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This paper contains preliminary findings from research work still in progress and should not be quoted without prior approval of the author.

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Impacts of A 50% Tariff Reduction in an Eight-Region Global Trade Model[1]

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I INTRODUCTION

This paper reports results on the impacts of various 50 percent tariff reduction exercises produced by an eight-region numerical general equilibrium model of global production, trade, and demand, described in more detail in Whalley (forthcoming). The paper is one of a set of eight being simultaneously prepared as part of a comparative modelling project in which each modeller is to consider a similar trade policy change. The aim is to produce relatively compact papers which report and also describe the main features of his or her model relevant to an understanding of the results. The approach adopted in this paper is to present the key elements of structure in the model, highlight the parameter values crucial for results, and present results from the common policy change, along with a discussion of what model features account for them.

II The General Equilibrium Model of World Trade

The general equilibrium model used to analyze 50 percent tariff reductions is most easily thought of as a global trade model in the Hecksher-Ohlin tradition. Its main features are summarized in Table 1. The present eight-region model is an outgrowth of an earlier project which used a four-region global trade model with more commodity disaggregation, but less regional detail to evaluate the effects of the Tokyo Round tariff and non-tariff changes on developed country trade.[1] The present model has been used to examine the effects of developed

[1] See Brown and Whalley (1980), Whalley (1982), and Whalley (forthcoming).

Table 1

Main Features of Eight-Region Global Trade Model

1. Model Dimensions: Eight regions;[1] six products[2] (one non traded) produced in each region; two primary factors in each region which are intersectorally perfectly mobile, but internationally immobile.

2. Armington Assumption: Products are treated as qualitatively different, even if similarly labelled across regions eg. Japanese and U.S. cars are not perfect substitutes. Treatment adopted due to cross trading in trade data, and desired to calibrate model specification to literature trade elasticities.

3. Production: Production of each product uses primary factors, and other products (both domestic and imports) in CRS production processes. Primary factor requirements represented by CES value added functions across capital and labour services. Intermediate requirements involve fixed coefficients in 'composite' goods, but substitution across sources of supply ie. fixed requirement of steel per car produced in, say, the EEC, but substitution across steel supplied by EEC, Japan, U.S., and other regions.

4. Final Demands: Each region generates demands by utility maximization subject to regional budget constraint. Four-level nested CES/LES functions used to provide required flexibility on income and price elasticities.

5. Trade Distorting Policies: Each region has tariffs, non-tariff barriers (in ad valorem equivalent form), and domestic tax policies.

6. Equilibrium: Set of prices for goods and factors in all regions such that (i) demands equal supplies for all goods and factors (ii) no industry makes above normal profits (zero profits after allowing for return to capital). In equilibrium, government budgets are balanced in each region. External Sector Balance holds in each region (at world, not domestic gross of tariff prices) from the regional budget constraints.

7. Choice of Parameter Values: Model calibrated to 1977 global benchmark equilibrium date set (ie. reproduces this data as a model equilibrium solution if there are no policy changes). Elasticities in CES functions, and minimum requirements in LES functions need to be specified prior to calibration. Literature search used for these key values.

8. Key Parameter Values for Model Results: (i) 'trade' elasticities: elasticities of substitution between domestic and foreign products in demands and intermediate production (ii) trade protection policies; tariffs and NTB ad valorem equivalents.

9. Most Common Model Use: Counterfactual Equilibrium Analysis i.e. hypothetical equilibrium under complete adjustment to the change in the trade policy regime in one or more regions. Neither time for adjustment to occur, nor costs of adjustment analyzed.

10. Other Features: Savings by any region appears as part of final demands (newly produced capital goods appear in utility functions).
    - Non-merchandise trade external sector transactions incorporated (interest and dividends paid, aid and other transfers, and inward (outward) investment flows).
    - Static equilibrium; a single period equilibrium only is considered; no dynamic elements appear.

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[1] EEC, U.S., Japan, Canada, Other Developed, Oil Producers (OPEC), Newly Industrialized Countries NICs), Less Developed Countries (LDCs).

[2] Agriculture, Non oil Extractive Products, Energy Products, Non-Mechanical Manufacturing, Machinery and Transport Equipment, Services and Non Traded.

country protection on the North-South terms of trade, the impacts of various geographically discriminatory trade arrangements, and the effects of border tax adjustments on developed country trade.[1] Both because of the unreliability of key parameter values (elasticities, for instance), and the need to preselect one from a range of possible models (eg. with or without international factor mobility), insights from counterfactural equilibrium calculations relevant prevailing perceptions which dominate current policy debate are stressed, rather than forward looking projections of future trends. The preferred mode for model use is best summarized by the phrase "modelling for insights rather than precise numbers."[2]

Regional and Product Detail

Eight regions are incorporated reflecting major participants in world trade. These are the (nine-member) EEC, the US, Japan, Canada, Other Developed Countries (including USSR and Eastern Europe), OPEC, Newly

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[1] See Whalley (1984a), Hamilton and Whalley (1983a), Hamilton and Whalley (1983b).

[2] For example, in Hamilton and Whalley (1983b) the tax basis issue is taken up using the model. The current opinion in the US seems to be at a policy level that the US is at a disadvantage due to the use of destination based indirect taxes abroad, while academics stress the neutrality of the tax basis switches in the uniform case. The EEC, Japan, and Canada all have taxes with higher rates on manufacturing than non manufacturing. Since the model incorporates terms of trade effects, results show that the US is best off if the trading partner uses a destination basis where the US is a net importer of manufactures from the partner and an origin basis where the opposite holds. Results therefore suggest that, contrary to current opinion, the US should not push all trading partners to adopt the same tax basis.

Industrialized Countries (NICs), and Less Developed Countries (LDCs). The sizes of these regions in the model reflect their relative U.S. dollar GNP for 1977 taken from the World Bank Atlas.

The model considers six products produced in each region; Agriculture and Food; Mineral Products and Extractive Ores; Energy Products (including oil); Non-Mechanical Manufacturing; Machinery and Transport Equipment; (including vehicles); Construction, Services, and other Non-Traded Products. Each of the first five goods are internationally traded with an assumed heterogeneity by region prevailing across production sources. The sixth commodity is non-traded for all regions. The same commodity classification is used for trade, domestic production, and final demand data, with an approximate concordance used between different classification systems in basic data. The model incorporates less product detail than the full version of the four-region model (Whalley (1982)) which identifies 33 commodities in each region. Problems of data availability for all regions on this classification, plus the large dimensionalities involved in solution for an eight-region model have limited the dimensionality to six products and eight regions; 48 products in total.

Armington Assumption

In the model, products are differentiated on the basis of geographical point of production as well as by their physical characteristics, with 'similar' products being close substitutes in demand. This is often referred to as the Armington assumption (following Armington (1969)). Japanese manufactures are thus treated as qualitatively different products from U.S. or EEC manufactures. This assumption of product heterogeneity by region is used both to accommodate the statistical phenomenon of cross-hauling in international trade data, and to exclude complete specialization in production as a behavioural response in the model. This structure also enables empirically based import demand elasticities to be incorporated into the model specification.

Pricing System and Equilibrium Concept

Producers maximize profits and competitive forces operate such that in equilibrium all supernormal profits are competed away. Thus, equilibrium in the model is a situation where demands equal supplies for all products, and in each industry a zero-profit condition is satisfied representing the absence of supernormal profits. A zero foreign external sector balance condition (including investment flows, dividends, interest and transfers) applies for each country from the regional budget constraints.

Both production and demands in each region respond to changes in both domestic and world prices. Explicit demand functions are used, derived from hierarchical CES/LES preference functions; CES functions characterize production sets. For each product the market price in the model is the price at the point of production. Sellers receive these prices, purchasers (of both intermediate and final products) pay these prices gross of tariffs, NTB tariff equivalents, and domestic taxes; no transportation costs are considered. Investment flows, interest and dividends, and foreign aid enter the world market system, with the second two of these being treated as income transfers. Foreign investment is treated as purchases of capital goods by agents located in the country of source of capital funds. The difference between investment flows and merchandise trade is that the capital goods acquired are not repatriated to the country of location of the purchaser, but remain in the source country. These will, of course, generate income in future time periods, but no dynamic features enter the model. The future income stream from capital goods underlies their appearance in utility functions, but there is no explicit interest elasticity of either savings or international capital flows.

Demand and Production Functions

An important feature of the model is the structure of substitution possibilities incorporated through CES functions. The elasticities of substitution in these functions are the parameters which determine price elasticities in both goods and factor demand functions. Because of the Armington product heterogeneity assumption these elasticities also control import and export demand elasticities for any region, and thus indirectly determine the terms of trade effects of any policy change.

The hierarchical structure used in demand and production functions is outlined in Table 2. On the production side, each industry has a CES value-added production function which specifies substitution possibilities between the two regional primary factor inputs, capital and labour services. These are both intersectorally perfectly mobile, but immobile between regions. No technical change is incorporated.

Table 2

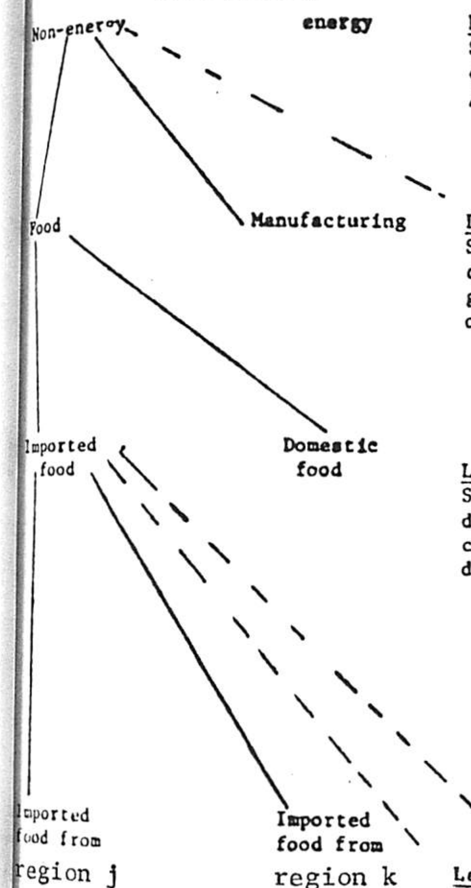
Hierarchy of Substitution Possibilities in Eight-Region Model

DEMAND

Final Demand Functions

In each region, a 4 level CES/LES functional form is used.

CES Hierarchy



Level 1
Substitution between categories (e.g. energy /non energy)

Level 2
Substitution within categories among composite goods (e.g. among components of non-energy)

Level 3
Substitution between domestic and import composites (e.g. between domestic and imported food)

Level 4
Substitution between import types in import composites (e.g. between imported food from regions k and j)

LES Hierarchy

Minimum requirements for each import composite at level 3 used. These allow income elasticities for import demands to be different from unity.

PRODUCTION

Value added Functions

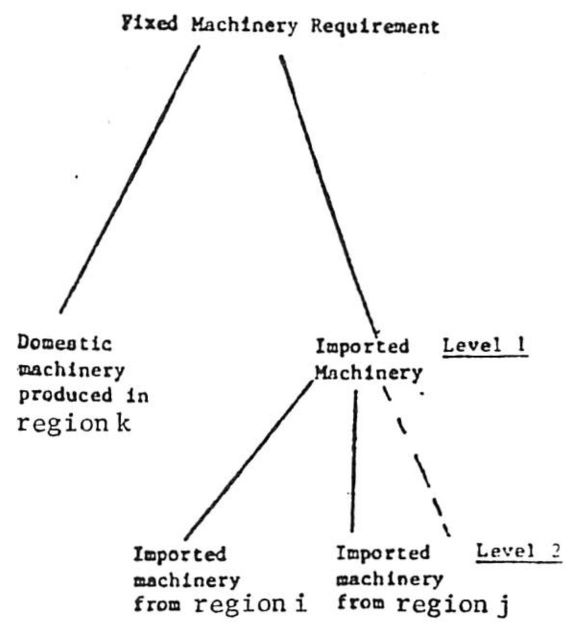
Each industry in each region has a CES value added function with capital and labour services as primary inputs

Intermediate Substitution

Fixed coefficient intermediate requirements technology, but with each fixed coefficient expressed in terms of composites only (i.e. a fixed machinery requirement per unit of manufacturing).

Each fixed coefficient input requirement met by cost minimizing bundle of domestic and import composites obtained from CES substitution functions.

CES hierarchy (For each fixed coefficient in terms of composites e.g. machinery requirement per unit of manufacture).



In addition to the CES value-added functions, each industry uses the outputs of other industries (both domestic and imported) as inputs into its own production process. Substitution between intermediate products is allowed while fixed coefficients in terms of composite goods are assumed. Each fixed coefficient (in terms of composite good requirements) is a nested CES function with elements of the composite (products identified by geographical point of production) entering as arguments. Substitution occurs between comparable domestic and composite imported commodities at the top level of nesting, with further substitution taking place between import types differentiated by location of production.

By way of example, this technology would specify a fixed requirement of steel in the production of a car in any region. The fixed steel requirement could be met by a substitutible mix of domestic and imported steel. Imported steel, in turn, would be a composite of the various types of steel available (differentiated by location of production) with substitution between each. Were the model to separately identify steel as a commodity, the substitution elasticity between domestic and imported steel would be the major determinant of the price elasticity of demand for steel imports. Substitution between types of steel affects the price elasticity of the demand function facing individual exporting regions.

On the demand side of the model a single set of final demand functions is specified for each region, obtained by maximizing a nested CES/LES utility function. Within this functional form, a hierarchy of substitution possibilities also operates. Elasticities separately control substitution between similar products imported from the various regions, and between composites of imports across import sources and comparable domestic products. Two[1] final levels of elasticity values determine substitution between the composite domestic-import products. The LES feature of the demand functions specify minimum requirements for commodities appearing in the nesting structure.

Use of these nested functions enables empirical estimates of price elasticities in world trade to be incorporated into the model. These values guide parameter choice for inter-nest elasticity values in the CES functions (i.e., between 'similar' products subscripted by location and production). The LES features in the hierarchy allow income elasticities in import demand functions to differ from unity.

Since each region generates demands from utility maximization, the market demand functions in the model satisfy Walras' Law. This is the condition that at any set of prices the total value of demands equals the total value of incomes. The incomes of regions are derived from the sale of primary factors owned by each region plus transfers received, including foreign aid.

Trade Distorting Policies

The model incorporates trade protection policies in each region in ad valorem equivalent form. These include tariffs, non-tariff barriers (NTBs), and certain features of domestic tax policies. Data, especially on ad valorem equivalents of non-tariff barriers, is limited and potentially unreliable. For four of the regions in the model single countries are involved and the trade

[1]The use of two rather than one level nesting above the import substitution stage reflects a general purpose design of the model which is not exploited in the present paper. Future applications of the model to world energy trade were anticipated at point of construction, and the price elasticity of energy demand would become a key parameter in such an analysis. The need to separately treat energy in such an analysis explains the presence of this additional level of flexibility in the nesting.

policy regime represented by that country alone. For the other four regions, composites of countries are involved making numerical representation of the trade policy regimes more difficult. A summary of the values used, along with the main sources are given in Table 3.

A reasonable summary of the way trade policies are represented in the model would be that trade protection policies in developed countries are relatively mild in aggregate, but have sharply discriminatory impacts on particular items (eg. agricultural products in the EEC and Japan). On the other hand, highly protective trade policies operate in developing countries. This specification reflects the feature that trade policies in developed countries have been subject to negotiated reductions under the GATT in the post war period, while trade policies in developing countries have remained largely unaffected and if anything have become more protectionist.

The tariff data are taken from a 1976 data file prepared by the U.S. Special Trade Representatives Office from the GATT Tariff Study for that year. This provides estimates by product for the developed country regions, but not for the developing country regions for which estimates in Balassa (1971) are used.[1] NTB estimates for both developed and developing countries draw on a number of sources which estimate the additional protection from NTBs beyond that due to the tariff. For developed countries, among others the estimates by Yeats (1978) are used which draw on UNCTAD data to estimate NTB equivalents by a residual method from differences between domestic and world prices. For developing countries, estimates of import premia due to import licensing are used.[2]

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[1] OPEC tariffs on manufactures are set at 15 percent, supposedly representative of the tariff structure in Saudi Arabia.

[2] See Pal (1964), Algamir (1968), and Bhuyan and Mahmud (1979).

Table 3

Ad Valorem Tariff and NTB Tariff Equivalents

Used in the Model[1]

A. Ad Valorem Tariff Rates (Aggregated Over all Import Sources)

	Commodity	EEC	US	Japan	Canada	Other Devel.	OPEC	NIC	LDC
1.	Agriculture and Food	.042	.063	.233	.048	.048	.0	.500	.080
2.	Minerals and Extractive Ores	.009	.040	.0	.0	.036	.0	.230	.350
3.	Energy	.037	.035	.077	.039	.059	.0	.230	.350
4.	Non-Mechanical Manufacturing	.085	.079	.068	.130	.047	.15	.860	.960
5.	Machinery and Transport	.082	.045	.084	.08	.057	.15	.860	.800
6.	Services and Non-Traded	.0	.0	.0	.0	.0	.0	.0	.0

B. Ad Valorem Equivalents of NTBs[2] (Aggregated Over all Import Sources)

	Commodity	EEC	US	Japan	Canada	Other Devel.	OPEC	NIC	LDC
1.	Agriculture and Food	.332	.438	.721	.468	.497	.0	.125	.202
2.	Minerals and Extractive Ores	.485	.0	.460	.315	.315	.0	.058	.088
3.	Energy	.282	.056	.377	.0	.239	.0	.058	.088
4.	Non-Mechanical Manufacturing	.079	.075	.081	.103	.078	.0	.215	.240
5.	Machinery and Transport	.017	.0	.018	.013	.012	.0	.200	.200
6.	Services and Non-Traded	.0	.0	.0	.0	.0	.0	.0	.0

[1] Sources are given in Whalley (forthcoming). Tariff data for developed countries come from a USSTR 1976 data file based on GATT data; tariffs for NICs and LDCs are based on estimates given in Balassa (1971). Tariffs for OPEC reflect the Saudi Arabia tariff on manufactures. NTB equivalents for developed countries are based on data in Yeats (1978) who uses UNCTAD data; for developing countries various studies of import premia due to import licensing are used (see Bhuyan and Mahmud (1979)).

[2] This is incremental protection in addition to that due to tariffs.

There are a number of reasons why this representation of NTBs in ad valorem equivalent form is not wholly satisfactory, and these should be highlighted. Included are the assumption of a constant ad valorem equivalent, even when prices change (which is not true of a quantity constraint); the allocation of the rents from NTBs to the importing region through the tariff equivalent revenues rather than the exporting region (which is inappropriate for such devices as VERs, and quotas under the MFA); and the assumption that both tariffs and non-tariff barriers are distortions with simultaneous marginal impacts (typically with a tariff and a quota both in place, only one of these will have effects at the margin). On top of these problems, there are several well known conceptual issues with the calulation of NTB equivalents using a residual method.[1]

The difficulty from a modelling point of view is that to separately incorporate quantitative restrictions into the model on each product would require an equilibrium formulation of much higher dimensionality, since the price for each additional ticket[2] or licence (one per restricted commodity) would be required. When the data problems of identifying and estimating quantitative restrictions for each region and for the aggregated product classification used here are also taken into account, the reasons for using the ad valorem equivalent treatment for NTBs are perhaps more understandable. Nonetheless, this treatment is a key element of the model to be borne in mind in interpreting results. In ongoing work, Hamilton, Mohammed, and Whalley (1984) are incorporating quantitative restrictions in the LDC and NIC regions along with rent-seeking into this model in a further examination of the North-South terms of trade issue. This produces quite different results from the earlier analysis of this issue with a seven-region model based on the same treatment of trade protection as used here.

[1]See Holzman (1969).

[2]See Shoven and Whalley (1972).

III Benchmark Calibration, Elasticities, and Equilibrium Solution of the Model

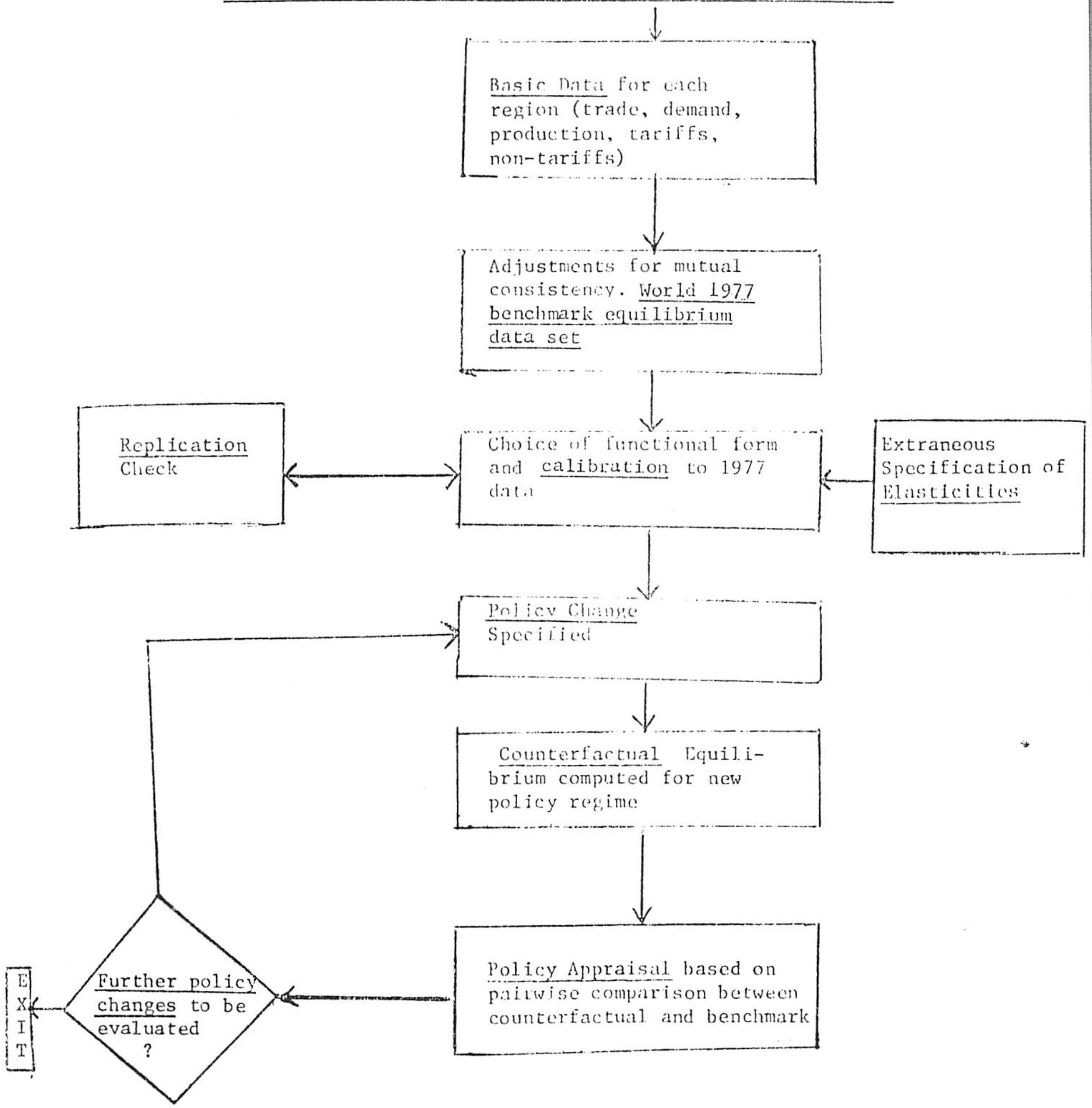
The way the global general equilibrium trade model is used for policy evaluation is to compute counterfactual equilibria under changed policies and compare these to an original (or benchmark) equilibrium data set. A flow chart outlining this procedure is given in Table 4. A worldwide general equilibrium is assumed to hold in the presence of existing trade policies. The model is then calibrated to a micro consistent data set consisting of 1977 trade, production and demands by region through a procedure which determines parameter values for the model function consistent with the equilibrium restriction. Counterfactual analysis then proceeds for any specified trade policy change.

Calibration

The calibration procedure begins with the construction of a data set for a given year in a form which is consistent with the equilibrium solution concept of the model; the benchmark equilibrium data set. The 1977 micro consistent benchmark equilibrium data set assembled for this purpose has the properties of a worldwide competitive equilibrium in that demands equal supplies for all products, no profits are made in any of the domestic industries, and each region is in zero external sector balance. Many divergent source materials are required and need adjustment for inconsistent classification and definitions. In addition, further modifications are necessary to mutually adjust the data so that the equilibrium conditions of the model are satisfied. The assembly of data on such a scale inevitably involves a substantial degree of summary judgement and accommodation between data of varying quality. A description of the sources and methods used in assembling the data set appears in Whalley (forthcoming).

TABLE 4

MODEL FLOW CHART FOR WORLD TRADE GENERAL EQUILIBRIUM MODEL



Once assembled, parameter values for equations can be directly calculated from the equilibrium conditions using the calibration procedure described in Mansur and Whalley (1983). This involves a non-stochastic procedure for the determination of parameter values which takes the model equilibrium conditions and solves for parameter values from equilibrium observations. Because of the CES/LES functional forms used, implementing this procedure requires more information than that contained in the benchmark equilibrium data set. On the demand side, for instance, benchmark data yield equilibrium consumption bundles and slopes of budget constraints. With Cobb-Douglas preferences this is enough information to infer the parameters of the utility function, but this is not the case with CES/LES functions. These additional informational requirements are met by specifying elasticities of substitution and minimum requirements in the functional forms. Once these are chosen, demand functions are solved for share parameters consistent with both equilibrium prices and quantities. On the supply side, cost functions are similarly solved for share and unit parameters consistent with equilibrium prices and input use by industry.

The model specification is then capable of reproducing the benchmark data as an equilibrium solution to the model, and comparative statics can be performed with the model by computing new equilibria for alternative trade policy regimes.

Elasticity Specification

Not surprisingly, the values chosen for substitution elasticities when the model is calibrated have a substantial impact on the results produced by the model. An especially important set of parameters is the substitution elasticities which determine import demand elasticities, and because of their special importance for the results presented later a fuller discussion is provided of the choice of these values.

In Table 5 literature survey import price and income elasticities and export price elasticities are reported by region, based on a number of literature sources. These (predominantly time series) estimates provide the basis for the selection of trade substitution values in the model.

Table 5 suggests import price elasticities in the neighbourhood of unity and export price elasticities a little higher. Income elasticities of import demand are in the region of 1.5. The OPEC income elasticity of 0.24 reflects a single set of estimates for Venezuela. Import prices elasticities for developed countries are based on the Stern, Francis, Schumacher (1977) compendium of trade elasticities, and estimates for developing countries are due to Khan (1974).

These ranges appear to reflect the current consensus on trade elasticities, although their use should not pass without comment. Several authors have, in the past, raised difficulties with time series estimation of trade elasticities. Orcutt (1950) long ago raised the issue of specification bias, and Kemp (1962) suggested that errors in measurement of import price indices may lead to a bias toward unity. Trade researchers frequently argue that time series estimates are too low, and some (such as Balassa and Kreinen (1967)) have used significantly higher values. In spite of these reservations, estimates of these types are still commonly employed and are also used here. Time series estimates provide the main source for the compendium of trade elasticities compiled by Stern, Francis, and Schumacher (1977). Subsequent estimates for the US, EEC, and Japan by Stone (1981) which also provide detailed product by product estimates are approximately consistent with the values reported in Table 5. Some further recent detailed product estimates by Shiels, Stern and Deardorff (1983) are a little higher (in absolute terms) than the estimates reported in Table 5.

Table 5

Literature Survey Trade Elasticities

Used in the Model

Trading Area	'Central Tendancy' Import Price Elasticities	'Central Tendancy' Import Income Elasticities	'Central Tendancy' Export Price Elasticities
EEC	- .91	1.77	-1.14
US	- 1.66	1.51	-1.41
JAPAN	- .78	1.23	-1.25
CANADA	- 1.30	1.20	-0.79
OTHER DEV.	- 1.02	1.41 (Portugal)	-1.26
OPEC	- 0.89 (Venezuela)	0.24 (Venezuela)	-0.83 (Venezuela)
NIC	- 1.38	1.29 (Turkey)	-1.41 (Turkey)
LDC	- 1.28	1.43 (India)	-1.82 (Pakistan)

Sources:
- EEC - Weighted average over country 'best guess' estimates suggested by Stern, Francis and Schumacher (1976) from their literature survey, and Houthakker/Magee (1969)
- US - Stern, Francis and Schumacher 'best guess' plus Houthakker/Magee
- JAPAN - Stern, Francis, and Schumacher 'best guess' plus Houthakker/Magee
- CANADA - Stern, Francis, Schumacher 'best guess' plus Houtakker/Magee
- OTHER DEV - Arithmetic average over EEC, U.S., and Japan, plus Houtakker/Magee
- NIC - Estimates for Uruguay, Colombia, Brazil, Argentina, and Turkey reported by Khan (1974), Weisskoff (1979), and Taplin (1974)
- LDC - Estimates for Bangladesh, Sri Lanka, Phillipines, Pakistan, Morocco, Ghana, India, and Ecuador due to Kahn (1974), Nguyen and Bhuyan (1977), and Houthakker/Magee (1969)

The elasticity configuration used in the central case specification of the model is reported in Table 6. Substitution elasticities between comparable domestic and foreign goods in both final demands and intermediate production are set at own price elasticities of import demands by region reported in Table 5. For any region, the same values are used for all products. Elasticities between import types in both final demand and intermediate substitution are all set at 1.5. This parameter determines export price elasticities for exporting regions. No simple method is available to relate literature estimates of export price elasticities by region to the substitution elasticities in importing regions in the model, since regions typically import from all (or most) sources. This explains the common value of 1.5 with sensitivity analysis around this specification. Import income elasticities are all set at unity in the central case with sensitivity analysis in later cases to reflect values above unity. Unitary income elasticities correspond to the case of homothetic preferences. Other elasticities are: (i) Cobb-Douglas at higher levels for substitution between composite goods in demand; and (ii) literature based estimates for capital labour substitution in the CES value added functions.[1]

The parameters used in the model are not separately calibrated to estimates of import and export supply elasticities, even though Goldstein and Kahn (1978) report high export supply elasticities for some countries from their simultaneous estimation of export demand and supply functions. Effectively,

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[1]The survey by Caddy (1976) provides the main source for these estimates. An average over the estimates reported by Caddy is used for each industry in the model with use of 'best guesses' where industry estimates do not occur in Caddy. The values adopted are the same for each region, and are on average below unity reflecting the preponderance of time series estimates (as opposed to cross section) in Caddy. The problems of reconciliation between time series and cross section estimates are discussed in Berndt (1976).

Table 6

Elasticity Configuration in Central Case Model Specification

Demand

1. Top level elasticities (substitution between categories) set equal to 1.0 (Cobb-Douglas) in all regions.

2. Second level elasticities (substitution within each category) set equal to 1.0 (Cobb-Douglas) in all regions.

3. Third level elasticities (substitution between comparable domestic and import composites) set equal to literature survey import price elasticities. Within any region the same value is used for all commodities

4. Fourth level elasticities (substitution between import types in forming import composites) set equal to 1.5.

5. Income elasticities for import demand functions set equal to unity. LES functions have zero minimum requirements.

Production

1. CES value added functions based on weighted average of industry estimates from Caddy (1976). The same values are used in each region.

2. Elasticities in CES intermediate coefficient functions.

   (a) Elasticities between comparable domestic and import composites are set equal to import price elasticities in Table 5 .

   (b) Elasticities between import types in forming import composites are all set equal to 1.5 in all regions.

infinite supply elasticities for Japan are found, values in the neighbourhood of 5.0 are found for the U.S. and West Germany, and values closer to 1.0 for smaller economies such as Belgium. A difficulty in using such estimates in the specification of general equilibrium trade models is that there is not a supply function for exports as such in these models, but rather a supply function for exportables. The market is in the homogeneous product which is consumed both domestically and abroad, rather than only in the product consumed abroad. Trade models with linear homogeneous production will yield partial equilibrium supply elasticities for exportables. These approach infinity in the sense that profit maximizing producers who face equilibrium prices for which zero profit conditions hold are indifferent as to what quantity they sell. Thus, to the extent that one is willing to interpret estimated supply elasticities in this way, no necessary contradiction exists between the elasticities used in the present model and large estimated values for export supply elasticities.

Once specified, the model is solved for a new general equilibrium for a policy or other change using a Newton method involving an estimate of the Jacobian matrix of excess factor demands and government budget imbalances. This method works more rapidly than Scarf's algorithm[1] or the restart methods of Merrill and others for the type of general equilibrium problems solved with this model. Although there is no ex ante argument of convergence with the Newton method used it has been successful in implementation.

A final point is that no guarantee of uniqueness of equilibrium is available for the model. With numerical solution of similar models, some experimentation involving displacing equilibria once found and checking that these

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[1] See Scarf (1973) and the extension to international trade models with tariffs by Shoven and Whalley (1974).

are returned to, and also in approaching equilibria from different points and at different speeds. None of these tests has revealed a situation of non-uniqueness, although it is certainly not excluded.[1]

IV Results of 50% Tariff Reduction Exercises

In this section results of alternative 50 percent tariff reduction exercises are presented. The main focus of results is on annual welfare and terms of trade effects of the policy change, with further results also reported on inter industry factor adjustments between equilibria. Welfare effects are presented though Hicksian equivalent variations, calculated in terms of 1977 billions of dollars. Terms of trade impacts appear as percentage changes in each region's net barter terms of trade; a positive entry indicates a terms of trade improvement.

Column 1 of Table 7 considers the case where the U.S. unilaterally cuts tariffs by 50 percent. This results in an annual welfare loss to the U.S. of around $3 billion, along with a terms of trade deterioration of around 2 percent. These welfare and terms of trade impacts reflect the fact that because of the trade elasticities used in the model, a reduction in tariffs by the U.S. represents a movement away from an optimal tariff. The resulting terms of trade deterioration is clearly displayed by the results,

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[1] However, using a simple numerical example involving four commidities, four households with Cobb-Douglas demands, and a small number of activities, Kehoe (mimeo) has illustrated a case of non-uniqueness for what does not seem to be in any way an extreme or implausible specification. In this example, the equilibrium prices are widely separated between the equilibria, suggesting that non-uniqueness may not be as unlikely an occurrence as these numerical ad hoc tests seem to indicate. In a further paper Kehoe (1980) has suggested that for models with two factors of production, uniqueness may be more likely to hold. In related work, Kehoe and Whalley (1982) have demonstrated uniqueness for a particular numerical specification of an applied general equilibrium tax model used by Fullerton, King, Shoven and Whalley (1981) which suggests that uniqueness may also hold for the current trade model.

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Table 7

Annual Welfare and Terms of Trade Impacts of Alternative 50% Tariff Cuts

	U.S. cuts tariffs by 50%	U.S. cuts protection by 50%	50% Tariff Cut in the EEC	50% Tariff Cut in Japan	50% Tariff Cut in all regions	50% Tariff Cut in Regions 1-5	Regions 1-5 Cut all Protection 50%	50% Tariff Cut in Regions 1-3
A. ANNUAL WELFARE IMPACTS BY REGION (Hicksian Equivalent Variations in $bill, 1977)								
1. EEC	0.9	1.7	-3.5	.1	10.5	1.2	- .6	-2.5
2. U.S.	-3.1	-5.5	.4	.1	1.1	-2.2	- .5	-2.7
3. Japan	.5	.7	.1	-.8	6.1	.6	- .7	- .2
4. Canada	.6	1.1	.1	.0	.9	.4	1.3	.7
5. Other Developed	.2	.7	2.3	.1	- .4	-2.0	1.8	2.6
6. OPEC	.5	.6	.6	.5	3.6	2.1	2.5	1.5
7. Newly Industrialized Countries	1.0	2.3	.5	.4	- 3.7	2.3	7.6	1.9
8. Less Developed Countries	.7	1.7	1.2	.6	- .8	2.8	10.7	2.4
TOTAL	1.3	3.3	1.7	1.0	17.4	5.2	22.2	3.9
B. TERMS OF TRADE IMPACTS BY REGION (% change, +ve denotes improvement)								
1. EEC	.3	.6	-1.7	.0	3.7	- .1	-2.6	.3
2. U.S.	-2.0	-3.7	.2	.0	- .0	-1.5	- 1.0	-2.0
3. Japan	.4	.5	.1	-1.3	5.6	- .1	- 4.2	.4
4. Canada	1.3	2.2	.1	.1	1.2	.3	.8	1.3
5. Other Developed	.1	.3	1.1	.1	- 1.1	-1.5	- .7	.1
6. OPEC	.2	.2	.6	.4	1.4	1.3	2.3	.2
7. Newly Industrialized Countries	.6	1.5	.3	.2	- 9.2	1.4	4.8	.6
8. Less Developed Countries	.4	.9	.6	.2	÷ 8.6	1.4	5.3	.4

and is the main feature accounting for the welfare loss sustained by the U.S. The largest terms of trade improvement occurs for Canada, a major U.S. trade partner which has around 70 percent of its trade with the U.S. The change represents a global welfare gain since the losses sustained by the U.S. are more than offset by gains elsewhere.

Column 2 of Table 5 considers the case where the U.S. cuts both tariffs and NTB tariff equivalents by 50 percent. Combined protection levels are higher than tariffs alone, and the impacts on the U.S. and its major trading partners are more pronounced. A notable difference between Columns 1 and 2 of Table 5 occurs in the terms of trade impacts on the Newly Industrialized countries which change sharply. This reflects the importance of textile quotas, and other NTBs relevant to these countries in the U.S.

In Columns 3 and 4 comparable cases are considered for the EEC and Japan with 50 percent unilateral cuts in tariffs. In the EEC case, the terms of trade impact on the EEC is comparable to that for the U.S. in Column 1 (tariff rates are similar). However, the major impact is on the Other Developed region rather than Canada since this region accounts for a large portion of European trade. Similarly, in the Japanese case a terms of trade deterioration against Japan occurs with a 50 percent unilateral tariff cut. Effects are smaller than for the U.S. and EEC cases since Japan is smaller in absolute size, and the 1976 tariff data used include unilateral reductions made by the Japanese in the early 1970's bringing their tariffs below U.S. and EEC levels.

Column 5 considers a 50 percent tariff cut in all regions. Because tariffs in the developed countries in the model are significantly lower than those in the Newly Industrialized and the Less Developed Countries, developed countries as a regional group gain. Interestingly, developing countries suffer only a small welfare loss, even though they suffer a significant terms of trade deterioration, suggesting the high levels of protection incorporated in the model for this region are beyond optimal tariff levels. The Other Developed Country region suffers a welfare and a terms of trade loss since they have higher tariffs than the first four developed country regions.[1] Larger gains accrue to the EEC and Japan than to the U.S., since these two regions have larger trade shares in manufactures on which there are higher tariffs than non-manufactured products. These results thus suggest that the U.S. has something of a community of interest with the developing world when it comes to trade liberalization issues, because of their major agricultural exports.

In Columns 6 and 7 of Table 7, 50 percent tariff cuts and cuts in all protection are considered for only the five developed country regions. In both cases the major effect is a terms of trade gain to the developing world who get increased penetration of developed country markets. Major losses occur in the tariff case for the U.S., since unlike the EEC and Japan, the U.S. has less to gain from increased penetration of manufactured goods markets elsewhere in the developed world. This picture changes with a reduction in all protection because of the importance of EEC and Japanese agricultural non-tariff barriers for the U.S. Finally in Column 8 of Table 5

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[1]This region includes smaller OECD countries including Austria, Australia, and New Zealand which have higher tariffs than the larger OECD countries, although the data used for the Other Developed region do not fully reflect this feature.

the effects of tariff reductions in only the major developed country regions (the EEC, U.S., and Japan) are considered. Again, countries cutting protection tend to lose.

The main theme of results in this table is the potentially crucial importance of terms of trade effects in analyzing the impacts of tariff cuts, the significance of which in turn depends directly on the trade elasticities used. In all cases a unilateral tariff cut results in a worsening of the terms of trade and a welfare loss for the region cutting the tariff. In the case of more wide ranging tariff cuts, comparable effects across regional groups are produced. In the case of global tariff cuts, the asymmetries in the initial levels of protection are crucial since they are the major determinant of whether regions improve or worsen their terms of trade.

A second theme is that while the impacts by region may appear significant, the global impacts are small. With 1977 World GNP in the region of $7 trillion, even a 50 percent reduction in protection in all regions yields a global gain of only $22 billion; less than 1/3 percent of World GNP. This reflects a long standing feature of calculations of the impacts of trade policy changes in models with constant returns to scale which consistently come out as in aggregate small.[1] This view has been recently challenged, especially for small economies, by Harris (1983) who suggests that by incorporating scale

[1] For instance, Scitovsky (1958) in his pioneering calculations of the impact of the formation of the EEC put the gain from increased specialization at only 1/20 of 1 percent GNP per year. Also Johnson (1958) in his calculation of benefits to the UK from joining the EEC estimated the gains at 1 percent of GNP spread over a 13-year period, a very small yearly gain.

economies much larger estimates will be produced. I have elsewhere (Whalley (1984b) commented on both Harris' model and his calculations. While I believe his estimates are too large, there is no doubt that the potential exists for substantially changing estimates of the type presented here by incorporating scale economies.

In Table 8 inter industry factor adjustments in the U.S. from various trade policy changes are reported. While these are small in percentage terms, the most important feature is that in all three cases employment of both factors falls in the service and non-traded good industry which accounts for the largest portion of factor employment. This highlights an often neglected aspect of adjustments of trade policy changes; that potentially the major adjustments occur across the groups of traded and non-traded good industries rather than only among traded goods as often assumed.

All three cases involve an increase in trade for the U.S. and the non-traded good industry correspondingly contracts. With a 50 percent U.S. cut, U.S. imports increase and take U.S. market share away from U.S. producers, but the increase in exports more than offsets this effect. Because of the deterioration in the U.S. terms of trade, the production loss in traded goods industries from reduced domestic market share is more than offset by increased production for export. With 50 percent cuts abroad exports increase from the increased penetration of foreign markets and a similar reduction in the size of the non-traded goods industry occurs.

Table 8

Inter Industry Factor Adjustments in the U.S.

From Alternative 50 Percent Tariff Cuts

U.S. Industry	% Change in Factor Employment Under 50% Tariff Cut in the U.S.		% Change in Factor Employment Under 50% Tariff Cut in the EEC		% Change in Factor Employment Under 50% Tariff Cut in all regions	
	Capital	Labour	Capital	Labour	Capital	Labour
1. Agriculture and Food	-.14	.04	.00	.00	-.01	-.04
2. Minerals and Extractive Ores	.88	1.08	-.10	-.10	.35	.32
3. Energy	.57	.78	-.14	-.14	.46	.43
4. Non-Mechanical Manufacturing	-.16	.06	-.00	.00	.21	.14
5. Machinery and Transport Equipment	.11	.30	.01	.01	.81	.78
6. Services and Non-Traded	-.32	-.07	-.01	-.00	-.11	-.15

In Table 9 various sensitivity analyses of results for a 50 percent tariff cut in the U.S. are reported. These all involve changing key elasticities in the model in various ways. If elasticities of substitution between import types in all regions are set at the higher values of first 3 and then 5 (Columns 1 and 2), welfare effects against the U.S. are correspondingly smaller.[1] Alternatively, varying elasticities of substitution between domestic and imported products (Columns 3-5) moves the terms of trade and welfare effects in the opposite direction. The final three columns report on sensitivity of results with respect to import income elasticities. These elasticities appear relatively unimportant for the results. Substitution rather than income effects induced by trade policy changes are the more important effect.

In broad terms these results therefore indicate the importance of incorporating price endogeneity in models used to analyze trade policy impacts. While the aggregate welfare results of trade policy changes appear to be somewhat small, whether they produce a benefit or not for any particular region depends crucially on what happends to that region's terms of trade. These effects are often ignored in trade policy analysis, and results here serve to emphasize their potential role.

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[1] In other results not reported here, results from the central case specification remain largely unaffected if estimates of import price elasticities by product by region from Stone (1979) are used, in place of values common across all products for each region,

Table 9

Sensitivity Analysis of a 50% Tariff Cut in the U.S.

	Elasticity of Substitution Between Import Types Equals 3.0 in all Regions	Elasticity of Substitution Between Import Types Equals 5.0 in all Regions	Elasticity of Substitution Between Domestic Products and Imports Equals 0.75 in all Regions	Elasticity of Substitution Between Domestic Products and Imports Equals 1.5 in all Regions	Elasticity of Substitution Between Domestic Products and Imports Equals 3.0 in all Regions	Import Income Elasticities Equal 0.9 in Regions 1-5 and 1.1 in Regions 7,8	Import Income Elasticities Equal 0.75 in Regions 1-6 and 1.25 in Regions 7,8	Import Income Elasticities Equal 1.5 in all Regions
A. ANNUAL WELFARE IMPACTS BY REGION (Hicksian Equivalent Variation in $bill, 1977)								
EEC	.4	.2	.7	.8	1.0	.8	1.0	1.0
U.S.	-2.0	-1.2	-2.7	-3.0	-3.2	-3.1	-3.0	-3.1
Japan	.2	.0	.4	.5	.6	.5	.8	.5
Canada	.5	.3	.6	.6	.6	.6	.6	.7
Other Developed	- .0	- .1	.1	.2	.4	.2	.1	.2
OPEC	.4	.4	.5	.5	.5	.5	.4	.5
Newly Industrialized Countries	1.0	1.0	.9	1.1	1.3	1.1	1.2	1.3
Less Developed Countries	.7	.7	.6	.7	1.0	.7	.8	.9
	1.3	1.4	1.0	1.4	2.1	1.4	1.7	2.2
B. TERMS OF TRADE IMPACTS BY REGION (% change, +ve indicates improvement)								
EEC	.1	.0	.2	.3	.3	.3	.3	.3
U.S.	-1.3	- .9	-1.7	-1.9	-2.0	-2.0	-2.0	-2.0
Japan	.1	- .0	.3	.4	.4	.4	.4	.4
Canada	1.0	.7	1.2	1.1	1.0	1.3	1.3	1.3
Other Developed	- .0	- .0	.1	.1	.1	.1	.1	.1
OPEC	.3	.3	.2	.2	.2	.2	.2	.2
Newly Industrialized Countries	.6	.5	.6	.6	.7	.6	.6	.6
Less Developed Countries	.4	.4	.4	.4	.4	.4	.4	.4

V Conclusion

This paper reports results from a series of 50 percent tariff reduction exercises obtained from an eight region numerical general equilibrium model of global trade, production and welfare. This is one of a series of papers being simultaneously prepared as part of a comparative modelling exercise involving eight separate models. The main features of the model are highlighted, and those parameter values which are especially crucial for results are commented on. Results from the common policy change are presented in a final section.

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