				
Old Quantity Weights	1.0	1.002	0.994	0.997
New Quantity Weights	1.0	1.004	0.993	0.999
U.S.				
Old Quantity Weights	1.0	1.017	1.015	1.036
New Quantity Weights	1.0	1.014	1.014	1.034
Japan				
Old Quantity Weights	1.0	1.068	1.027	1.103
New Quantity Weights	1.0	1.071	1.026	1.105

[1] In both the old and new equilibria the sum of commodity prices is constant and the two different sets of quantity weights associated with each equilibrium is used to construct the price indices reported.

demand for imported tobacco from the US accounts for the production increase. The large changes in activity in petroleum and coal product industries in the EEC and Japan are also a derived effect from the removal of non-tariff barriers on US coal. The larger response in coal and petroleum products derives from two model features; coal is primarily used in intermediate production where there is no substitutability, and significant exports to the rest of the world are made by all trading blocs for coal and petroleum products but not for coal. In the rest of the world, the model specifies no intermediate production and thus higher degrees of substitution in aggregate between products. The expansion of agricultural production in the EEC in spite of the removal of CAP reflects an expansion of EEC agricultural exports to Japan following the removal of Japanese non-tariff barriers. It may prove possible to correct for features of the model yielding implausible production responses in later runs. Outside of these large variations, another interesting feature is the limited adjustment implied in textiles by the removal of US quotas on textile products. Steel quotas are not included in the model as no ad valorem equivalents for these quotas have yet been obtained. On the whole, variations in production levels by industry are small, suggesting that concerns over adjustment impacts of trade liberalization may be overemphasized.

Further Areas for Application of the Model

At the current stage of development of the model it is premature to claim immediate policy relevance for results obtained thus far. More investigation of model properties is needed in addition to the completion of the structure. In addition, until the personal sectors of each of the trading blocs are fully specified, no impacts of policy variations on the income distribution can be obtained. Current findings suggest the impacts on the functional distribution are small (and thus probably small for the personal distribution). While it is not anticipated that results reported will

Figure 10

Trade Liberalization and Domestic Production

Percentage Change in Production Levels From Original Situation

Industries	EEC Case 1	EEC Case 2	EEC Case 3	US Case 1	US Case 2	US Case 3	Japan Case 1	Japan Case 2	Japan Case 3
Agriculture									
(1) Meats and Dairy Products	6.6	1.6	4.9	-.6	-.3	-.3	-6.2	-.2	-5.0
(2) Cereals	6.0	1.5	4.6	3.6	1.1	1.9	-3.1	-.9	-2.0
(3) Other Agricultural Products	3.8	.8	3.1	-.4	.5	-.7	-7.7	-.4	-6.6
(4) Forestry and Fisheries	-.3	-.1	-.2	-2.9	.1	-3.3	-1.3	-.2	-1.0
Mining									
(5) Coal	-15.0	-.6	-14.5	1.2	-.1	1.2	-8.7	-.2	-8.5
(6) Oil, Natural Gas	- 3.4	2.0	-5.7	.3	.3	-.1	-1.2	-.2	-.9
(7) Metallic, Non-Metallic and Other	1.1	.1	.9	-1.3	-.5	-.8	3.0	.4	2.4
Manufacturing									
Non-Durable Goods									
Prepared Food and Kindred Products									
(8) Tea, Sugar, Coffee, Spices, Cocoa	.5	.2	.6	-.2	.1	-.4	17.2	4.9	10.6
(9) Alcoholic Drinks	1.5	.8	.9	1.2	-1.1	2.2	-.6	-.2	-.4
(10) Other Foods	6.3	1.6	4.5	1.7	.1	1.7	4.6	.4	4.2
(11) Tobacco	3.7	-1.7	5.5	43.2	43.0	1.2	-10.4	-10.5	.1
(12) Apparel and Textile Products	5.7	1.4	3.9	-3.4	-.6	-2.1	12.0	1.1	9.6
(13) Paper, Printing, Publishing	1.9	.3	1.7	.1	-.1	.3	-1.4	-.2	-1.0
(14) Pharmaceuticals and Toiletries	-.6	.5	-.2	1.1	.2	.9	-.2	-.1	.1
(15) Other Chemical and Allied Products	8.9	1.3	7.0	-.1	-.1	-.1	8.5	1.2	6.7
(16) Petroleum and Coal Products	38.5	.1	38.4	-.3	.1	-.2	28.2	.2	26.6
(17) Rubber and Plastics	3.3	.9	2.2	.5	.2	.3	14.1	2.0	11.0
Durable Goods									
(18) Lumber, Wood and Furniture	2.9	1.2	1.8	2.2	.4	1.8	3.3	-.4	3.8
(19) Primary and Fabricated Metals, Stone Glass	2.2	.9	1.1	-.1	-.4	.2	.7	.8	-.2
(20) Machinery Except Electrical	.7	.4	1.3	1.0	.4	.4	2.1	.8	1.2
(21) Electrical Machinery	.5	.4	.1	.1	-.2	.2	1.3	1.1	-.2
(22) Transport Vehicles	.7	.7	-.1	.8	-.1	.6	6.9	3.0	3.4
(23) Scientific and Precision Instruments	-.2	.1	-.3	.8	.2	.4	2.0	.8	1.0
(24) Miscellaneous Manufacturing	.3	.7	-.4	.4	-.4	.7	1.4	.4	.8
(25) Construction	.4	.1	.4	-2.5	-.9	-1.5	1.8	.4	1.3
(26) Water Transportation	6.3	1.0	5.3	-.7	.1	-.8	3.2	1.5	1.5
(27) Other Transportation and Communications	.1	-.1	.2	.4	.1	.2	-.6	-.1	-.5
(28) Housing Services	-.6	.1	-.6	-.5	-.3	-.1	-2.8	-.6	-2.0
(29) Electricity, Gas and Sanitary Services	.1	-.1	.2	-.4	-.2	-.2	3.9	.2	3.7
(30) Wholesale and Retail Trade	-.3	-.1	-.3	-.2	-.2	-.1	-2.0	-.4	-1.4
(31) Finance, Insurance and Real Estate	1.3	.6	.8	-.2	-.2	-.1	-2.3	-.5	-1.7
(32) Other Services	-1.4	-.3	-1.1	.6	-.2	.3	.8	.3	.6
(33) Government	-3.8	-.8	-3.0	-.4	.2	-.2	-6.3	-1.2	-4.7

Case 1: Abolition of all tariff and non-tariff barriers.

Case 2: Abolition of all tariff barriers.

Case 3: Abolition of all non-tariff barriers.

change substantially with the inclusion of the remaining features, no model findings should be casually accepted. It is particularly important that numerical features of the model that give rise to particular results be understood and upon reflection thought to be reasonable. A period of time is also needed to reflect on results.

The findings obtained thus far do, however, seem to be of special interest as they appear to be the first of their kind obtained by any numerical model be it partial or general equilibrium. There are also a number of fruitful areas for further application of the model which would seem worth investigating once the model is complete.

(a) The effects of explicit tariff-cutting formulae can be considered and their general equilibrium effects appraised.

(b) The relative importance of tariff barriers and non-tariff barriers seems worthy of extensive investigation to determine which features of these policies have the largest impacts. This would provide an approximate ranking of trade policies by relative importance for liberalization negotiations.

(c) The impacts of particular policies are of special interest as they figure so prominently in trade liberalization negotiations (CAP in the EEC, textile quotas, for example). These can be systematically explored.

(d) The general equilibrium impacts of protection pursued by trading blocs through tariff policy have not been investigated for a regime where non-tariff barriers and domestic taxation/subsidy policy co-exist. The role of these additional policies in tariff policy appraisal is little explored in the literature.

(e) The extent of incentives for trading blocs to pursue retaliatory trading policies towards each other can be investigated. These retaliatory incentives are stressed repeatedly in the optimal tariff literature and are raised in many discussions of policy actions by trading blocs. Little is known numerically as to whether there are likely to be large or small variations in policies as retaliatory processes occur.

By way of qualification it should be repeated that this is a large and computationally expensive model and even at a production run phase it may well only be possible to solve the model three or four times a week.[1] This means that considerable care has to be taken in deciding the forms of policy variations explored. Furthermore, there are difficult decisions of research strategy involved as to whether policy variations alone are explored, or whether model variations are also considered at the cost of some policy investigation. The absence of substitutability between intermediate products would clearly seem to bias results and would appear worthy of considerable investigation. Expanding the model to include this feature would, however, result in much enlarged execution times and a considerable simplification in the dimensions of the model would probably be needed.

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[1]Computer time for the solution and use of this model has been contributed by the University of Western Ontario. The current estimate is that debugging along with production run usage could well finish up involving an average of 12 hours of execution time per week over a two-year period.

V. Conclusion

In this paper, a large scale general equilibrium trading model of the US, the (9 member) EEC, and Japan has been described. This is a numerical model which integrates the effects of tariff and non-tariff barriers with domestic production and consumption activity. Recently developed computational techniques are used in solving the model. These are explained, and the list of data sources used in specifying the model provided. A substantial constraint on the extensive use of the model (and on further elaborations in dimensionality or structure) is the large amount of execution time which solution requires.

The model aims to provide a general capability of analysis of variations in trade policies by each of the major trading blocs. The interacting effects of policy variations can be traced in terms of trade flows by commodity by trading bloc, relative price variations, income distribution effects, and industry adjustments which policy variations imply. Even though the model is not yet wholly completed, some preliminary findings of the impacts of wholesale trade liberalization are reported. An estimate is obtained that the abolition of all trade barriers by the US, the EEC, and Japan would expand the volume of world trade by around 8%, although considerable caution is urged in the use and interpretation of this figure at this stage. Terms of trade effects and industry adjustment effects are also reported. The further uses of the model and possible extensions are also discussed.

APPENDIX A

Algebraic Representation of the Model

A. Notation

The subscripts k, j, i, c refer to countries, industries, commodities, and consumer groups, respectively. K and L refer to the factors capital and labor; without a bar indicating usage, with a bar indicating ownership. Thus, K_j^k is the use of capital of type k (that is, associated with country k) in industry j located in country k. $\bar{K}_k^c$ indicates the ownership of capital of type k by consumer group c.

Y refers to the value added originating in any industry while G refers to the gross output level of any industry. The notation H will refer to a vector of intermediate usage of commodities by any industry, X refers to consumption of commodities for final purposes by any agent, and U refers to the utility level attained by any consumer group. P refers to a vector of world market prices for both goods and factors. The notation X_1, X_2, and P_1, P_2 refer to quantity and price indices of 'artificial' composite commodities whose calculation is required in the solution of demand functions from the nested utility functions used.

Functional notation is used in two different contexts. The solutions of behavioral functions dependent on prices are represented as functional relations; X(P) being total consumer demands for products at the vector P, G(P) being the vector of gross outputs of commodities which meet the vector of final demands X(P). In addition, functional notation is used on occasions for subscripts; thus k(j) is the country where industry j is located and k(c) is the country where the c^{th} consumer group is located.

There are 128 commodities (33 in the US, 33 in EEC, 33 in Japan, 29 in ROW), and 8 factors (2 in each trading bloc). The index i will therefore run from 1,...,136 but as zero demands for labour are considered i will be written to run from 1,...,132. The index j will be written to run from 1,...,33 even though in ROW it runs from 1,...,29. The notation j(i) indicates the j subscript corresponding to any i, and i(j) vice versa. i(k) is the i subscripts of goods produced in country k. The three level nesting in preference functions is identical in structure for all agents and is a three-way partition of the single index i. There are 34 intermediate nests (containing similar products of the four trading blocs) grouped in turn into 6 top level nests (containing broad categories of commodities). The notation $i(\ell,m,q)$ indicates the i subscript corresponding to the three level identification (ℓ,m,q).

41 groups of consumers are considered, and the notation W is used to refer to consumer transfer income received $W^{C}_{R_{k(c)}}$ being the transfers received by c from the government in k where he resides. R_k is the government revenue collected in country k and α_k the proportion retained by the government to finance real expenditures. IT are payments of income taxes.

B. Technology

(i) Industry Value Added Functions

$$Y^k_j = \gamma^k_j \left[\delta^k_j (K^k_j)^{-\rho^k_j} + (1-\delta^k_j)(L^k_j)^{-\rho^k_j} \right]^{-\frac{1}{\rho^k_j}} \qquad k = \text{US, EEC, J, ROW} \quad j=1,\ldots,33 \text{(29 for ROW)}$$

(ii) Intermediate Production Requirements

$$H^k_{ij} = a^k_{ij}\, Y^k_j \qquad k = \text{US, EEC, J} \quad j=1,\ldots,33;\ i=1,\ldots,99$$

$$a^k_{ij} = 0.0 \qquad k = \text{US, EEC, J} \quad j=1,\ldots,33;\ i=100,\ldots,128$$

$$a^{ROW}_{ij} = 0.0 \qquad j=1,\ldots,29;\ i=1,\ldots,128$$

C. Consumer Preferences and Incomes

(i) Utility Functions

$$U^c = \left[\sum_{\ell=1}^{6} b_\ell^c (X2)_\ell^{c\,\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \qquad c=1,\ldots,41$$

$$(X2)_\ell^c = \left[\sum_{m=1}^{N^\ell} d_m^c (X1)_m^{c\,\frac{(\sigma_\ell-1)}{\sigma_\ell}} \right]^{\frac{\sigma_\ell}{\sigma_\ell-1}} \qquad c=1,\ldots,41$$

$$(X1)_m^c = \left[\sum_{q=1}^{4} e_q^c X_q^{c\,\frac{(\sigma_m-1)}{\sigma_m}} \right]^{\frac{\sigma_m}{\sigma_m-1}} \qquad c=1,\ldots,41$$

Index i on commodities corresponds to index (ℓ,m,q) on nests. Commodities with i subscripts 1,...,33 (US products) have (ℓ,m,q) subscripts ((1,1,1),...,(5,10,1)); commodities with i subscripts 34,...,66 (EEC products) have (ℓ,m,q) subscripts ((1,1,2),...,(5,10,2)); commodities with i subscripts 67,...,99 (Japanese products) have (ℓ,m,q) subscripts ((1,1,3),...,(5,10,3)); commodities with i subscripts 129, 130, 131, 132 (factors appearing in utility functions) have (ℓ,m,q) subscripts ((6,1,1),...,(6,1,4)).

(ii) Consumer Disposable Incomes

private sector households $I^c = \sum_{k=1}^{4} P_k^K \cdot \bar{K}_k^c + P_{k(c)}^L \cdot \bar{L}_{k(c)}^c + W_{k(c)}^c - IT_{k(c)}^c$

c=1,...,10(US)
c=1,..., 8(EEC)
c=1,...,16(J)
c=1(ROW)

government $I^c = \sum_{k=1}^{4} P_k^K \cdot \bar{K}_k^c + \alpha_{k(c)}^c \cdot R_{k(c)}$

c=1(US)
c=1(EEC)
c=1(J)
c=1(ROW)

corporate sector $I^c = \sum_{k=1}^{4} P_k^K \bar{K}_k^c$

c=1(US)
c=1(EEC)
c=1(J)
c=1(ROW)

D. Tariff/Non-Tariff/Tax/Subsidy System

Trade Policies

(i) Tariffs: ad valorem rates t_{ik}^{M1} on imports of good i into country k. (i=1,...,128); (k=US,EEC,J).

(ii) Non-tariff barriers: ad valorem rates t_{ik}^{M2} on imports of good i into country k. (i=1,...,128); (k=US,EEC,J).

Domestic Taxes and Subsidies

(iii) Domestic factor taxes and subsidies; ad valorem rates t_{jk}^{L}, t_{jk}^{K} on the usage of labor and capital in industry j in country k. (j=1,...,33); (k=US,EEC,J).

(iv) Domestic intermediate usage taxes and subsidies: ad valorem rates t_{ik}^{I} on the purchase of commodity i for use by industries located in country k (i=1,...,128); (k=US,EEC,J).

Domestic production taxes and subsidies: ad valorem rates t_{jk}^{P} on the production of the j^{th} industry located in country k (j=1,...,33); (k=US,EEC,J).

(v) Value Added Tax: ad valorem rates t_{ik}^V on the i^{th} commodity in country k. The system is administered on a destination basis and is rebated on exports and charged on imports. (i=1,...,128); (k=EEC). Although the tax only operates in the EEC, its introduction in other trading blocs can also be considered by the approach.

(vi) Consumer purchase taxes: t_{ik}^c ad valorem rate on the purchase of the commodity in the k^{th} country (i=1,...,128); (k=US,EEC,J).

(vii) Income tax system: t_T^c ad valorem marginal income tax on taxable income of c^{th} consumer group; (i=1,...,46); e_i^c proportion of c^{th} consumer group's purchase of i^{th} commodity exempt from tax (c=1,...,46) (i=1,...,128); L^c, tax free personal allowance of c^{th} consumer group (assumed constant in real terms) (c=1,...,46).

E. Prices and Their Interpretation

P_k^K, P_k^L; market prices for capital and labor of type k. These are the prices paid by domestic industries using these factors net of factor taxes and factor subsidies; they are also the prices received by factor owners (before liability to income taxes).

P_i i=1,...,128; selling prices for producer outputs gross of domestic production taxes and production subsidies; they are also f.o.b. world export prices received by exporters, and are the prices paid by domestic consumers before consumer purchase taxes.

P_k^T; price per unit of transportation services of type k. Water transportation services only are assumed to be used in foreign trade transactions and are identified among the 33 domestic industries in each trading bloc.

S_{ik}; per unit transport requirement to ship a unit of commodity i from its point of production to country k.

$(P_i + S_{ik} \cdot P_k^T)$; c.i.f. import price of commodity i in country k. It is assumed that only k's transportation services are used to ship k's imports.

P : vector of world prices $(P_1, \ldots, P_{128}, P_1^K, P_1^L, P_2^K, P_2^L, P_3^K, P_3^L, P_4^K, P_4^L)$.

F. Demand Function Solutions

(i) Final Demands

$$X_i = \sum_{c=1}^{41} X_i^c \qquad (i=1,\ldots,132)$$

$$X_i^c = \frac{(e_q^c)^{\frac{1}{\sigma_m}} \cdot P_q^c (X1)_m^c}{{P_q^c}^{\sigma_m} \sum_{q=1}^{4} (e_q^c)^{\frac{1}{\sigma_m}} (P_q^c)^{(1-\sigma_m)}} \qquad \begin{array}{l}(i=1,\ldots,132)\\ (c=1,\ldots,41)\\ [(e,m,q)=(1,1,1),\ldots,(6,1,4)]\end{array}$$

$$(X1_m^c) = \frac{(d_m^c)^{\frac{1}{\sigma_e}} \cdot (P2_e^c)(X2_e^c)}{(P1_m^c)^{\sigma_e} \cdot \sum_{m=1}^{N^e} (d_m^c)^{\frac{1}{\sigma_e}} \cdot (P1_m^c)^{(1-\sigma_e)}} \qquad \begin{array}{l}(c=1,\ldots,41)\\ [(e,m)=(1,1),\ldots,(6,1)]\end{array}$$

$$(X2_e^c) = \frac{(b_e^c)^{\frac{1}{\sigma}} \cdot I^c}{(P2_e^c)^{\sigma} \cdot \sum_{e=1}^{6} (b_e^c)^{\frac{1}{\sigma}} \cdot (P2_e^c)^{1-\sigma}} \qquad \begin{array}{l}(c=1,\ldots,41)\\ [e=1,\ldots,6]\end{array}$$

$$(P1_m^c) = \sum_{q=1}^{4} (e_q^c)^{\sigma_m} \cdot (P_q^c)^{1-\sigma_m} \qquad \begin{array}{l}(c=1,\ldots,41)\\ (m=1,\ldots,N^e)\end{array}$$

where

$$P_q^c = ((P_{i(e,m,q)} \cdot (1+t_{i,k}^{M1}) \cdot (1+t_{i,k}^{M2})) + S_{ik(c)} \cdot P_R^T)$$

$$\cdot (1+t_{ik}^c) \cdot (1-e_i^c \cdot t_T^c)$$

$$(P2_e^c) = \sum_{m=1}^{N^e} (d_m^c)^{\sigma_e} \cdot (P1_m^c)^{1-\sigma_e} \qquad \begin{array}{l}(c=1,\ldots,41)\\ (e=1,\ldots,6)\end{array}$$

The vector X(P) denotes market demands for commodities for final use at the vector P.

(ii) Industry Production Levels to Meet Consumer Demands

$$G(P) = [I - A]^{-1} X(P)$$

(iii) Derived Industry Demands for Factors

$$K_j^k(P) = \left[\delta_j^k\left[\frac{(1-\delta_j^k)\cdot P_k^L(1+t_{jk}^L)}{\delta_j^k P_k^K(1+t_{jk}^K)}\right]^{\frac{\rho_j^k}{\rho_j^K+1}} + (1-\delta_j^k)\right]^{\frac{1}{\rho_j^k}} \cdot \frac{G_{i(j)}^k(P)}{\gamma_j^k}$$

$$L_j^k(P) = \left[(1-\delta_j^k)\left[\frac{\delta_j^k P_k^K(1+t_{jk}^K)}{(1-\delta_j^k)P_k^L\cdot(1+t_{jk}^L)}\right]^{\frac{\rho_j^k}{(\rho_j^k+1)}} + \delta_j^k\right]^{\frac{1}{\rho_j^k}} \cdot \frac{G_{i(j)}^k(P)}{\gamma_j^k}$$

G. Equilibrium Conditions of the Model

(1) Demand-Supply Equalities for Commodities and Factors

(a) For Commodities

$$X_i(P) = G_i(P) - \sum_{k=1}^{4}\sum_{j=1}^{33} a_{ij}^k G_{j(i)}^k(P) \qquad (i=1,\ldots,128)$$

(b) For Factors

$$\sum_{j=1}^{33} K_j^k(P) + X_K^k(P) = \sum_{c=1}^{41} \overline{K}_k^c \qquad (k=US,EEC,J,ROW)$$

$$\sum_{j=1}^{33} L_j^k(P) = \sum_{c=1}^{41} \overline{L}_k^c \qquad (k=US,EEC,J,ROW)$$

(2) Zero Profit Conditions for all Industries

$$\frac{P_{i(j)}}{(1+t^V_{ik})} = (1+t^P_j)\left[P^K_k \frac{K^k_j(P)}{G_{i(j)}(P)}(1+t^K_{kj}) + P^L_k \cdot \frac{L^k_j(P)}{G_{i(j)}(P)}(1+t^L_{kj})\right.$$

(Domestic factor costs)

$$+ \sum_{i(k)} a_{ij} \cdot P^j_i \cdot (1+t^I_{ik}) \cdot \frac{1}{1+t^V_{ik(j)}} \cdot G_{i(j)}(P)$$

(Costs of intermediate usage of domestic products)

$$\left. + \sum_{i \neq i(k)} a_{ij} \cdot P^j_j \cdot (1+t^I_{ik}) \cdot \frac{1}{1+t^V_{ik(i)}} \cdot G_{i(j)}(P)\right]$$

(Costs of intermediate usage of imported products)

(j=1,...,33)
(k=US,EEC,J,ROW)

(3) Zero Trade Balance in All Trading Blocs

$$\sum_{i(k)} \sum_{\ell \neq k} P_{i(k)} \cdot X^{\ell}_{i(k)}(P) + P^K_k X_{K_K}(P) + \sum_{\ell \neq k} X^K_{\ell}(P) \cdot \bar{K}^k_{\ell}$$

(value of exports) + (capital inflows) + (capital income from abroad)

$$= \sum_{i \neq i(k)} P_i \cdot X^k_i(P) + \sum_{\ell \neq k} P^K_{\ell} \cdot X^k_{K_{\ell}}(P) + \sum_{\ell \neq k} P^K_k \cdot \bar{K}^{\ell}_k$$

= (value of imports)+(capital outflow)+(capital income paid abroad)

(k=US,EEC,J'ROW)

The notation k and ℓ refers to country types; $X^{\ell}_{i(k)}(P)$ are the market demands in ℓ for good i produced in country k; P^K_{ℓ} is the market price of capital of type ℓ ; $\bar{K}^k_{\ell}$,$\bar{K}^{\ell}_k$ are the ownerships of capital of type ℓ by country k and type k by country ℓ respectively. $X^k_{K_{\ell}}$ (P) is the demand by country k for capital of type ℓ.

Appendix B. Data Sources and Adjustments

1. Data on merchandise trade:

The basic source for these data is the January to December 1973 issue of O.E.C.D. Trade Statistics, Series 'B'. Foreign trade by commodity in 1973 U.S. $ is reported for the trading blocs for a combination of three and four digit SITC classifications. A correspondence between SITC code numbers and the classification of 33 used in the study is adopted to convert OECD figures on to the classification used in the model.

As the same value of trade flows must appear in the model for imports by and exports from each trading bloc with any other, there are two different sources for trade data in this publication. The convention followed has been to uniformly use export figures reported by the export partners in any trade transaction. These export figures are on an f.o.b. basis and their use avoids the problems of adjustments of c.i.f. import figures.[1]

Some problems as to the completeness of coverage of the model classification are encountered, and additional information is used to disaggregate the trade figures. The notable example of this is the U.S. export statistics which do not report separately 'water transportation' and 'other transportation'. In this case the aggregate ratio for these components was obtained from Foreign Trade Division of the U.S. Bureau of the Census and was assumed to apply to trade in 'transport' with all three other trading blocs.

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[1] As is well known with 'mirror' trade statistics, there are discrepancies which remain after this adjustment of basis, and the use of one set of figures alone here merely avoids rather than resolves such difficulties (see Morgenstern [1961]).

A further difficulty arises with world export figures. OECD data only report imports by trading blocs from the world, which are on a f.o.b. basis only for the U.S.; no world exports are given. World export statistics by product and by trading bloc on a f.o.b. basis are, however, given in the U.N. Yearbook of International Trade Statistics, Volume 1, Trade by Country, 1974. Where the detail by commodity is not sufficiently complete for the model classification used, OECD world imports for the corresponding trade bloc are used as a sequence of weights for purposes of disaggregation. Trade statistics for the 'rest of the world' are determined by residual from trade with the world.

2. Use of Balance of Payments Data

Balance of payments data for each of the three major trading blocs are used to provide information for use in the model on trade in non-merchandise items, inward and outward capital investment, income on investments paid abroad and received from abroad, and transfers made and received from abroad.

Unlike the trade statistics a single unified source is unavailable. Each of the separate balance of payments publications uses different accounting concepts and is incomplete to some extent in coverage. The U.S. Balance of Payments data (Survey of Current Business, Vol. 54, No. 12, December 1974, Tables 1, 2, 9) are most complete in terms of coverage of items in the reported regional balances, but report transactions on a net rather than gross basis for a large range of items. Except for current account data, and information on securities transactions a net basis is used to report only the net transaction, whereas the gross basis is desirable for use in the model.

The Japanese Balance of Payments data (Balance of Payments Monthly, Bank of Japan, April 1975, No. 105, Tables 6, 7, 8, 9, 10, 11, 12) are more complete in providing information on a gross rather than a net basis, but are incomplete in that the regional balances, unlike the total balances, do not report information on short-term capital movements or the balance of monetary movements. EEC data (Balance of Payments 1970-74, Eurostat, 1975) are sparse for the regional balances, and provides more limited coverage of items than the U.S. accounts, and a net basis is used except for current account transactions, direct investments, and a residual 'other asset' category.

The procedure adopted is to first construct a correspondence between item headings identified in all accounts and model equivalent concepts. Service items and transfers are easily identified, but all other items are classified as relating to investment inflows and outflows, and capital income received from or paid to abroad. All figures are converted into 1973 U.S. $. The incomplete regional Japanese balances are completed by assuming a similar composition of missing items in regional balances as in total balances. Balances between each trading bloc and the world come from each separate trading bloc's figures. Because of the limited coverage of the EEC figures, U.S. and Japanese data are used to give US-EEC and Japan-EEC balance items. In the case of U.S.-Japan balance items where gross U.S. figures are available these are used, with Japanese figures being used where available on a gross basis.

3. Adjustments for zero trade balance

The combined set of merchandise trade and balance of payments data as used in the model must satisfy the equilibrium conditions of the model. These conditions are that each trading bloc must be in 'zero trade balance' overall with other trading blocs in the sense that the value of exports plus capital inflows plus income from abroad must equal the value of imports plus capital outflows plus income paid abroad. This is not the case after the component data sources are combined into an overall trade and capital movements data set.

The procedure used has been to adjust capital movements of each trading bloc with the 'rest of the world' until the overall zero trade balance conditions are achieved.

4. Tariff data

The main source for tariff data is the GATT tariff study [Basic Documentation for the Tariff Study, Summary by Industrial Product Categories, Tariffs 1973, Imports 1970 and 1971, Geneva, March 1974.] In this study, average MFN tariff rates for manufactured products and raw materials are reported for some 177 individual items which have in turn been aggregated from a four digit BTN level. There are many differences in valuation procedures which are pointed out in this study (such as the US use of f.o.b., and A.S.P. for certain chemical products), and average rates have to be used with caution. In addition to differing valuation procedures, however, a more fundamental difficulty is the different averaging schemes which the GATT study uses to derive average tariff rates. The difference between these averaging schemes makes a substantial difference to final figures.

These averaging schemes are divided according to two criteria; firstly, as to whether to average over only dutiable items within a category or over all items whether duitable or not, and secondly as to whether an arithmetic or weighted average is used. For the weighted averages, two different weighting schemes are used with both the imports of the trading bloc and world imports (by commodity) being used.

This information is used here by selecting the world import weighted tariff average over all items in a category (whether dutiable or not). A correspondence is formed between the 177 items in the GATT study and the 33 of the model and the averaging procedure extended.

The primary sources for tariff rates on agricultural and processed food items are Yeats [1976], Sampson and Yeats [1976] and the UNCTAD research document, Illustrative tariff profiles of selected developed countries, Kennedy Round, Parts I and IV. A correspondence is taken between detailed information in these sources and the more aggregative classifications of the model, and weighting by world imports is again used.

5. Information and data on non-tariff barriers

A number of sources exist which attempt to document non-tariff barriers in a qualitative manner. Among the most complete and more recent of these is the report of the U.S. Tariff Commission [Trade Barriers, Report to the Committee on Finance of the U.S. Senate, Washington, D.C. 1974; 15 section report published in three parts "Trade Barriers: An Overview"; "Non Tariff Barriers"; and "Product Sectors: Tariffs and Other Trade Barriers"]. A further source is the GATT report [Joint Working Group on Import Restrictions - Revision on Annexes to report of Joint Working Group, December 1975]. This information can be used to obtain a qualitative sense of the relative importance of various non-tariff barriers.

Obtaining quantitative estimates is more difficult, and use is made of two main sources for this purpose both of which report estimates of quantitative impacts of non-tariff barriers in equivalent ad valorem form. These two sources are Robert Baldwin ['Non-Tariff Distortions of Internation Trade,' Brookings, 1970] and V. Roningen and A. Yeats [Non tariff Distortions of International Trade; Some Preliminary Empirical Evidence,' Weltwirtschaftliches Archiv, 1976]. Baldwin reports some best guess estimates for a number of selected important items but does not attempt to be comprehensive in coverage, either with respect to commodities or trading blocs.

Roningen and Yeats, estimate non-tariff barriers for 26 products for France, Japan, Sweden, and the U.S. by a residual method. The differential over a world market price by product is calculated, from which is subtracted the nominal tariff involved. Further adjustments are made to these figures for the role of transportation costs, and are used where appropriate for the classification of 33 in the model.

In the case of the variable levies under the EEC Common Agricultural policy more complete information is available in Yeats [1976] and these estimates are used in addition to those provided by the above two sources.

6. Domestic value-added data

Data on domestic value-added for each trading bloc are constructed from national accounts and related source material. For each industry,series on net of tax profit-type return, taxes on these returns, return to labour, and taxes on labour hired,are constructed. This procedure of using national accounts data to construct series, rather than adjusting input-output value-added data,is used for three reasons. Components of value-added reported in input-output sources do not correspond to the concepts used in the model. There are further difficulties of matching classifications, and the dates of available input-output data are substantially different from that of the study.

Included in the profit type return are net of tax trading profits of companies,net of depreciation; the profit component of income of small business; and rental income,including the imputed income from owner occupation. Taxes on the profit type return comprise corporate and property taxes. Labour return by industry comprises compensation of employees plus the labour component of income of small business; and taxes on labour return comprise social security taxes.

For the U.S., information of this type has been collected for 1973 by Fullerton, Shoven, and Whalley [1977] and further disaggregation of these data is necessary for agricultural industries and is achieved using input-output data for 1967 for the U.S.

For the EEC, the basic source material is provided by the EEC publication (National Accounts, Eurostat, 1976) in which value added by component by country by industry is given. The correspondence from this source to the classification of 33 is not complete and additional information on agricultural production and power industries (in EEC Agricultural Statistics, and Energy Statistics, respectively) is used as a basis for further disaggregation. The item for capital type return is a net operating surplus figure and this is adjusted to remove the labour return to small business. No EEC source provides data on payments of corporate or property taxes by industry for any country, and attempts to obtain this information from national statistical offices proved unsuccessful. The procedure adopted was to obtain the total collections of these taxes (and similar taxes as in the Italian case) from EEC sources [Fiscal Statistics] by country. These were summed and then converted into U.S. $. The distribution of the total of each type by industry was assumed to be similar to that calculated for the U.K. by Piggott and Whalley [1976]. Labour return by industry is constructed from compensation of employees by industry by country and the labour return of small business is added. No information is directly available for labour taxes by industry and so the EEC publication [Labour Costs by Industry, EEC, 1974] is used along with information on the total collections by country.

In the case of Japan, the basic source is material in the Japanese Statistic Yearbook, 1974, Bureau of the Prime Minister, Japan along with National Accounts

<u>of Japan 1975</u>, National Planning Agency, Japan. The industry divisions of components of value added in the national accounts are limited to six items and so extensive use is made of more detailed information in the statistical Yearbook and on occasions the input-output tables. For trading profits of companies, a survey of 'main enterprises' (Table 228 of the 1975 Yearbook p. 308) projected onto an economy-wide basis, and for the capital type return to small business, survey data on unincorporated enterprises are used (Table 219, p. 318). Detailed data on rents and interest paid by industry are also given in the 1975 Yearbook (Tables 228, p. 310, 1975). In addition, the surpluses of Japanese public corporations are also added into the capital type return. Taxes on capital comprise enterprise liabilities not only to the corporate tax but also the Prefectural Inhabitants Tax, Municipal Inhabitants Tax, the Enterprise Tax, and the Property Tax. Total collections for 1973 from all these taxes appears in the Tax Bureau Publication (<u>An Outline of Japanese Taxes</u>, 1975). Industry data for the corporate tax are given in a Japanese publication (Table 8, <u>Revenue from Payment of Local Taxes in 1973</u>, pp. 16-17) and as all the related taxes (except property taxes) work with the corporate tax base their distribution by industry is assumed similar. Property taxes are allocated by industry on the basis of calculation of structures by industry given in the 1975 Yearbook (Table 228, p. 308). Data on compensation of employees by industry are given in the Yearbook and this is added the labour component of return to small business. No data exist on social security taxes by industry, and as there are no industrial discriminants in Japanese social security arrangement it is assumed a similar rate applies for each industry. Total collections for 1975 appear in the 1976 Yearbook (Table 337, p. 495). The ratio of 1975 treasury collections to local collections is used to calculate the 1973 local charge, which is unreported for 1973.

7. Input-Output Data

US input-output data come primarily from the 1970 85x85 tables (Survey of Current Business, February 1974) with additional information (primarily on agricultural industries) from the 1967 tables (US Input-Output Tables for 1967, Commerce Department, 1972). These tables are converted onto the classification of 33 via an aggregation routine. A major difficulty with these tables is that use of imported commodities by industry by type of import is not separately identified and Commerce Department worksheets on directly allocated imports are used to separate out use of imports from use of domestically produced goods. These import data are then broken into imports by regions using the merchandise trade data.

Japanese input-output data are available for 1970 at 3 different levels of aggregation 564x564, 160x160, and 60x60 [Input-Output Tables for Japan 1970 Reports 1,2,3, Administrative Management Agency, Japan]. A combination of the 60x60 and 160x160 tables is used to obtain tables for the model classification of 33. Imports used by industries are separately identified in these data and are further broken down by region using merchandise trade data. A small updated 13x13 1973 table [Japanese Input-Output Data for 1973 MITI Japan] is not used as the classification is too crude for use in the model.

No EEC input-output table exists for 1970, the latest being for 1965 [Coefficients Directs, Tableaux-Entrée Sortie, EEC 1965, Série Spéciale 8-1970 Sonderreihe]. Thus the individual country tables for 1970 are added to give a community table. Tables are available for UK, Belgium, Netherlands, W. Germany, and France, and these are added and projected onto a Community basis using the ratio of 1970 Community GNP to the combined GNP for included countries. Imports are separately identified and broken down by region as far as the US and Japan. Similarly a correspondence is taken between the EEC NACE-CLIO classification and the model classification of 33.

All tables are converted into US $ and projected to a 1973 basis by using the ratio of 1973 current price GNP at factor cost to that for 1970 for the trading bloc concerned.

8. Expenditure Data

For the US two basic sources are used:

(Survey of Consumer Expenditures 1960-1961. Consumer Expenditures and Income, Detail of Expenditures and Income, Urban US, Bureau of Labour Statistics, Supplement 3-Part C to BLS Report 237-38, 1961.)

Consumer Expenditure Survey Series Diary Survey 1973; US Department of Labour, Bureau of Labour Statistics, Report 448-2.

The 1960-61 source is the most complete data source presently available on matched expenditure and income characteristics of US households. Data for 1973 will shortly be available (of which the Diary Survey is the first publication) but is at present unpublished. This source provides information on expenditures by type of product for the ten household groupings listed in the text;the diary survey being used to obtain more detailed information on food categories. Expenditures on imported and domestically produced goods are not separately identified and are assumed to be proportional for all households to domestic production and imports by type by region.

For Japan similar data are available but for a more recent year:

(Annual Report on the Family Income and Expenditure Survey. Bureau of Statistics, Office of the Prime Minister, Japan, 1973 TABLES: 7, 14).

These give data for the 16 households reported in the text, and as with the US data no distinction is made between imported and domestically produced goods. A similar procedure of using foreign trade and domestic production data is followed.

For the EEC, no recent reliable survey data exist and in the model a single household sector is assumed for each country. Data on household sector expenditures by type by country are given in the EEC National Accounts. Again, no distinction between imported and domestically produced goods is made and a procedure similar to that used above is adopted.

These same sources are also used to provide information on the composition of incomes (profit type return, labour income, and transfers) and on personal tax liabilities (chiefly income tax).

9. Data on domestic indirect taxes

Information on domestic indirect taxes comes chiefly from national accounts and national tax statistics sources, with the exception of VAT for the EEC.

U.S. data from these sources are organized by Fullerton, Shoven and Whalley [1977] who include all federal state and local excise sales taxes in this category. For Japan, data on excises come from the Outline of Japanese Taxes. Data on payments of Commodity Tax by item are also given in the Outline. For the EEC excise tax payments by type by country are given in the Fiscal Statistics, and these are aggregated onto a community wide basis. No set of averaged VAT rates by product for the whole of the EEC appears to exist, and a set has been constructed by averaging national rates. For this purpose the EEC Inventory of Taxes (1974 edition) has been used as a guide to national rate structure) and weighted averages constructed using market price GNP by country as weights.

10. Consistency adjustments to domestic data sets

As mentioned in the text, a number of consistency adjustments are necessary with the domestic data sets (as is also the case with foreign trade data) so that the data satisfy the equilibrium conditions of the model. Demands must equal supplies for all products, costs must equal sales for each industry, incomes must equal expenditures for households, government budgets must balance, and factor usage by industry must match factor ownership across agents.

A number of adjustments are therefore made to ensure these conditions are satisfied in the benchmark equilibrium data set used in the model. Some of these adjustments are technical in nature and are explained in Piggott and Whalley [1977]. For adjustments to input-output data (to ensure sales equal costs for all industries), and to expenditure data (to ensure expenditures equal incomes, and demands equal supplies) use is made of the R.A.S. consistency technique originally developed for updating input-output tables (see Bacharach [1970]).

APPENDIX C Computational Methods Used to Determine General Equilibria

An international trade competitive equilibrium in the presence of tariff policies involves three conditions; demand supply equalities for all commodities; zero profitability conditions (net of producer taxes) for all available activities in each trading bloc; and a zero foreign trade balance for each trading bloc.

The Newton solution routines used to solve the model considered here make use of some specific structural features of the model and substantially simplify the calculations which have to be performed. The first simplification involves the use of factor prices to generate corresponding output prices which guarantee zero profit in each industry for the cost-minimizing activity. Use of these prices ensures all other activities not in use (those represented by the industry value-added production functions) make losses. The second simplification is to assume the cost-minimizing activities in each industry are operated at levels which meet consumer demands for industry outputs, determined from solution of consumer demand functions at the output prices calculated from the factor prices. These techniques directly impose two segments of the equilibrium conditions at each stage of a search procedure which does not consider commodity prices but instead generates output prices from any factor prices considered. This considerably simplifies the computational operations and reduces the amount of execution time required. Zero profitability in all industries is directly imposed as are the demand supply equalities for industry outputs.[1] Because of the limitations placed on the structure of

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[1] And hence the excess demands for commodities are equal to zero. The process of "scaling" of cost-minimizing activities will yield aggregate derived demands for productive factors and hence excess demands by subtracting economy-wide factor endowments.

the model, zero overall trade balance is a property of an equilibrium and also does not have to be imposed; thus a search procedure can be restricted to examination of factor prices and tax collections for each government for which excess demands for factors are zero and all government budgets are in balance. This search procedure considers all vectors $(\Pi_1,\ldots,\Pi_Z, R_1,\ldots,R_K)$ on the sub-simplex of dimension Z + K which contain the factor prices and country tax revenues, normalized such that $\sum_{i=1}^{Z} \Pi_i + \sum_{k=1}^{K} R_k = 1$. A point $(\tilde{\Pi} = \tilde{\Pi}_1,\ldots,\tilde{\Pi}_Z, \tilde{R}_1,\ldots,\tilde{R}_K)$, designated the 'initial point', will correspond to the benchmark equilibrium for the period under consideration.

This point can be surrounded by a sequence of vectors $\tilde{\Pi}^1,\ldots,\tilde{\Pi}^z,\tilde{\Pi}^{z+1},\ldots,\tilde{\Pi}^{z+K}$, each of which is perturbed from $\tilde{\Pi}$ sequentially in the coordinate corresponding to the index of its superscript. The vector $\tilde{\Pi}^1$ contains an element $\tilde{\Pi}^1_1$ decreased by x per cent from $\tilde{\Pi}_1$, $\tilde{\Pi}^2$ contains an element $\tilde{\Pi}^2_2$ decreased by x per cent from $\tilde{\Pi}_2$, and so on. For all these vectors, the normalization to sum to one is still applied.

Corresponding to each of these vectors $\tilde{\Pi}^j$ there are Z derived excess demands for factors of production which can be determined, and K government budget imbalances (surpluses or deficits). These can be represented by the (Z + K), the excess 'demands' $f_i(\tilde{\Pi}^j)$. If for any vector $\tilde{\Pi}^j$ all these (Z + K) excess demands $f_i(\tilde{\Pi}^j)$ were equal to zero this would mean that the conditions for a competitive equilibrium would be met and a competitive solution would have been determined. This situation will typically not apply at the initial point and some systematic search procedure yielding an equilibrium price vector must be used.

For this purpose, all weighted combinations of the vectors $\tilde{\Pi}^1,\ldots,\tilde{\Pi}^{Z+K}$ which also lie on the sub-simplex $\sum_{i=1}^{Z} \tilde{\Pi}_i + \sum_{k=1}^{K} R_k = F$ are considered. The weights on these vectors are denoted by α_j; where $\sum_{j=1}^{Z+K} \alpha_j = 1$; $\alpha_j \geq -\theta$. The last of these conditions represents a negative bound on each weight α_j which prevents the weighted vector $\sum_{j=1}^{Z+K} \alpha_j \tilde{\Pi}^j$ straying "too far" from $\tilde{\Pi}$.

Having constructed the weighted vector $\sum_{j=1}^{Z+K} \alpha_j \tilde{\Pi}^j$, an assumption is used which it is known will be violated at each stage of the operations to be performed, but it is hoped will hold to a closer and closer approximation as the calculation procedure gets closer to an exact solution. The assumption is that the (Z + K) excess demands at $\sum_{j=1}^{Z+K} \alpha_j \tilde{\Pi}^j$ are approximated by the weighted sums of excess demands at $\tilde{\Pi}^1,\ldots,\tilde{\Pi}^{Z+K}$, or

$$f_i\left(\sum_{j=1}^{Z+K} \alpha_j \tilde{\Pi}^j\right) \approx \sum_{j=1}^{Z+K} \alpha_j f_i(\tilde{\Pi}^j) \qquad (i=1,\ldots\ldots,Z+K)$$

This allows a problem to be stated to

$$\min \epsilon$$

$$\text{sto.} \quad \sum_{j=1}^{Z+K} \alpha_j f_i(\tilde{\Pi}^j) \leq \epsilon \qquad (i=1,\ldots\ldots,Z+K)$$

$$\sum_{j=1}^{Z+K} \alpha_j = 1, \ \alpha_j \geq -\theta$$

which can be solved through the solution of the transformed linear programming problem

$$\max \sum_{j=1}^{Z+K} y_j$$

$$\text{sto.} \quad \sum_{j=1}^{Z+K} y_j \left(f_i(\tilde{\Pi}^j) - C_i\right) \leq 1 \qquad (i=1,\ldots\ldots,Z+K)$$

$$y_j \geq 0$$

$$\text{where} \quad y_j = \frac{\alpha_j + \theta}{\epsilon + M}; \sum_{j=1}^{Z+K} y_j = \frac{1 + (Z+K)\theta}{\epsilon + M}; M >> 0; C_i = \frac{[\theta \sum_{j=1}^{Z+K} f_i(\tilde{\Pi}^j) - M]}{1 + (Z+K)\theta}$$

From the second of these problems the solutions y_j are found from which $\hat{\alpha}_j$ are in turn calculated to yield a vector $\sum_{j=1}^{Z+K} \alpha_j \tilde{\Pi}^j$. Actual excess demands for the productive factors and the budget imbalances are evaluated at this vector and if not within a desired tolerance a new linear programming problem set up by a repetition of the process. The area of outward search from each new trial vector is sequentially reduced if the solution to the linear programming problem yields a vector interior to the search area ($\alpha_j > 0$ for all j). As the area of search diminishes, the assumption on excess demands at $\sum_{j=1}^{Z+K} \alpha_j \tilde{\Pi}^j$ becomes a less severe approximation until a solution within a desired tolerance is found.

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