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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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# A GENERAL EQUILIBRIUM ANALYSIS OF TARIFF REDUCTIONS

by

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CONTENTS

## 1. INTRODUCTION

This paper presents the results of several tariff reduction policies from the counterfactual simulation of a multi-region numerical general equilibrium (GE) model. The model is firmly neoclassical in structure and is empirically calibrated to represent the structure of the global economy as of 1975. It represents an application of the techniques for interregional GE analysis developed in Kimbell and Harrison [1984], the solution methods introduced in Kimbell and Harrison [1983 ], the techniques of systematic sensitivity analysis of numerical GE models presented in Harrison and Kimbell [1983b], and the approach to model aggregation developed in Harrison and Manning [1984]. A more detailed description of the model is provided in Harrison and Kimbell [1983a].

The model incorporates two major "novelties" from the perspective of general methodology. The first is a simple technique for allowing intermediate input substitutability that does not involve significant increases in computational expense.[1] This feature is particularly important for international trade models in the face of the empirical significance of trade in intermediates and prevailing estimates of non-zero import price elasticities. The second novelty is the use of systematic sensitivity analyses in order to determine how robust or fragile are the policy results obtained from our model.

A brief overview of the model is presented in Section 2. A number of policy simulations are reported in Section 3, along with sensitivity analyses of our results. Section 4 provides some concluding perspectives.

## 2. MODEL SPECIFICATION

By way of perspective, we employed three broad criteria in specifying the model. The first was that it be understandable, in the sense of having a (neo-classical) structure that would be readily familiar to all economists despite great sectoral detail and a large number of trading regions. The second was that it be readily operational with existing data sources. The third requirement was that it be repeatedly soluble for the purposes of systematic sensitivity analysis. A number of additional requirements, specific to a diverse range of intended policy applications, are of secondary importance but have nonetheless influenced the chosen specification.

### 2.1 Trading Regions

The model identifies twelve trading regions, listed in Table 1 along with several aggregate statistics. These regions represent a diverse range in terms of degree of industrialization, size, and "openness" to international trade. In terms of geographic coverage, our model subsumes the three region (U.S., Japan, EEC) model presented in Whalley [1980a] [1980b] [1982a] [1984] and Brown and Whalley [1980], while providing certain country-specific detail for less-developed countries abstracted from in the 7-sector (U.S., Japan, EEC, Other Developed Countries, OPEC, Newly Industrialized Countries and Less Developed Countries) model presented in Whalley [1982b] [1984]. These similarities in coverage provide a basis for the casual comparison of policy results from the model in Harrison and Kimbell [1983a; Section 3] and the formal reconciliation of results attempted in Harrison [1984b].

TABLE 1

Trading Regions

| Region | GDP | Exports | Imports | Population | GDP per capita |
|---|---|---|---|---|---|
| 1. Australia | 87.3 | 11.7 | 9.5 | 13.8 | 6326 |
| 2. Canada | 165.2 | 33.9 | 34.3 | 22.7 | 7277 |
| 3. Indonesia | 30.5 | 6.9 | 5.5 | 135.2 | 226 |
| 4. Malaysia | 9.3 | 3.8 | 3.5 | 11.9 | 781 |
| 5. Philippines | 15.8 | 2.3 | 3.5 | 42.1 | 375 |
| 6. Singapore | 5.6 | 5.1 | 7.5 | 2.3 | 2435 |
| 7. Thailand | 14.6 | 2.2 | 2.8 | 41.9 | 348 |
| 8. Korea | 20.6 | 5.0 | 6.7 | 35.3 | 583 |
| 9. Japan | 501.9 | 54.7 | 49.7 | 111.6 | 4497 |
| 10. U.S.A. | 1518.3 | 107.1 | 98.1 | 213.6 | 7108 |
| 11. E.E.C. | 1373.2 | 146.3 | 148.0 | 258.0 | 5323 |
| 12. Rest of World | | | | | |

Notes: GDP, Exports (fob) and Imports (fob) are measured in billions of U.S. dollars in 1975, and were obtained from lines 99b, 77aad and 77abd, respectively, of the International Financial Statistics of the IMF (period average exchange rates used). Population is measured in millions, and is obtained from line 99z of the IFS. GDP per capita is measured in U.S. dollars. Note that the Exports and Imports listed here are not the model-equivalent values.

## 2.2 Commodities

Two levels of commodity aggregation are adopted, and are listed in Table 2. The reasons we adopt two levels of aggregation are the relative ease of computation and interpretation of results with the aggregated model. In addition to the commodities listed, each household in each trading region allocates income to "savings", which are in turn allocated to the purchase of a bundle of investment goods (primarily, but not exclusively, in the household's own region).

## 2.3 Production Structure

Each of the commodities listed in Table 2 are assumed to be produced in each region and are, in principle, tradeable. Each commodity is therefore distinguished by producing region, implying that our model has 84 or 240 commodities (depending on the aggregation adopted). Each sector uses intermediate inputs from its own region and from all other regions, as well as primary factors (labour and capital). Although it is useful to visualize the use of intermediate inputs in the form of a complete multi-regional (international) input-output table, an important feature of the present model is that the implied technical coefficients are not fixed with respect to relative input prices. That is, we do not employ a Leontief technology in the use of intermediate inputs, but assume instead a Cobb-Douglas technology. Thus intermediate inputs are substitutable and, as a composite, substitutable with a composite of primary inputs. Primary inputs, in turn, are characterized with a standard CES technology.

TABLE 2

Commodities Considered

| Twenty Sector Aggregation | Seven Sector Aggregation |
|---|---|
| 1. Agriculture, Forestry and Fishing | 1. Agriculture, Forestry and Fishing (1) |
| 2. Minerals and Extractive Ores | 2. Mining and Quarrying (2,3) |
| 3. Energy Products | 3. Manufacturing (4/15) |
| 4. Food, Beverage and Tobacco | 4. Utilities (16) |
| 5. Textiles, Clothing, Footwear and Leather | 5. Construction (17) |
| 6. Lumber and Wooden Products | 6. Trade and Transport (18) |
| 7. Pulp, Paper and Printing | 7. Services (19,20) |
| 8. Chemicals | |
| 9. Rubber and Plastic Products | |
| 10. Non-Metallic Mineral Products | |
| 11. Basic and Fabricated Metal Products | |
| 12. Industrial Machinery | |
| 13. Electrical and Other Machinery and Equipment | |
| 14. Motor Vehicles | |
| 15. Other Transport Equipment | |
| 16. Electricity, Gas and Water Supply | |
| 17. Construction | |
| 18. Trade, Transport and Communications | |
| 19. Services | |
| 20. Public Administration and Community Services | |

Notes: The bracketed numbers for the seven sector aggregation indicate the aggregated sectors from the twenty sector list.

We adopt a Cobb-Douglas technology for intermediate inputs here for two reasons. The first is the comparative unease that economists have in accepting unchanging "trade coefficients" (viz., the off-diagonal blocks of the multi-regional IO table) in an international, as opposed to inter-regional (sub-national), context. The second reason is the need to calibrate our model to (own-price) import elasticities that are significantly different from zero. These elasticities typically reflect imports intended for intermediate use and also directly for final demand; the available estimates do not differentiate between these two, and must therefore be somehow allocated to each.[2] Employing a Leontief technology in intermediates implies an inordinately high import elasticity for final demand; employing a Cobb-Douglas technology in intermediates implies much more reasonable final demand import elasticities.

The two primary factors employed in each sector are characterized by a CES technology. In general, the Heckscher-Ohlin (HO) factor mobility assumptions are adopted: each factor is free to move within the sectors of each region but not between regions. In some cases alternative Ricardo-Viner (RV) factor mobility assumptions are also examined, with capital in one region being specific to either Manufacturing or Non-Manufacturing sectors (and mobile within the sectors of each block). Kimbell and Harrison [1984] discuss the procedure for calibrating the model to these alternative factor mobility assumptions. Whalley [1980a] [1980b] [1982a] [1982b] and Brown and Whalley [1980] adopt the HO approach; Whalley and Wigle [1982] adopt, *inter alia*, the RV approach.[3]

There are two major data sources required to calibrate this production structure: a complete multi-regional IO table for the regions listed in Table 1 (including sectoral value-added data), and extraneous estimates of the elasticities of substitution between labour and capital. The Institute of Developing Economies [1982] and Harrison [1984a] describe the construction of the IO table. The relative availability of national IO data for 1975 determined the dating of our model.

Table 3 lists the point estimates of the elasticity of substitution for each of the Australian sectors based on 1947/67 U.S. time-series estimates from Mayor [1971], U.S. cross-section estimates for Manufacturing sectors from Zarembka and Chernicoff [1971], and estimates for all other sectors from Piggott and Whalley [1984; Table 6.1] or Whalley [1980b; p. 1191, fn. 5].[4] Standard errors for each point estimate are also shown, and are used in our sensitivity analysis (discussed in Section 2.7).[5] The estimates for Manufacturing sectors shown in Table 3 represent value-added weighted averages of estimates obtained at the IO level of aggregation (109 sectors in the Australian case). They are "Australian" estimates simply because Australian value-added weights were employed to compute the averages. Thus each trading region has different elasticities corresponding to those in Table 3 to the extent that the share of each sector in that region's total value added differs from the corresponding Australian share.

## 2.4 Demand Structure

The demand pattern in each trading region is represented by a single private household and a single public household. Thus the model identifies 24 households in all.

TABLE 3

Elasticities of Substitution Between Primary Factors

"Australian Estimates"

| Sector | Cross-Section | | Time Series | |
|---|---|---|---|---|
| | Point Estimate | Standard Error | Point Estimate | Standard Error |
| **Twenty-Sector Aggregation** | | | | |
| 1. Agriculture, Forestry and Fishing | 0.640 | 0.640 | 0.780 | 0.200 |
| 2. Minerals and Extractive Ores | 0.500 | 0.500 | 0.110 | 0.540 |
| 3. Energy Products | 1.132 | 0.790 | 0.858 | 0.683 |
| 4. Food, Beverage and Tobacco | 1.044 | 0.173 | 0.801 | 0.140 |
| 5. Textiles, Clothing, Footwear and Leather | 1.293 | 0.170 | 1.317 | 0.100 |
| 6. Lumber and Wooden Products | 0.925 | 0.172 | 0.995 | 0.235 |
| 7. Pulp, Paper and Printing | 1.105 | 0.107 | 0.328 | 0.173 |
| 8. Chemicals | 1.462 | 0.337 | 0.599 | 0.152 |
| 9. Rubber and Plastic Products | 1.041 | 0.135 | 0.450 | 0.212 |
| 10. Non-Metallic Mineral Products | 0.828 | 0.422 | 1.453 | 0.160 |
| 11. Basic and Fabricated Metal Products | 1.141 | 0.128 | 0.567 | 0.224 |
| 12. Industrial Machinery | 0.701 | 0.179 | 0.460 | 0.563 |
| 13. Electrical and Other Machinery and Equipment | 0.662 | 0.260 | 0.736 | 0.222 |
| 14. Motor Vehicles | 1.706 | 0.362 | 1.030 | 0.250 |
| 15. Other Transport Equipment | 0.871 | 0.220 | 0.327 | 0.339 |
| 16. Electricity, Gas and Water Supply | 0.167 | 0.167 | 0.360 | 0.050 |
| 17. Construction | 0.324 | 0.324 | 0.324 | 0.324 |
| 18. Trade, Transport and Communications | 0.970 | 0.970 | 0.970 | 0.970 |
| 19. Services | 0.970 | 0.970 | 0.240 | 0.400 |
| 20. Public Administration and Community Services | 0.970 | 0.970 | 0.970 | 0.970 |
| **Seven-Sector Aggregation** | | | | |
| 1. Agriculture, Forestry and Fishing | 0.640 | 0.640 | 0.780 | 0.200 |
| 2. Mining and Quarrying | 0.500 | 0.500 | 0.110 | 0.540 |
| 3. Manufacturing | 1.096 | 0.205 | 0.749 | 0.215 |
| 4. Utilities | 0.167 | 0.167 | 0.360 | 0.050 |
| 5. Construction | 0.324 | 0.324 | 0.324 | 0.324 |
| 6. Trade and Transport | 0.970 | 0.970 | 0.970 | 0.970 |
| 7. Services | 0.970 | 0.970 | 0.240 | 0.400 |

Private households maximize a nested utility function with three levels (for convenience we shall assume the 20-sector commodity aggregation). The "top" level is a Klein-Rubin utility function,[6] leading to an Extended Linear Expenditure System (ELES) defined in principle over eight commodity groupings (Food, Clothing, Housing, Durables, Personal Care, Transportation, Recreation, and Other Services) and savings. The "middle" level is a CES function defined over the commodities within each of these eight commodity groupings. Thus "Agriculture, Forestry and Fishing" and "Food, Beverage and Tobacco" from Table 2 are combined in a CES function to form the composite grouping "Food".[7] Finally, the "bottom" level is a CES function defined over each of the commodities listed in Table 2 differentiated by origin.

The consumption problem of the private household may therefore be viewed in three stages. Given the income to be allocated to consumption (i.e., non-savings), the allocation of expenditure to the eight commodity groupings is decided. Then, conditional on the expenditure for each group, the allocation to each of the (varying number of) commodities within each group is decided. Finally, the household decides between alternative sources of each commodity given the expenditure allocated to that commodity. Specific functional forms aside, this type of utility nesting structure is common to recent international trade GE models.

The basic data to parameterize the top level of our utility function for each private household are obtained from Lluch, Powell and Williams [1977] (LPW) and input-output data on final demand expenditure shares. LPW (pp. 74/80) estimate an approximate relationship between the ELES "Frisch parameter"[8] and real GNP per capita. This relationship is used to estimate the value of this "parameter" for those countries in our model (Table 1) that are not directly included in the LPW study.[9] Expenditure elasticities, and their implied asymptotic standard errors, are obtained from Table 3.12 of LPW (p. 54); for those countries not directly covered by their estimates the average estimates for "real GNP per capita" class intervals are used.[10] Harrison and Kimbell [1983a; Appendix 3] discuss the calibration of the top level Klein-Rubin utility function using these estimates and expenditure shares (including savings) obtained from the input-output data.

The middle and bottom levels of our utility function are calibrated to uncompensated own-price elasticities using the procedures outlined in Mansur and Whalley [1984] and widely used in other models. The relevant elasticities, and implied standard errors, for the <u>middle</u> level calibration are obtained from LPW (Table 3.13, p. 55) in the same manner as the expenditure elasticity estimates discussed above. Where available, import price elasticities obtained from Alouze [1977], Stern, Francis and Schumacher [1976; pp. 15/24] and Stone [1979] were similarly used to calibrate the <u>bottom</u> level. Such data were available for Australia, Canada, Japan, U.S.A. and the EEC. For every other country in our model the own-price elasticity estimates used at the middle level were also used at the bottom level.[11]

Household savings are allocated entirely to the purchase of a Cobb-Douglas composite of commodities from all regions for the purpose of capital formation. These expenditures refer to purchases of real goods and services.

Public households in each region spend their revenues on various own-region and foreign commodities. A Cobb-Douglas utility function is used for these households, and is calibrated using expenditure shares by each government (for current consumption purposes <u>and</u> capital formation).

Private household income is generated from the sale of their factor endowment to own-region industries and from transfers received from their government. Each government receives revenue from the taxes, tariffs and non-tariff barriers that it levies on own-region and foreign economic activity; these policy instruments are discussed in more detail in the next section. In principle the model allows for inter-government transfers, in the form of (untied) aid; in practice we have been unable to obtain adequate data to include these transfers in the present model.

Although each and every household has a "balanced budget" in equilibrium, there is no explicit or implicit presumption in the model that bilateral trade flows between any two regions balance.

## 2.5 Tariffs and Non-Tariff Barriers

In principle the model incorporates a wide range of taxes, tariffs and non-tariff barriers (NTB's) differentiated by commodity, region and stage-of-production of (legal) incidence, and taxing government. In practice, however, data limitations severely circumscribe the detail, coverage and accuracy of our "model equivalent" estimates of these policy instruments.[12]

The basic source of data on tariffs was the international input-output table presented in Institute of Developing Economies [1982] and Harrison [1984a]. We draw a distinction between tariffs levied on imports of intermediate inputs and those levied on imports of final goods. Recall that we allow a given sector to import intermediates from all other sectors in all regions. Thus the total import duties paid by this sector reflects the various tariff rates applicable to the range of intermediates it imports, weighted by the expenditure on each imported intermediate. The "ad valorem" tariff implied by this procedure need bear no similarity to the posted tariff on imports of the commodity of the sector in question.[13] Moreover, the same tariff rate applies to all intermediate input imports of the given sector. The implied tariff rates on final demand imports bear a direct similarity to posted rates (due allowance being made for "water in the tariff"). Although our model-equivalent tariff rates on intermediate input imports do not correspond directly to posted rates, it can be shown that they can be reconciled satisfactorily with the 1976 rates used by Whalley [1980b; Table 2] for the U.S., EEC and Japan.

The available data on "ad valorem equivalents" of NTB's are notoriously poor. We rely heavily on the aggregative estimates listed in Whalley [1982b; Table A1] and the detailed estimates employed in Whalley [1980a] and Yeats [1978]. Government procurement practices are approximated by a 50% tariff applied to imports of each public household in each region, following Whalley [1982a; p. 356]. Note that domestic tax systems are often viewed as NTB's (see Lloyd [1973; Ch. 7]), and their discriminatory features are included in the model.

## 2.6 Solution Procedures

A benchmark equilibrium solution for 1975 was obtained by solving "backwards" for certain parameter values in the usual fashion. Apart from the treatment of intermediate input substitutability these procedures were standard to the literature. Mansur and Whalley [1984; Section 3] and

Piggott and Whalley [1984; Ch. 4] provide general discussions of these procedures, and Kimbell and Harrison [1984; Section 3.2] discuss the calibration of models with immobile factors (i.e., our Heckscher/Ohlin assumption). Given some counterfactual policy change, we solve the model for a new equilibrium using the Factor Price Revision Rule introduced by Kimbell and Harrison [1983].[14]

### 2.7 Sensitivity Analysis

The policy-relevance of numerical GE models, and their avowedly "empirical" nature, render them open to casual criticism. Most economists are deeply familiar with their underlying neoclassical structure; we are not therefore concerned to defend them from criticisms based on rejection of that structure. On the other hand, criticism based on suspicion of the particular empirical calibration adopted currently leads to non-systematic and/or uninformed debate. The general techniques used to calibrate numerical GE models are discussed in the references given above. Given, then, that users of numerical GE models are increasingly "informed" as to the various sources of data embodied in their simulations, how is one to identify the robustness of the results for some particular policy decision? Our response to this important question is to undertake a systematic sensitivity analysis of our policy simulations in Section 3.

A number of critical dimensions to such analysis may be readily identified from any discussion of the procedures used to calibrate GE models. For one obvious example, consider the elasticities of substitution listed in Table 3 that are used to calibrate the CES production functions of each sector. Popular calibration procedure is to employ the vector of point estimates based on a search of the available econometric literature. Such estimates are usually accompanied by standard errors, such as those also listed in Table 3. The vectors of estimates formed by considering all combinations of estimates within (say) one standard error either side of the point estimate for each sector provides a continuum of distinctly calibrated GE models whose comparative static (policy) properties need not be identical.

In the present case we undertake a systematic sensitivity analysis for each policy simulation with respect to three sets of elasticities: the elasticities of substitution between primary factors (Section 2.3), the import demand elasticities (Section 2.4), and the own-price demand elasticities (Section 2.4). In the first and third cases we have available well-defined standard errors and a presumption that the distribution of each parameter estimate is well behaved (i.e., follows a t-distribution); we may therefore completely define a Bayesian prior distribution for these elasticities.[15] In the case of the import elasticities we adopt a uniform prior over the range of estimates tabulated by Stern, Francis and Schumacher [1976; p. 15 ff.][16] <u>or</u> the same prior as used for the demand elasticities when we had no separate import elasticity estimates available. Harrison and Kimbell [1983b] explain the procedure used to weight each of the simulations in the sensitivity analyses.

Harrison and Kimbell [1983b] distinguish between "conditional" and "unconditional" systematic sensitivity analyses. The former refers to a series of simulations in which each parameter is perturbed from its point estimate a certain number of times (four in the present case) conditional on all other parameters being set only to their point estimate value. The latter refers to perturbations of each parameter conditional on all other parameters also being perturbed from their point estimate a certain number of times; thus the set of simulations is "unconditional". Clearly the latter type of analysis is more complete than the former, but at a severe cost in terms of the number of required simulations. Given the size of the present model and the large number of parameters subject to perturbations (252 in the seven-sector model and 720 in the twenty-sector model), we have opted for the conditional systematic sensitivity analysis.

We shall consider five values for each parameter, including the point estimate. Thus we have four perturbations for each parameter. Two of these perturbations will be one-half of a standard error above and below the point estimate, and the other two will be one standard error above and below the point estimate. The exact marginal probabilities for these values depend on the relevant degrees-of-freedom for the parameter estimate; where we are unable to infer that value from published data it is assumed large enough for asymptotic results to hold. We therefore require 1009 simulations for each policy change in the seven-sector model (252 relevant parameters times 4 perturbations per parameter, plus one simulation with all parameters equal to their point estimate), and 2881 simulations in the twenty-sector model. In all cases reported in Section 3 we initially solved the seven-sector model for the given policy change with all parameters set equal to their point estimates. The solution vector of relative factor prices (containing 23 elements) was then employed as starting values for the twenty-sector model.

Given the solution values for this simulation as starting values for the sensitivity analysis simulations involving a perturbed elasticity, we were able to find the new solution values extremely quickly.[17]

### 2.8 Aggregation Procedures

Harrison and Manning [1984] propose a "best approximate aggregation" (BAA) method of constructing aggregate IO systems that minimizes the mean-square-error of aggregate predictions. The BAA method is proposed as an alternative to Naive aggregation procedures (that ignore the decision-theoretic objective of the eventual use of the IO model) and the Holy Grail of Consistent (or Exact) Aggregation (which is simply not feasible in general).[18] The illustrative applications of BAA reported by Harrison and Manning [1984; Section 4] indicate the dangers of using Naive aggregation procedures on the Leontief Inverse Transpose. Moreover, BAA in these cases yields significant improvements in the predictive power of the aggregate IO model. This result has some importance for applied GE models, in the context of well-known examples of the loss in predictive power when one aggregates sectors (e.g., Fullerton, Henderson and Shoven [1984] on the Harberger two-sector aggregation scheme). Harrison [1984b] demonstrates that applying the BAA method to the IO data of the present GE model in several tariff reduction policy simulations indeed allows predictions of welfare effects in the resulting aggregate GE model that are virtually identical to those obtained with the disaggregated GE model.[19] Several of the policy results reported in Section 3 are based on a "best approximate" aggregate GE model in this limited sense.[20]

## 3. POLICY RESULTS

In this section the welfare incidence of a series of hypothetical tariff reduction policies is reported. In each case an indication of the robustness of the results is given, based on the sensitivity analysis described earlier. Section 3.1 considers the aggregate welfare impact in each region of various unilateral tariff reductions. Section 3.2 considers the impact of two multilateral tariff reductions. Finally, Section 3.3 reconsiders the results of one of the policies when a degree of factor immobility is assumed.

### 3.1 Unilateral Tariff Liberalization

Table 4 presents the welfare impact of three unilateral 50% tariff reduction policies by the U.S., the EEC and Japan, respectively. The welfare change for the private household in each region is measured by the Hicksian equivalent variation between the benchmark equilibrium and the various counterfactual equilibria (conditional on various parameter estimates). This measure is then expressed as a percentage of GDP in the base year in order to allow comparisons between regions of such diverse size.

The Point Estimate column reflects the impacts of the policy in the counterfactual equilibrium conditional on all parameters being set equal to their respective point estimates. The remaining three columns report summary statistics for the set of counterfactual equilibria implied by our sensitivity analysis. The Mean welfare impact is the average change in the welfare impacts, with the prior probability density functions discussed earlier being used to weight the results. The Standard Deviation of the welfare impact is similarly computed from the pdf of welfare impacts.[21] The final column reports the

TABLE 4

Welfare Impact of Unilateral Tariff Reduction Policies

| Region Reducing Tariffs | Impacted Region | Point Estimate | Mean | Standard Deviation | Probability of Welfare Gain |
|---|---|---|---|---|---|
| U.S. | Australia | 0.02 | 0.03 | 0.001 | 0.90 |
| | Canada | 0.37 | 0.42 | 0.03 | 0.93 |
| | Indonesia | 0.01 | 0.01 | 0.0 | 0.97 |
| | Malaysia | 0.01 | 0.01 | 0.0 | 0.96 |
| | Philippines | 0.03 | 0.03 | 0.0 | 0.94 |
| | Singapore | 0.01 | 0.01 | 0.0 | 0.98 |
| | Thailand | 0.002 | 0.003 | 0.0 | 0.95 |
| | Korea | 0.07 | 0.07 | 0.01 | 0.84 |
| | Japan | 0.17 | 0.14 | 0.08 | 0.71 |
| | U.S.A. | -0.21 | -0.29 | 0.04 | 0.02 |
| | EEC | 0.07 | 0.09 | 0.02 | 0.91 |
| EEC | Australia | 0.01 | 0.01 | 0.0 | 0.81 |
| | Canada | 0.02 | 0.01 | 0.0 | 0.83 |
| | Indonesia | 0.0 | 0.0 | 0.0 | 0.87 |
| | Malaysia | 0.01 | 0.01 | 0.0 | 0.92 |
| | Philippines | 0.0 | 0.0 | 0.0 | 0.83 |
| | Singapore | 0.01 | 0.01 | 0.0 | 0.91 |
| | Thailand | 0.01 | 0.01 | 0.0 | 0.89 |
| | Korea | 0.01 | 0.01 | 0.0 | 0.89 |
| | Japan | 0.02 | 0.04 | 0.01 | 0.83 |
| | U.S.A. | 0.01 | 0.04 | 0.01 | 0.79 |
| | EEC | -0.14 | -0.23 | 0.07 | 0.18 |
| Japan | Australia | -0.03 | -0.03 | 0.001 | 0.07 |
| | Canada | 0.003 | 0.002 | 0.0 | 0.76 |
| | Indonesia | -0.02 | -0.03 | 0.002 | 0.15 |
| | Malaysia | -0.01 | -0.01 | 0.0 | 0.19 |
| | Philippines | 0.0 | -0.001 | 0.0 | 0.43 |
| | Singapore | 0.0 | 0.0 | 0.0 | 0.37 |
| | Thailand | -0.01 | -0.01 | 0.0 | 0.18 |
| | Korea | -0.05 | -0.06 | 0.01 | 0.21 |
| | Japan | -0.21 | -0.25 | 0.03 | 0.09 |
| | U.S.A. | 0.03 | 0.04 | 0.01 | 0.87 |
| | EEC | 0.02 | 0.05 | 0.01 | 0.92 |

Notes: Welfare impact is measured by the Hicksian equivalent variation expressed as a percentage of GDP. A reported value of "0.0" indicates an absolute value less than 0.0049. The results for the EEC and Japanese tariff reductions were generated by the "best approximate" aggregate model.

Probability of Welfare Gain, obtained by numerically evaluating the (proper) pdf of welfare gains. This column provides a useful measure of the confidence one can attach to qualitative inferences about welfare impacts in the model.

Several features of the results in Table 4 are noteworthy. First, the impacts of such a large tariff reduction are consistently small, even when one allows for their interpretation as ongoing annual impacts. Second, the largest impact is on the region reducing tariffs, with the U.S. tariff reduction having more noticeable spillover effects on other regions (especially Canada, Japan, the EEC, and Korea). Third, each region that reduces tariffs suffers a welfare loss that is qualitatively robust. Fourth, all other regions benefit from separate tariff reductions by the U.S. and the EEC, but the spillover effects are mixed in the case of Japanese tariff reductions. Fifth, the spillover effects of the U.S. and EEC reductions, although small, are extremely robust qualitatively. Finally, an intriguing implication of these results is the extent to which the economic fate of the smaller Pacific Basin nations (viz., Australia, Korea and the ASEAN nations) is positively correlated with Japanese fortunes, and negatively correlated with U.S. fortunes.

### 3.2 Multilateral Tariff Liberalization

Table 5 presents the welfare impact of two multilateral 50% tariff reductions: one by "Developed Countries" (defined as Australia, Canada, Japan, U.S.A. and EEC) and one by all regions (including a residual Rest of World).

There are several noteworthy features of these results. First, the own-region welfare impacts of unilateral tariff cuts by the U.S., the EEC and

TABLE 5

Welfare Impact of Multilateral Tariff Reduction Policies

| Regions Reducing Tariffs | Impacted Region | Point Estimate | Mean | Standard Deviation | Probability of Welfare Gain |
|---|---|---|---|---|---|
| Developed | Australia | 0.02 | 0.03 | 0.003 | 0.23 |
| | Canada | 0.01 | -0.01 | 0.002 | 0.31 |
| | Indonesia | 0.01 | 0.01 | 0.0 | 0.60 |
| | Malaysia | 0.02 | 0.02 | 0.0 | 0.75 |
| | Philippines | 0.01 | 0.01 | 0.0 | 0.68 |
| | Singapore | 0.01 | 0.01 | 0.0 | 0.89 |
| | Thailand | 0.02 | 0.02 | 0.0 | 0.73 |
| | Korea | 0.03 | 0.04 | 0.02 | 0.78 |
| | Japan | 0.03 | 0.06 | 0.05 | 0.87 |
| | U.S.A. | -0.10 | -0.15 | 0.07 | 0.12 |
| | EEC | 0.03 | -0.02 | 0.06 | 0.36 |
| All | Australia | 0.01 | 0.20 | 0.11 | 0.87 |
| | Canada | 0.10 | 0.21 | 0.06 | 0.74 |
| | Indonesia | -0.55 | -0.83 | 0.09 | 0.26 |
| | Malaysia | 0.98 | 1.10 | 0.03 | 0.89 |
| | Philippines | -0.71 | -0.93 | 0.07 | 0.13 |
| | Singapore | 1.39 | 1.54 | 0.03 | 0.92 |
| | Thailand | -1.88 | -2.19 | 0.15 | 0.06 |
| | Korea | 1.07 | 1.81 | 0.08 | 0.95 |
| | Japan | 1.02 | 1.10 | 0.02 | 0.97 |
| | U.S.A. | 0.17 | 0.23 | 0.03 | 0.78 |
| | EEC | 0.39 | 0.50 | 0.07 | 0.91 |

Notes: The results for the Developed Countries tariff reductions were generated by the "best approximate" aggregate model.

Japan (cf. Table 4) are significantly offset by a multilateral tariff cut by Developed Countries (DC). The U.S. and the EEC do suffer a welfare loss, although the impact on the EEC is not particularly robust, and Japan has a robust welfare gain. Second, a global multilateral tariff reduction leads to robust welfare gains for all DC, with significant losses for three ASEAN nations. Third, the specific results for Australia and Canada reflect two common and conflicting characteristics of each region. One is the relative significance of Non-Manufacturing exports; thus there is a deterioration in their terms-of-trade (TOT) evaluated at base period trade levels in each sector. On the other hand, the backward linkages via trade in intermediates with Japan, the U.S. and the EEC tend to counteract the direct TOT effects. Fourth, the specific results for the remaining Pacific Basin nations largely reflect direct TOT effects. As the major ASEAN exporter of Agricultural products to the Pacific Basin, Thailand suffers relatively heavily.

Given the importance of TOT effects in the present model, it should be noted that the DC multilateral tariff cut is slightly concentrated on Manufacturing goods.[22] This is true even in the face of heavy Japanese tariff protection of Agriculture.[23] The expansion of trade in Manufactured goods which follows the tariff reduction outweighs the direct effect on Manufacturing prices, leading to a net move in the (trade-weighted) TOT against countries that export Non-Manufacturing goods.

### 3.3 Multilateral Tariff Liberalization and Factor Immobility

In Table 6 we report the welfare impacts of a 50% global multilateral tariff reduction assuming that Capital is "specific" to certain blocks of sectors in the U.S. These blocks are Manufacturing and

TABLE 6

Welfare Impacts of Tariff Reductions With Immobile Factors

| Impacted Region | Point Estimate | Mean | Standard Deviation | Probability of Welfare Gain |
|---|---|---|---|---|
| Australia | 0.01 | 0.20 | 0.11 | 0.89 |
| Canada | 0.10 | 0.18 | 0.06 | 0.76 |
| Indonesia | -0.55 | -0.84 | 0.09 | 0.25 |
| Malaysia | 0.98 | 1.11 | 0.03 | 0.89 |
| Philippines | -0.71 | -0.93 | 0.07 | 0.13 |
| Singapore | 1.39 | 1.56 | 0.03 | 0.94 |
| Thailand | -1.88 | -1.20 | 0.14 | 0.05 |
| Korea | 1.09 | 1.93 | 0.07 | 0.96 |
| Japan | 1.08 | 1.14 | 0.02 | 0.97 |
| U.S.A. | 0.04 | 0.09 | 0.05 | 0.52 |
| EEC | 0.44 | 0.61 | 0.08 | 0.93 |

and Non-Manufacturing; Capital is free to relocate within the sectors of each block. These results may be otherwise compared with those in Table 5, in which complete mobility was assumed within each region. The major difference between the two sets of results is obtained for the U.S., with all other regions showing little or no change from the previous results apart from a slightly greater robustness of the qualitative implications of the policy. The welfare impacts for the U.S. are similar to those with complete mobility, but somewhat larger. The probability of a welfare gain to the U.S. decreases from 0.78 to 0.52 with factor immobility.

Two natural extensions to our modelling of factor mobility could be undertaken. The first is to allow a factor to be specific to certain sectors, rather than to a large block of sectors. One would expect significantly greater effects on welfare in such a case due to larger changes in factor prices required to maintain full employment (see Hartigan and Tower [1982]). The second extension would assume factor mobility in more than one region. Our results and the results in Whalley and Wigle [1982; Table 9] indicate that own-region welfare impacts are larger with own-region factor immobility. It would be interesting to see how robust our policy simulations are to each of these extensions.

## 4. CONCLUDING REMARKS

Despite its size, the model presented in this paper is conceptually a simple one. Many important and interesting issues are neglected (e.g., economies of scale) or dealt with superficially (e.g., the model-equivalent characterization of NTB's). Without wanting to deprecate exploratory attempts to address such issues, one theme to emerge from the present study is the need to systematically explore the empirical properties of simple models before investing heavily in more complicated formulations. Given that we know so little about these properties for the simple models that are currently available, much remains to be done.

FOOTNOTES

[1]Whalley [1980b; p. 1185] notes the significant computational expense involved in solving his 33-sector model when CES intermediate input substitutability is allowed. Indeed the additional expense is such as to force him to aggregate his model to five sectors (contrast Whalley [1980a]). The use of Cobb-Douglas intermediate input substitutability was apparently first developed by Boadway and Treddenick [1978; p. 430 ff.]. Harrison and Kimbell [1983a; Appendix 1] provide a formal statement of this approach and its benchmark calibration.

[2]See Burgess [1974a] [1974b] and Dixon, Parmenter, Sutton and Vincent [1982; pp. 182-183] for an explicit recognition of this point.

[3]Cook [1981] and Hartigan and Tower [1982] explore the implications of alternative factor mobility assumptions in models of "small" open economies applied to the United States.

[4]Whalley [1980b; p. 1191, fn. 15] attributes his estimates primarily to the compendium in Caddy [1976], although Caddy only presents estimates for Manufacturing sectors. Mayor [1971] does present estimates for several non-manufacturing sectors, and we use these for our sectors 1, 2, 16 and 19 (time series estimates).

[5]A standard error exactly equal to the point estimate indicates that no data-based error estimate is available. This is common in non-manufacturing sectors, and is consistent with a reasonably diffuse prior on the point estimate. The sensitivity analysis reported below employs the time series estimates in Table 3.

[6]Lluch [1973] and Howe [1975] advance alternative interpretations of the formal household problem leading to the ELES; see also Lluch, Powell and Williams [1977; p. 14].

[7]In several cases, given the level of commodity aggregation adopted, this level of the utility tree is redundant (e.g., the grouping "Clothing" includes only one commodity from Table 2, "Textiles, Clothing, Footwear and Leather") or ambiguous (e.g., the commodity "Services" in Table 2 is allocated to two groupings, "Recreation" and "Other Services"). The full ELES disaggregation is retained, in the face of such redundancy and ambiguity, for three reasons: (i) data exist for two trading regions (Australia and the U.S.) to split up commodities between commodity groupings, removing any ambiguity; (ii) it is possible to simply aggregate commodity groupings to remove any remaining ambiguity; (iii) we hope to employ greater commodity disaggregation in due course (and do not wish to recode the model or data).

[8]The "Frisch parameter" under LES is the expenditure elasticity of the marginal utility of expenditure; this "parameter" is well-defined under ELES, and is the concept we are directly concerned with.

[9]Korea, Thailand, Australia and the U.S. are directly covered by LPW.

[10]An alternative approach might be to use the regressions across countries of expenditure elasticity against GNP per capita reported in Table 3.18 (p. 62) of LPW. However, the explanatory power of four of the eight regressions is extremely low.

[11]The bottom level of the utility function for these countries is obviously redundant with this formulation. It is retained for coding convenience and to allow for the possible future use of import elasticities for these countries.

[12]Harrison and Kimbell [1983a; Section 2.5 and Appendix 4] provide details on the data sources for the estimates used, as well as a description of the various taxes included in the model. Given the present focus on tariff reductions, we do not discuss the treatment of taxes.

[13]Unless, of course, all of those imports were directed solely to the corresponding domestic sector (i.e., the off-diagonal _elements_ of the off-diagonal trade _blocks_ in our international IO table are _all_ zero). This is not the case in the present IO table.

[14]The substitutability of intermediate inputs is algorithmically transparent in the sense that any procedure that can solve models with fixed intermediate requirements will also be able to solve models assuming (Cobb-Douglas) substitutability. Moreover, this new feature only adds one matrix operation during each iteration of the algorithm.

[15]There is an implicit presumption here that the off-diagonal elements of the covariance matrix of our elasticity estimates are all zero. Although non-zero elements are theoretically available for certain blocks of elasticity estimates (e.g., the demand elasticities) this presumption is adopted in the present model.

[16]Those authors are quite explicit in eschewing any probabilistic interpretation of their point estimates or range of estimates: "It should be reiterated that the ranges shown are not meant to be interpreted as confidence intervals. Rather, they refer to point estimates. In using either the ranges or 'best' estimates for analytical purposes, it is therefore advisable to avoid attaching probability statements to any conclusions" (p. 14). Our prior corresponds to the Bayes-Laplace diffuse prior in Bayesian analysis: see Zellner [1971; pp. 41-53] for further discussion. Harrison and Kimbell [1983a] adopted the _median_ of the range of estimates as their "point estimate";

in the present study the mean of the implied uniform prior pdf is adopted as the "point estimate" instead. This change in parameterization significantly reduces the skewness of the probability density functions of policy impacts (see Section 3).

[17]A procedure for computing "good" starting values for large GE problems, based on an analytic solution for a stylized version of the original GE model, is proposed in Kimbell and Harrison [1983; Section 6.3]. Indeed this method was employed to solve the seven-sector model (parameters equal to their point estimates) with substantial savings in execution time compared to a "cold start" (initial solution values equal to the benchmark solution values). Using the seven-sector solution values as starting values for the twenty-sector model proved more efficient (in all cases studied) than using the analytic approximation technique directly on the larger model.

[18]BAA generalizes the notion of Consistent aggregation (i.e., if the latter is feasible it is the BAA solution). In the present context we are assuming that the aggregation scheme is given (e.g., see Table 2).

[19]Note that there is some significant loss in predictive power for certain endogenous variables other than the welfare measures.

[20]The aggregation is "limited" in the sense that we do not apply the BAA principle to the final demand and primary factor demand systems (Naive aggregation was employed in these cases). Harrison [1984b] discusses this issue in more detail.

[21]Note that there is absolutely no presumption that the policy impacts (welfare impacts in this case) have a Gaussian distribution. One should not therefore assume that the Mean and Standard Deviation are in any way "sufficient statistics" of that distribution. In fact, many of the policy impact pdf's in this study and Harrison and Kimbell [1983a] are skewed, in some cases significantly.

[22]The tariff reductions negotiated during the Tokyo Round, as applied to post-Kennedy-Round tariffs, are more heavily concentrated on Manufactured goods. Whalley [1982a] and Harrison and Kimbell [1983a; Section 3.1] examine the impact of a "Tokyo Round" multilateral reduction.

[23]Many of the tariffs applied to Agriculture in Japan nominally apply to Food Processing sectors (which correspond to our "Food, Beverage and Tobacco" sector). Given the heavy backward linkages of these sectors to own-region Agricultural sectors, and the lack of other forward linkages of Agriculture to any other own-region sectors, nominal tariffs in the Food Processing sector correspond closely to effective tariffs on Agriculture. See Saxon and Anderson [1982] for further discussion.

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