A Disaggregated Model of World Production and Trade: An Estimate of the Impact of the Tokyo Round

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We present in this paper a computational model of world production, trade, and employment that is disaggregated by country and sector and report on the application of the model to the changes in tariffs and quantifiable nontariff barriers negotiated in the Tokyo Round that was concluded in 1979. The model incorporates supply and demand functions and market-clearing conditions for 22 tradable industries, plus markets for 7 nontradable industries, in each of the 18 major industrialized countries and 16 major developing countries. The equations of the model are presented in the text and the explicit functional forms in an appendix. The implementation of the model is discussed briefly.

Application of the model to the Tokyo Round suggested that there will be small but beneficial effects on trade, domestic prices, and economic welfare in practically all the major industrialized countries and in some of the major developing countries. Because many of the NTB codes negotiated in the Tokyo Round were stated in advisory terms, their impact cannot be evaluated unambiguously at present. Further, many existing NTBs of importance were exempted altogether from the negotiations. The Tokyo Round must be viewed accordingly as having dealt with a somewhat limited part of all interferences with trade.

In this paper, we describe a disaggregated model of world production and trade and report on its application to the changes in tariffs and nontariff barriers that were negotiated in the Tokyo Round of multilateral trade negotiations concluded in 1979. Although our model was originally designed to study the effects of multilateral tariff reductions,[1] it also includes several additional exogenous variables which allow us to study other problems.[2] The current version of the model includes, besides tariffs,

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[1] See Deardorff and Stern (1979), where an 18-country version of the model was used to study the tariff and nontariff barrier reductions negotiated in the Tokyo Round. As will be made clear below, the microeconomic focus of our model distinguishes it from the macro-oriented world linkage systems typified by the LINK, DESMOS and METEOR models. These latter models are also highly aggregated in terms of their sectoral coverage within countries.

[2] See Deardorff et al. (1979), where the effects of exchange rate changes are presented and Deardorff and Stern (1980*a*, *b*) for analyses of the effects of changes in trade on employment and changes in the structure of protection under fixed and flexible exchange rates in the major industrialized countries.

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taxes on exports and home production, quantitative restrictions on trade, a variable to represent government procurement regulations, and a facility for making the volume of trade exogenous. The model can be solved under a variety of assumptions about exchange regimes, including, in addition to fixed and flexible exchange rates, the possibility of pegging to a basket of currencies and the use of import licensing. And finally, we include a characterization of labor markets in which wages can be either exogenous or endogenous at the country or industry level.

EQUATIONS OF THE MODEL

The complete model, though without functional forms, is presented as equations 1–17 in Table 1. Functional forms appear in the Appendix and will be explained below.

The model includes m countries, $i = 1, \ldots, m$, producing and trading n goods, $j = 1, \ldots, n$, and producing an additional $(n' - n)$ nontradable goods, $j = n + 1, \ldots, n'$. A distinguishing characteristic of our model, however, is that both producers and consumers distinguish, within tradable industries, between home goods, which are produced and used domestically, and those that are either exported or imported.

Thus, within each country and tradable industry, producers are separated into a home sector and an export sector. Each has its own supply function, reflecting certain fixed factors of production that cannot easily be transferred between the sectors. This nontransferability may result from locational requirements or from the need to tailor products to national markets, though these features are not explicit in our model.

Demanders, too, differentiate between home-produced and imported products of a given tradable industry. Consumers, as well as producers who demand intermediate inputs, are assumed to regard home-produced and imported goods as imperfect substitutes, but imports from various foreign countries as perfect substitutes.[3] Thus, demands for imports and home-produced goods are separate, but depend on the prices of both.

Three separate prices obtain in each country, i, for each tradable industry, $j = 1, \ldots, n$. First, a home price, p_{ij}^H, is paid by users and received by producers in the home sector.[4] It is determined by the equality of home-sector supply and demand in equation 8. The second and third prices are those received for exports, p_{ij}^X, and those paid for imports, p_{ij}^M. All countries face a common world price, p_j^W, in each tradable industry, and it is

[3]Ideally, we would like imports from different countries to be imperfect substitutes as well. However, data limitations and the difficulty of solving a more general model prevented this.

[4]Actually, if the tax on home production $(1 - t_{ij}^H)$, is not zero, producers receive only $t_{ij}^h p_{ij}^H$

Table 1: Equations of the Model

Country System Equations

Supply functions of products for export

$$S^X_{ij} = S^X_{ij}(p^X_{ij}, p^H_{i1}, \ldots, p^H_{in'}, p^M_{i1}, \ldots, p^M_{in}, w_{ij}, K^X_{ij}),$$

$$i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{1}$$

Supply functions of products for home use

$$S^H_{ij} = S^H_{ij}(t^H_{ij} p^H_{ij}, p^H_{i1}, \ldots, p^H_{in'}, p^M_{i1}, \ldots, p^M_{in}, w_{ij}, K^H_{ij}), \tag{2}$$

$$i = 1, \ldots, \quad j = 1, \ldots, n'.$$

Demand functions for imported goods[a]

$$D^M_{ij} = D^M_{ij}(p^M_{ij}, p^H_{ij}, E_i, [p^H_{i1}]S^H_{i1}, \ldots, [p^H_{in'}]S^H_{in'}, \tag{3}$$

$$[p^X_{i1}]S^X_{i1}, \ldots, [p^X_{in}]S^X_{in}, G_{ij}), \quad i = 1, \ldots, m, \quad j = 1, \ldots, n.$$

Demand functions for home-produced goods[a]

Tradables:

$$D^H_{ij} = D^H_{ij}(p^H_{ij}, p^M_{ij}, E_i, [p^H_{i1}]S^H_{i1}, \ldots, [p^H_{in'}]S^H_{in'}, \tag{4a}$$

$$[p^X_{i1}]S^X_{i1}, \ldots, [p^X_{in}]S^X_{in}, G_{ij}), \quad i = 1, \ldots, m, \quad j = 1, \ldots, n.$$

Nontradables:

$$D^H_{ij} = D^H_{ij}(p^H_{ij}, E_i, [p^H_{i1}]S^H_{i1}, \ldots, [p^H_{in'}]S^H_{in'}, [p^X_{i1}]S^X_{i1}, \ldots, [p^X_{in}]S^X_{in}), \tag{4b}$$

$$i = 1, \ldots, m, \quad j = n + 1, \ldots, n'$$

Export prices

$$p^X_{ij} = t^{Xeq}_{ij} R_i p^W_j, \quad i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{5}$$

Import prices

$$p^M_{ij} = t^{Meq}_{ij} R_i p^W_j, \quad i = 1, \ldots, m, \quad j = , \ldots, n. \tag{6}$$

Consumer expenditure and tariff revenue

$$E_i = E^0_i + \sum_{j=1}^{n} (t^{Meq}_{ij} - 1) R_i p^W_j D^M_{ij} + \sum_{j=1}^{n} (1 - t^{Xeq}_{ij}) R_i p^W_j S^X_{ij} \tag{7}$$

$$+ \sum_{j=1}^{n'} (1 - t^H_{ij}) p^H_{ij} S^H_{ij}, \quad i = 1, \ldots, m.$$

Market equilibrium for home goods

$$S^H_{ij} = D^H_{ij}, \quad i = 1, \ldots, m, \quad j = 1, \ldots, n'. \tag{8}$$

Tariff Equivalents

To reflect quantitative restrictions:

$$t^{Meq}_{ij} = t^{Meq}_{ij}(t^M_{ij}, D^M_{ij}, Q^M_{ij}), \quad i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{9a}$$

Table 1: Cont.

To reflect import licensing:

$$D_{ij}^{M} = L_{ij}\left(\sum_{k=1}^{n} p_k^W S_{ik}^X + B_i^{KO}\right), \qquad i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{9b}$$

To determine exogenous imports:

$$D_{ij}^{M} = D_{ij}^{MO}, \qquad i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{9c}$$

Export tax equivalents

To reflect quantitative restrictions:

$$t_{ij}^{Xeq} = t_{ij}^{Xeq}(t_{ij}^{X}, S_{ij}^{X}, Q_{ij}^{X}), \qquad i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{10a}$$

To determine exogenous exports:

$$S_{ij}^{X} = S_{ij}^{XO}, \qquad i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{10b}$$

Demand for labor by industry[a]

Tradables:

$$D_{ij}^{L} = D_{ij}^{L}([w_{ij}], [p_{ij}^{X}], [p_{ij}^{H}], S_{ij}^{X}, S_{ij}^{H}, K_{ij}^{X}, K_{ij}^{H}) \tag{11a}$$

$$i = 1, \ldots, m, \quad j = 1, \ldots, n.$$

Nontradables:

$$D_{ij}^{L} = D_{ij}^{L}([w_{ij}], [p_{ij}^{H}], S_{ij}^{H}, K_{ij}^{H}) \tag{11b}$$

$$i = 1, \ldots, m, \quad j = n + 1, \ldots, n'.$$

Labor markets

Exogenous wages:

$$w_{ij} = w_i^{O}, \qquad i = 1, \ldots, m, \quad j = 1, \ldots, n'. \tag{12a}$$

Country-wide labor market:

$$\sum_{j=1}^{n'} D_{ij}^{L} = S_i^{LO}, \qquad w_{ij} = w_{ik} \qquad i = 1, \ldots, m, \quad j \neq k = 1, \ldots, n'. \tag{12b}$$

Industry labor market:

$$D_{ij}^{L} = S_{ij}^{LO}, \qquad i = 1, \ldots, m, \quad j = 1, \ldots, n'. \tag{12c}$$

Net exports

$$N_{ij}^{X} = S_{ij}^{X} - D_{ij}^{M}, \qquad i = 1, \ldots, m, \quad j = 1, \ldots, n. \tag{13}$$

World System Equations

Market equilibrium for traded goods

$$\sum_{i=1}^{n} N_{ij}^{X} + N_j^{\text{row}} = 0, \qquad j = 1, \ldots, n. \tag{14}$$

Table 1: Cont.

Trade balances

$$B_i^T = \sum_{j=1}^{n} p_j^W N_{ij}^X, \qquad i = 1, \ldots, m. \tag{15}$$

Rest-of-world net supply

$$N_j^{ow} = N_j^{ow}(p_1^W, \ldots, p_n^W, R_1, \ldots, R_m), \qquad j = 1, \ldots, n. \tag{16}$$

Exchange rates

Fixed rates:

$$R_i = \prod_{j \neq i} R_j^{\phi_{ij}^R} R_i^O, \qquad i = 1, \ldots, m. \tag{17a}$$

Flexible rates:

$$B_i^T + B_i^{KO} = 0, \qquad R_m = R_m^O, \qquad i = 1, \ldots, m-1. \tag{17b}$$

Notation

Endogenous Variables:

S_{ij}^X, S_{ij}^H = Supply of good j by country i, export and home sectors, respectively.

D_{ij}^M, D_{ij}^H = Demand for good j in country i, imported and home-produced, respectively.

p_{ij}^X, p_{ij}^M = Domestic price of good j in country i, exported and imported, respectively.

p_{ij}^H = Home-sector price of good j in country i.

p_j^W = World price of good j.

E_i = Consumer expenditure in country i.

B_i^T = Balance of trade of country i.

R_i = Exchange rate of country i (domestic currency per unit of world currency).

D_{ij}^L = Demand for labor by industry j in country i.

w_{ij} = Wage of labor in industry j in country i.

$t_{ij}^{Xeq}, t_{ij}^{Meq}$ = Export tax and tariff equivalents in industry j in country i, respectively.

N_{ij}^X = Net exports of industry j in country i.

N_j^{ow} = Rest-of-world net supply in industry j.

Exogenous Variables:

K_{ij}^X, K_{ij}^H = Capital stock of industry j in country i, export and home sectors, respectively.

w_i^O = Money wage in country i, if exogenous.

t_{ij}^M = 1 plus the ad valorem tariff on imports of good j into country i.

t_{ij}^X, t_{ij}^H = 1 minus the ad valorem tax on exports and home production, respectively, in industry j of country i.

Table 1: Cont.

G_{ij} =	Shift parameter representing government procurement in industry j in country i.
E_i^O =	Exogenous component of expenditure in country i.
R_i^O =	Exogenous exchange rate.
B_i^{KO} =	Exogenous capital inflow in country i.
Q_{ij}^X, Q_{ij}^M =	Shift parameter for quantitative restrictions on exports and imports, respectively, in industry j in country i.
D_{ij}^{MO}, S_{ij}^{XO} =	Imports and exports, respectively, of industry j in country i, if exogenous.
S_i^{LO}, S_{ij}^{LO} =	Country i and industry j supplies of labor.
θ_{ij}^R =	Weight used in pegging currency of country i to that of country j.

[a]Square brackets indicate variables which appear only with Cobb-Douglas specification of technology.

determined in a world market to be described below. Export and import prices are obtained from this in equations 5 and 6 by using exchange rates, R_i, and export tax and tariff-equivalent variables to be explained below.

Equations 1–4, then, present supply and demand functions in terms of these prices, plus wages, expenditure levels, and various exogenous shift parameters. Supplies depend on all home and import prices, and demands depend on all supplies, both to reflect the use of intermediate inputs to production.

All tax and tariff revenue is assumed to be redistributed to consumers and spent. Thus, expenditure is given in equation 7 as this revenue plus an exogenous component. With this formulation we avoid a more detailed characterization of macroeconomic issues by making effective expenditure exogenous.

The remaining equations for each country, 9–13, determine tariff and export-tax equivalents, labor demands and wages, and net exports. The first of these include several cases that will be explained below. There are also three different assumptions made about labor markets, but these should be self-explanatory from the table. Net exports in each industry are just the difference between export supplies and import demands, and it is these that feed into the world-system equations, 14–17, where world prices and exchange rates, if flexible, are determined.

Focusing on the world-system equations, note first that equilibrium in world markets for traded goods is required in equation 14, where the sum of these net exports plus net supply from the rest of the world is set equal to zero. This determines world prices, p_i^W. Next, the values of net exports are added over industries to form each country's balance of trade in equation 15. Rest-of-world net supply in each industry is determined in equation 16 as a simple and rather ad hoc function of world prices and exchange rates.

Finally, the exchange rates are determined in equations 17, with separate cases for fixed and flexible exchange-rate regimes. For any country with a pegged exchange rate, equation 17a sets it equal to an index of other-country rates. Depending on the weights in this index, the peg may either be to a basket of currencies or to a particular currency. For any country with a flexible exchange rate, on the other hand, 17b determines it by the requirement that its balance of trade plus an exogenous capital inflow be equal to zero.

Only $m - 1$ markets need to be cleared explicitly, due to Walras' Law.[5] However, to determine absolute prices and exchange rates, we must then specify a numeraire. This is done in the last of equations (17b), where we fix the exchange rate of country m.

Since exogenous capital flows are specified in units of the numeraire, the selection of m is not trivial. In applying the model, we have chosen the United States dollar as the numeraire, which means that the dollar values of capital flows are assumed to be constant.

SUPPLY AND DEMAND FUNCTIONS

We derived explicit supply and demand functions from utility and profit-maximization of consumers and firms, assuming explicit utility and production functions. Details of these derivations are contained in a working paper, which can be consulted (Deardorff et al. 1976). Here we merely report the assumptions that were made and list the results in the Appendix.

Since both producers and consumers demand goods, and since each tradable industry has both imported and home-produced goods available, we first characterized the choice between the two. This was done, for each industry, with functions that aggregate the services of home and imported goods. These then enter as arguments in both utility and production functions. To permit choice of the degree of substitution between home

[5] For consistency we specify the total value of rest-of-world net supplies as equal to the sum of exogenous capital inflows. It then follows from equations 14–17 that $B_m^T + B_m^{KO} = 0$. This means, as Walras' Law would suggest, that equilibrium in all but the mth currency market implies equilibrium in it as well.

and imported goods, these aggregation functions were specified as Constant Elasticity of Substitution (CES) functions. The substitution elasticities for each industry were then inferred from published econometric estimates of import-demand elasticities.[6]

To obtain consumer demand functions, we used a Cobb-Douglas utility function. Its arguments were nontradable consumption levels plus these aggregates of home and imported tradable goods. By maximizing this utility function for a given level of expenditure, we obtained consumer demand functions for each industry.

It will be noted that the demands depend only on expenditure and on home and import prices of the own industry. Prices from other industries do not appear, since Cobb-Douglas utility forces cross elasticities of demand to be zero.

For firms, we assumed prodution functions whose arguments were again these home-import aggregates for each industry plus an aggregate of primary factors as well. The aggregate function for primary factors (labor and capital) was also specified as CES.[7] These aggregates were related by fixed coefficients in the primary version of the model, though we have also used a Cobb–Douglas technology, which permits more substitution among the inputs. The model can accommodate different input–output data for each country. However, we have so far been unable to gather and process that much data. Instead, we have used tables for only the United States and Brazil for all of the industrialized and developing countries, respectively, in the model.

By solving profit-maximization problems for firms, given their production technologies and capital stocks, we obtained supply functions for the export and home sectors, demand functions for home and imported intermediate inputs, and demand functions for labor. Unlike consumer demand functions, the firm supply functions depend on prices in all industries, since all may provide intermediate inputs. Also, while firm demand functions do not directly involve cross-price effects, they do have such effects indirectly, since they depend on supplies, which in turn depend on all prices.

The main difference between the two specifications of technology is that

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[6] These elasticities are surveyed in Stern et al. (1976). To infer elasticities of substitution from these estimates, we first used our model to derive import-demand elasticities in terms of substitution elasticities and measurable parameters such as import shares. The result was then solved for the substitution elasticities. Details are contained in Deardorff et al. (1976).

[7] Elasticities of substitution between capital and labor were taken from Zarembka and Chernicoff (1971). Shares of value added and intermediate inputs were obtained from the 1972 U.S. input–output table and the 1970 Brazilian table.

input-demand functions for Cobb–Douglas technology depend directly on output price and, for labor, on the wage. With fixed coefficients, output alone determines the demand for all inputs except for the division between home goods and imports. But with substitution allowed, the prices of inputs relative to output matter for input demands, even once the level of output is known.

A further difference is also worth noting. Own-price elasticities of supply and demand are all somewhat larger with Cobb–Douglas technology than with fixed coefficients, as one would expect with increased substitution.

The supply and demand functions of firms and consumers have been aggregated to get the explicit versions of equations 1–4 and 11 that appear in the Appendix.

NONTARIFF BARRIERS

We modeled the presence of quantitative restrictions (QRs) on imports by using tariff equivalents, t_{ij}^{Meq}, that vary endogenously to dampen the quantitative response of imports to changes in other variables. We also include a similar facility for handling QRs on exports, through an export-tax-equivalent variable, t_{ij}^{Xeq}, though we have not yet had much occasion to use this.

The tariff equivalent is defined as a weighted average of the nominal tariff variable, t_{ij}^{M}, and a second implicit tariff variable, t_{ij}^{QM} that would reflect binding QRs for the entire industry. The weights are given by the fraction of the industry in which QRs are binding. The implicit tariff is defined as one that would, in a typical import demand equation, keep the quantity demanded equal to an exogenous value, Q_{ij}^{M}, set by a quota. The result, as shown in the Appendix, is a simple expression relating the tariff equivalent to the nominal tariff and to the difference between the quota and import demand.

A rise in the quantity of permitted imports lowers the tariff equivalent and does in fact stimulate imports. On the other hand, changes (such as a fall in the world price) that would normally increase demand for imports will cause the tariff equivalent to rise and so cause the change in quantity to be smaller than it would otherwise be. Similar remarks apply to the export-tax equivalent, where it should be remembered that t_{ij}^{Xeq} is actually *one minus* the export-tax equivalent, which therefore varies inversely with t_{ij}^{Xeq}.

This formulation permits us to analyze problems other than nontariff barriers (NTBs) under the realistic and important assumption that NTBs are present and restrict the responsiveness of trade. This is accomplished by merely making the fractions θ_{ij}^{QM} and θ_{ij}^{QX} nonzero in industries where this is appropriate. In addition, by using the exogenous variables, Q_{ij}^M and Q_{ij}^X, we have been able to analyze the effect of changing a QR, so long as we know the volume of trade that is being released from a binding constraint. This is how we have treated the changes in agricultural quotas in our analysis of the Tokyo Round.

IMPORT LICENSING

A new feature of the model that we felt necessary with the addition of developing countries is the treatment of import licensing. Many of these countries have pegged exchange rates, but they are often unable to finance all of the imports that would be desired at that (or perhaps any) exchange rate and so resort to more direct regulation of import behavior.

We have modeled this again through the tariff-equivalent variable, t_{ij}^{Meq}. For countries where licensing is in effect, we suppress equation 9a and assume instead that t_{ij}^{Meq} incorporates the shadow price of scarce foreign exchange to a particular sector. The government is assumed to allocate the foreign exchange that is earned from exports and capital inflows among importers in proportion to some base level of imports that is established. As a result, each sector's imports depend on the total value of exports and capital inflow as shown in the licensing function L_{ij} of equation 9b. What this specification does is to assure approximate balance-of-payments equilibrium even though the exchange rate is pegged.

Along with import licensing, we also modeled a subsidy to exports equal to the export sector's payment of any tariff equivalent on imported inputs. This was done to prevent import licensing from adversely affecting exports through its effect on input prices. Essentially, we are saying that exporters are exempt from licensing when what they import will contribute to production for export.

REST-OF-WORLD NET SUPPLY

With the addition of 16 developing countries to our model, the importance of the sector representing the rest of the world is correspondingly reduced. In the past, we have experimented with several ways of specifying rest-of-world behavior, but for present purposes we have used only one.

We assume that rest-of-world exports in each industry respond positively to the world price with an elasticity, ε_j^r, that is typical of the included countries. Rest-of-world imports are assumed to be subject to import licensing and so are fixed at a constant fraction of the value of rest-of-world exports. Exchange rates in the rest of the world are assumed to be pegged to a basket of currencies of the included countries, with weights that depend primarily on their importance in trade. As a result, rest-of-world net exports in any particular industry depend upon all world prices and exchange rates.

IMPLEMENTATION OF THE MODEL

The model just decribed is designed to take into account as many as possible of the interconnections among industries and countries at the microeconomic level. This enables us to examine a variety of economic issues that other models cannot address, either because they are too highly aggregated, or because they are specified only in partial equilibrium terms. By the same token, however, our model is far too large to be able to say anything concrete without further specification of its parameters. Thus, to use the model, we must apply it to a realistic selection of countries and industries using, as far as possible, actual data to generate the parameters.

In our original model, we focused on the world's 18 major industrialized countries and treated the rest of the world as a residual in order to close the system.[8] We have since added 16 major developing countries so that the model now covers 34 countries plus a residual rest of world. The countries covered are listed below.

Major industrialized countries

Australia	Italy
Austria	Japan
Belgium-Luxembourg	Netherlands
Canada	New Zealand
Denmark	Norway
Finland	Sweden
France	Switzerland
West Germany	United Kingdom
Ireland	United States

[8]The reason for this choice was the compilation of detailed information on post-Kennedy Round ad valorem tariffs at the line-item level for these countries in machine-readable form by the General Agreement on Tariffs and Trade (GATT, 1974). These tariffs were first available based upon 1970 trade. They have since been updated to 1976, which was the reference year for the Tokyo Round.

Major developing countries

Argentina	Mexico
Brazil	Portugal
Chile	Singapore
Colombia	South Korea
Greece	Spain
Hong Kong	Taiwan
India	Turkey
Israel	Yugoslavia

Our industry classification is based upon the International Standard Industrial Classification (ISIC), and is broken down into tradables and nontradables as follows:

Tradables

ISIC Group	*Description*
1	Agriculture, hunting, forestry, & fishing
310	Food, beverages, and tobacco
321	Textiles
322	Wearing apparel, exc. footwear
323	Leather & leather & fur products
324	Footwear
331	Wood products, exc. furniture
332	Furniture & fixtures, exc. metal
341	Paper & paper products
342	Printing, publishing
35A	Industrial chemicals (351); Other chemical products (352)
35B	Petroleum refineries (353); Misc. prod. of petroleum & coal (354)
355	Rubber products
36A	Pottery, china & earthenware (361); Other non-metallic min. prod. (369)
362	Glass & glass products
371	Iron & steel basic industries
372	Non-ferrous metal basic ind.
381	Metal products, exc. machinery, etc.
382	Machinery, exc. electrical
383	Electrical machinery, apparatus, etc.
384	Transport equipment
38A	Plastic products, n.e.c. (356); Professional photogr. goods, etc. (385); Other manuf. industries (390)

Nontradables

ISIC Group	*Description*
2	Mining and quarrying
4	Electricity, gas, and water
5	Construction
6	Wholesale & retail trade, restaurants & hotels
7	Transport, storage, & communication
8	Finance, insurance, real estate, etc.
9	Community, social & personal services

Given appropriate data for the above countries and industries,[9] solution of the model should, in principle, be straightforward. By differentiating the equations of the model, we obtained a system of linear equations relating changes in all of the variables of the system. The coefficients in each of these linear equations were evaluated using the data and elasticity information we had collected. All that remained was to solve the system. Since the system was linear, it could in principle be solved by any of a variety of means.

In fact, however, the size of the model made this difficult. With 34 countries and 29 industries, what we have represented here as single equations each become a large number of separate equations to be solved. Depending on how many of these equations were first eliminated by substitution, the number of equations in the model could run to several thousand. A system of this size strains the capacity of even high-speed computers. And while the number of equations can be reduced substantially by prior substitutions, the substitutions themselves involve a tremendous amount of computation. It was to avoid these difficulties that, in earlier applications of the model, we introduced a number of approximations to reduce the amount of simultaneity in the system.[10]

We have since been able to obtain exact solutions. To do so, we first devised several Fortran subroutines that process large partitioned matrices in which many of the partitioned blocks contain only zeros, and which avoids costly but meaningless computations involving these zeros. Second, we used a Fortran programming technique known as dynamic

[9] The requisite import and export data used were obtained from United Nations trade tapes for 1976. Information on output and employment was obtained directly or otherwise estimated from the United Nations, Yearbook of Industrial Statistics, OECD publications on national accounts and labor statistics, and national statistical sources.

[10] These approximations consisted primarily of using exogenous tariff changes to approximate the change in both expenditure and the prices of intermediate goods, and of ignoring demands for intermediate goods in the demand functions, at certain stages of the solution.

dimensioning to avoid wasting computer-memory space on these empty blocks, even as the contents of all blocks change during the course of the solution. And finally, we applied these techniques first to each of the 34 countries separately, using only equations 1–13 to solve for their net exports in terms of world prices, exchange rates, and exogenous variables, and then used equations 14–17 to complete the solution. The resulting computer program is costly, but within reason.

APPLICATION OF THE MODEL TO THE TOKYO ROUND[11]

The conclusion of the Tokyo Round of Multilateral Trade Negotiations (MTN) marked the seventh round of multilateral reductions in trade barriers that have been negotiated under GATT auspices since the end of World War II. Tariffs on industrial products are to be reduced on average by a quarter to a third of their post-Kennedy Round (1972) levels, with the reductions to be phased in, beginning in 1980, over a period of up to eight years. In addition, and perhaps of even greater importance, a series of codes were negotiated covering a variety of NTBs, including customs valuation, government procurement, import-licensing procedures, subsidies and countervailing duties, and product standards. A safeguards code designed to deal with market disruption due to sudden upsurges in imports was also discussed. But it was not agreed upon because the advanced countries wanted authority to apply safeguards selectively by product and supplying country while the developing countries favored a global policy. Further, many existing NTBs were exempted altogether from the negotiations. These involved especially agricultural products and foodstuffs, textiles and wearing apparel, footwear, iron and steel products, consumer electronic products, and shipbuilding.

Since tariffs constitute an exogenous variable in our model, we can use the model to analyze the effects of the reductions negotiated in the Tokyo Round. For this purpose, we began by calculating the tariff changes at the line-item level based on the Brussels Tariff Nomenclature (BTN). These changes were aggregated using own-country total imports as weights, for each of the 22 tradable industries in each country. The resulting changes in tariffs were then entered into the model as exogenous changes. As mentioned, several codes governing NTBs were negotiated in the Tokyo Round. However, since the codes were stated in advisory terms, they

[11] The material in this section draws heavily on Deardorff and Stern (1980*b*). The effects of assumed reductions in tariffs and NTB's in the Tokyo Round have been treated by Baldwin et al. (1980), Brown and Whalley (1980), and Cline et al. (1978).

cannot be quantified readily. It turned out that the only changes in NTBs that we could analyze were those involving agricultural concessions granted by other countries to the United States and vice versa and the liberalization of nondefense government procurement that may occur. The values of the bilateral agricultural concessions were treated as a relaxation of import quotas in the agricultural sector in each of the countries. For government procurement, we had information by country on the amount of nondefense procurement that governments had tentatively agreed to open to foreign suppliers for bidding purposes. We assumed that the amount that each country had earmarked would be spent in proportion to the sector breakdown of government expenditure in each country. The estimated amounts of government imports by sector were then determined by applying the import propensities based upon expenditure data for the private sector.

All the foregoing exogenous changes in tariffs and NTBs were entered into the model, which was then solved by computer. For this purpose, we used the version of the model based upon fixed-coefficients technology, exogenous wages, and flexible exchange rates. Results were obtained for percentage changes in the endogenous variables in the model. Absolute changes in variables were then determined by multiplying the percentage changes times the initial 1976 levels taken as the reference point for all calculations. In addition, we made two separate calculations of the change in economic welfare by country using the results of the model to estimate changes in consumer and producer surplus and tariff revenues. The first measure (Method 1) used price changes directly from the model but is correct only if supply and demand functions are stationary. This is most appropriate for the reductions in tariffs and for changes in agricultural quotas. The second measure (Method 2) allows for shifts in these schedules by estimating price changes from quantity changes and, though less accurate, is more appropriate when liberalization extends to government procurement.

The overall results are summarized in Table 2 for the major industrialized and developing countries. The principal findings are as follows[12]:

(1) Based upon 1976 levels, exports will rise in total by over $13 billion for all the countries listed, which is about a 1.8% increase. All of this increase is accounted for by the major industrialized countries, since the

[12]The results reported here indicate generally less expansion of trade, employment, and welfare than we have reported before in, for example, Deardorff and Stern (1979). The reason is that we have revised and improved our method of calculating weights to be assigned to tariff revenues as they affect expenditure and welfare. It turns out that we were underestimating the importance of lost tariff revenue in our previous calculations.

exports of the major developing countries fall by a small $0.08 billion. U.S. exports rise by $3.1 and imports by $2.5 billion.

(2) The results for employment are mixed. Total employment rises in only 7 of 18 industrialized countries, including the United States, and in just half of the developing countries. Employment falls in the rest, accounting for an overall decline of about one hundred thousand workers for all countries combined. These changes are uniformly small, however, when compared to the sizes of the respective national labor forces. In no country do the changes, positive or negative, amount to more than a few tenths of one percent. In the United States, employment rises by eleven thousand workers, but this is only one hundredth of one percent.

(3) Economic welfare as measured by changes in consumer and producer surplus and tariff revenues will be increased in all the major industrialized countries except Australia, the Netherlands, and New Zealand. The total welfare gain for the industrialized countries is estimated at between $1.1 and $4.3 billion per annum, which is less than one tenth of one percent of their combined gross domestic product. Most of the developing countries will experience a decline in economic welfare. The developing countries with an increase in economic welfare are Argentina, Israel, and Mexico, and possibly several others.

(4) Exchange rates will change to a very small extent. The U.S. dollar will depreciate very slightly (0.3%), as will such currencies as the French franc and British pound. The German mark and the yen will appreciate very slightly. The exchange rates of most developing countries will remain more or less constant because of controls over foreign exchange licensing.

(5) Import and therefore consumer prices will fall to a limited extent in all of the industrialized countries except New Zealand. For the United States, the decline is less than 0.1%. For the developing countries, prices will fall only in Argentina, Colombia, Mexico, and Taiwan, but these changes and the rises elsewhere are extremely small.

All of the above changes, small as they are, assume that the changes in tariffs and NTBs that were negotiated in the Tokyo Round are to be implemented at once. In fact, they will be phased in over a period of up to a decade, so that the effects that will occur in any one year will be even smaller than noted.

The country results in Table 2 mask much industry detail. Indeed, one of the most important features of our model is that we can calculate the absolute and relative employment effects across the 22 tradable and 7 nontradable sectors in each of the 34 countries in the model. These results are too detailed for inclusion here, but are available upon request. To give some flavor of the employment effects by sector, we may note that in the United States, for example, the largest increases were recorded, in thousands of workers, for agriculture (53), chemicals (4), nonelectrical machinery (5), and transport equipment (4). There were negative employment effects in food and kindred products (−2), textiles and wearing apparel (−5), nonmetallic mineral products (−1), miscellaneous manufactures (−4), and for all the nontradable industries except mining and quarrying.[13] All of the foregoing changes for the United States are very small in absolute terms, it may be noted, and thus also in percentage terms, except in agriculture, where the rise in employment is 1.6% over the 1976 level.

The effects on the individual sectors in the other countries can be similarly discerned from the underlying details. While space constraints do not permit us to single out particular results, it is noteworthy that most of the negative employment changes in the developing countries were concentrated in agriculture and textiles and wearing apparel. We have already mentioned that the NTBs affecting these sectors were left intact in the Tokyo Round. With tariffs being reduced in most other sectors, there is a tendency for world prices (exclusive of tariffs) in these other sectors to rise and for consumer prices (inclusive of tariffs) to fall. As a consequence, the pattern of world demand shifts somewhat away from the exempted sectors and toward those in which tariffs are reduced. This fall in demand occurs in what are often the most important export sectors in the developing countries, and its adverse effects are augmented by the rise in prices of other manufactures which may serve as inputs to these sensitive sectors. It is the specialization in these sectors by developing countries that in large part accounts for the overall declines in employment and welfare that the Tokyo Round causes in these countries. By the same token, it should be mentioned that certain of the developing countries that have been successful in expanding their exports of durable manufactures enjoy the status of free riders in the Tokyo Round and will be encouraged further along these lines.

We made reference to the relatively small employment effects that are likely to occur in individual sectors in the United States, except in the case of agriculture. However, inspection of the detailed results for other countries suggests that there are numerous instances in which the percentage employment changes in particular sectors may be substantially greater than 1%. A possible way to assess these changes, without getting bogged down in detail, is to look separately at the gross employment

[13]There were numerous instances of negative employment effects in the nontradable sectors across countries. These negative effects reflect generally the substitution towards tradable goods and away from nontradables due to the reduction in the prices of tradable goods that will result from the Tokyo Round.

Table 2: Summary of Effects of Reductions in Tariffs and Selected Nontariff Barriers in the Tokyo Round on the Major Industrialized and Developing Countries

	Change in Exports $ Mill.	Change in Imports $ Mill.	Change in Employment 000 Wkr.	Change in Employment Pct.	Change in Economic Welfare $ Mill. Mthd. 1	Change in Economic Welfare $ Mill. Mthd. 2	Change in Economic Welfare Pct. of GDP Mthd. 1	Change in Economic Welfare Pct. of GDP Mthd. 2	Pct. Change in Eff. Ex. Rate[a]	Pct. Change in Prices[b]
Industrialized Countries										
Australia	22.0	36.6	−1.43	−0.02	−19.8	−17.3	−0.02	−0.02	0.00	−0.08
Austria	322.9	311.1	7.11	0.24	29.0	−5.1	0.07	−0.01	0.11	−0.78
Canada	1035.3	1021.1	−5.30	−0.06	45.0	266.9	0.02	0.14	0.03	−0.27
European Community										
Belgium-Luxembourg	810.9	816.6	8.01	0.21	18.9	264.0	0.03	0.38	0.62	−1.15
Denmark	335.2	323.6	7.35	0.31	27.7	115.6	0.07	0.28	0.07	−0.65
France	153[illegible]	1560.8	13.38	0.06	137.9	373.5	0.04	0.11	−0.25	−0.33
Germany	*2239.4*	*2446.9*	*16.76*	*0.07*	*147.1*	*653.7*	*0.03*	*0.15*	*0.02*	*−0.57*
Ireland	71.0	67.5	−2.32	−0.23	4.1	−16.1	0.05	−0.20	0.60	−0.67
Italy	729.3	744.5	−22.84	−0.12	63.3	139.1	0.04	0.08	−0.08	−0.33
Netherlands	814.1	835.2	−1.93	−0.04	−34.2	100.5	−0.04	0.11	0.43	−0.92
United Kingdom	1064.4	1084.0	−27.87	−0.11	108.3	101.9	0.05	0.05	−0.13	−0.33
Total EC	*7595.5*	*7879.2*	*−9.45*	*−0.01*	*473.0*	*1732.2*	*0.03*	*0.12*	*−0.02*	*−0.50*
Finland	*173.5*	*266.6*	*−3.86*	*−0.18*	*14.6*	*112.2*	*0.05*	*0.39*	*0.00*	*−0.45*
Japan	*441.9*	*613.6*	*−27.29*	*−0.05*	*176.4*	*343.0*	*0.03*	*0.06*	*0.15*	*−0.09*
New Zealand	−158.1	−166.9	3.77	0.31	−19.8	70.1	−0.15	0.52	0.00	1.09
Norway	205.9	342.7	−7.42	−0.41	16.3	178.3	0.05	0.57	0.00	−0.41
Sweden	*470.1*	*763.6*	*−7.90*	*−0.19*	*44.3*	*480.0*	*0.06*	*0.65*	*0.00*	*−0.51*
Switzerland	*232.0*	*418.9*	*−10.16*	*−0.36*	*22.9*	*253.5*	*0.04*	*0.45*	*0.10*	*−0.38*
United States	3112.1	2487.8	11.41	0.01	278.4	892.9	0.02	0.05	−0.30	−0.07
Total Industrialized	*13453.1*	*13974.4*	*−50.52*	*−0.02*	*1060.2*	*4306.6*	*0.03*	*0.10*	*−0.10*	*−0.24*

Developing Countries										
Argentina	−6.7	−1.7	−4.26	−0.04	0.9	1.1	0.00	0.00	0.00	−0.01
Brazil	−24.6	−38.3	2.57	0.01	−6.5	−4.8	−0.00	−0.00	0.00	0.01
Chile	1.3	−1.3	−21.73	−0.78	−62.2	−68.3	−0.74	−0.81	0.00	[illegible]
Colombia	0.9	1.9	−0.81	−0.01	0.5	−0.8	0.00	−0.01	0.00	−0.05
Greece	−17.4	−34.7	0.64	0.02	−11.8	6.8	−0.05	0.03	0.00	0.17
Hong Kong	0.7	−10.2	0.32	0.02	−7.0	−3.9	−0.08	−0.04	−0.02	0.04
India	−8.1	−11.5	−23.10	−0.01	−5.9	−4.6	−0.01	−0.01	0.00	0.01
Israel	0.4	−4.6	−0.21	−0.02	0.6	0.6	0.00	0.00	0.04	0.03
South Korea	−7.2	−12.9	5.21	0.04	−7.2	4.1	−0.03	0.02	0.00	0.06
Mexico	23.5	17.1	−8.19	−0.05	3.3	5.6	0.00	0.01	−0.07	−0.05
Portugal	−8.9	−21.0	1.22	0.04	−8.2	6.5	−0.05	0.04	0.06	0.22
Singapore	3.2	−8.9	0.28	0.03	−1.7	1.8	−0.03	0.03	0.00	0.06
Spain	−30.8	−55.3	2.30	0.02	−1.8	8.5	−0.00	0.01	0.00	0.06
Taiwan	15.2	12.9	−7.62	−0.13	2.9	−17.8	0.02	−0.10	0.00	−0.22
Turkey	−15.0	−30.2	2.43	0.02	−6.2	3.8	−0.02	0.01	0.00	0.08
Yugoslavia	−3.5	−12.2	−1.43	−0.03	−1.6	−1.4	−0.00	−0.00	−0.04	0.01
Total LDCS	−76.9	−211.0	−52.33	−0.01	−111.8	−62.7	−0.02	−0.01	−0.01	0.02
All Countries	13375.1	13763.4	−102.94	−0.02	948.4	4243.9	0.02	0.09	−0.09	−0.21

[a]Positive sign means appreciation: negative means depreciation.
[b]Refers to an index of import and home prices.

Table 3: Summary of Employment Effects of the Tokyo Round on the Major Industrialized and Developing Countries

	Net Change in Employment 000 of Workers	Net Change in Employment Pct.	Gross Increase in Employment[a] 000 of Workers	Gross Increase in Employment[a] Pct.	Gross Decline in Employment[a] 000 of Workers	Gross Decline in Employment[a] Pct.
Industrialized Countries						
Australia	−1.4	−0.02	3.3	0.06	−4.7	−0.08
Austria	7.1	0.24	19.1	0.65	−12.0	−0.41
Canada	−5.3	−0.06	25.5	0.27	−30.8	−0.32
European Community						
Belgium-Luxembourg	8.0	0.21	34.6	0.89	−26.6	−0.69
Denmark	7.4	0.31	17.5	0.73	−10.1	−0.42
France	13.4	0.06	64.4	0.31	−51.0	−0.24
Germany	16.8	0.07	107.0	0.44	−90.2	−0.37
Ireland	−2.3	−0.23	4.1	0.41	−6.5	−0.63
Italy	−22.8	−0.12	45.2	0.24	−68.1	−0.36
Netherlands	−1.9	−0.04	24.7	0.54	−26.6	−0.59
United Kingdom	−27.9	−0.11	50.9	0.21	−78.7	−0.32
Total EC	−9.5	−0.01	348.3	0.35	−357.7	−0.36
Finland	−3.9	−0.18	7.7	0.36	−11.6	−0.54
Japan	−27.3	−0.05	34.9	0.07	−62.1	−0.12
New Zealand	3.9	0.31	10.1	0.84	−6.3	−0.52
Norway	−7.4	−0.41	5.8	0.32	−13.2	−0.74
Sweden	−7.9	−0.19	17.4	0.43	−25.3	−0.62
Switzerland	−10.2	−0.36	9.0	0.32	−19.1	−0.68
United States	11.4	0.01	123.1	0.14	−111.7	−0.13
Total Industralized	−50.5	−0.02	604.2	0.22	−654.8	−0.24
Developing Countries						
Argentina	−4.3	−0.04	1.4	0.01	−5.6	−0.05
Brazil	2.6	0.01	8.0	0.02	−5.5	−0.01
Chile	−21.7	−0.78	0.9	0.03	−22.6	−0.81
Colombia	−0.8	−0.01	3.0	0.04	−3.8	−0.05
Greece	0.6	0.02	4.0	0.10	−3.4	−0.08
Hong Kong	0.3	0.02	2.5	0.19	−2.1	−0.16
India	−23.1	−0.01	20.7	0.01	−43.8	−0.02
Israel	−0.2	−0.02	0.5	0.04	−0.7	−0.06
South Korea	5.2	0.04	10.0	0.08	−4.8	−0.04
Mexico	−8.2	−0.05	26.1	0.15	−34.3	−0.20
Portugal	1.2	0.04	4.1	0.13	−2.9	−0.09
Singapore	0.3	0.03	1.1	0.12	−0.8	−0.09
Spain	2.4	0.02	7.1	0.06	−4.7	−0.04
Taiwan	−7.6	−0.13	5.3	0.09	−13.0	−0.23
Turkey	2.4	0.02	6.4	0.04	−3.8	−0.03
Yugoslavia	−1.4	−0.03	2.2	0.05	−3.7	−0.08
Total LDCS	−52.3	−0.01	103.2	0.03	−155.6	−0.04
All Countries	−102.9	−0.02	707.5	0.11	−810.3	−0.13

[a]Refers to sum of changes in the home and export sectors within industries.

increases and declines by country. This has been done in Table 3, in which the third column reports the sum of all positive sectoral employment changes and the fifth column reports the sum of all negative changes. Thus, the latter figure represents the total number of workers in the country who would have to change jobs as a result of the Tokyo Round. These gross changes are of course considerably larger than the net changes in the first column, but they still amount to only a fraction of a percent of employment in each country. It should therefore be fairly easy to accommodate these changes within the normal process of labor-market turnover. And once again, if we consider that the Tokyo Round reductions in tariffs and NTBs will be phased in over several years, it seems unlikely that any serious disruptions in labor markets will occur.

The smallness of our results need not be surprising if we consider the reasons for it. First of all, the tariff reductions which were negotiated in the Tokyo Round are themselves quite small. That is, average tariffs are to be cut from approximately 8% to 6%. Even if all tariff changes were reflected fully in import-price changes, the latter would fall by only 2%. But even this will not happen since tariff cuts in many industries and countries simultaneously cause world prices to be bid up and offset more than half of the tariff changes. Even in countries with above average tariff cuts such as the United States, exchange rates move to reduce differences from the world average. Finally, the price changes that do occur can have only limited effects on output and employment since their roles as output prices and input prices counteract. All things considered, then, it is to be expected that the effects of the Tokyo Round on trade, employment, and welfare should be measured in tenths, or even hundredths, of a percent.

SENSITIVITY OF RESULTS TO CHANGES IN PARAMETERS

The question naturally arises as to how sensitive our results may be to certain key parameters. In order to test for sensitivity, we ran three separate experiments. We first doubled all supply elasticities, then doubled all elasticities of substitution between home and imported goods (with the original supply elasticities unchanged), and finally doubled both supply and substitution elasticities. The results of these experiments are too detailed for presentation here, and we therefore describe them only qualitatively.

Doubling the supply elasticities enlarges the overall net employment increases and declines in individual countries, but the effects are still comparatively small. The effects on welfare are not unusually sensitive to the increased supply elasticities. Doubling the elasticities of substitution between imported and home goods has a negligible effect on the overall net changes in employment. Yet there is a sizable increase in one of our two measures of economic welfare because the higher substitution elasticities imply a shift of a more elastic schedule and thus a greater welfare effect. Doubling both the supply and substitution elasticities has a minor effect on the employment results, but the welfare calculation just noted is larger.

It should be pointed out that the elasticities of supply and substitution used in our model have been derived from empirical data and are thus reasonably firmly grounded on realistic data. Our confidence in the model is enhanced by the comparative stability of the employment results. By the same token, our welfare calculations have more of an ad hoc quality to them since they are not derived in a rigorous theoretical manner from the model itself. It is neverthless noteworthy that our one welfare measure, which assumes given demand and supply functions and is most appropriate for changes in tariffs and quotas, yields fairly stable results. Our second welfare measure, which assumes an implicit shift in demand, was designed to deal with the effects of liberalizing government procurement. It is apparently fairly sensitive to the elasticity parameters and should be interpreted cautiously therefore.

IMPLICATIONS OF THE TOKYO ROUND

Our analysis of the reductions in tariffs and quantifiable NTBs negotiated in the Tokyo Round suggests that there will be relatively small but beneficial economic effects for practically all the major industrialized countries and for some of the major developing countries. It is possible as well that there may be significant benefits from the particular NTB codes that we could not include in our calculations. The principal significance of these codes is that they signal the willingness and intent of participating governments to reduce their interference with trade. The benefits must ultimately depend therefore on whether governments will in fact adhere to the codes.

In order to put the Tokyo Round in perspective, we should recognize what it failed to accomplish. We noted earlier that negotiations on a safeguards code broke down on the issue of selective versus global implementation. Also, and perhaps even more important, several key sectors now subject to NTBs were exempted explicitly from the negotiations. We have not been able to use our model to investigate the significance of the NTBs exempted in the Tokyo Round because of data limitations. However, using a model somewhat similar to ours, Brown and Whalley (1980) have calculated that removing existing NTBs altogether would increase world welfare by about $16 billion (in 1973 prices), which is far in excess of their estimated $1.5 billion gain per annum resulting from the Tokyo Round concessions. The Tokyo Round must be viewed accordingly as having dealt with a relatively limited part of all interferences with international trade.

CONCLUSION

We have set out in this paper a computational model of world production, trade, and employment that has been constructed to analyze the likely effects of multilateral changes in tariffs, NTBs, and other exogenous events. The model focuses on the microeconomic interactions among industries and countries. It has undergone a series of refinements since its inception, and we have reported here its structure and specification as of early 1981. If time and resources permit, the model will be modified and expanded still more in the future as our experience with it and the world economy suggests possible avenues for improvement.

We have applied the model to the reductions in tariffs and NTBs that were negotiated in the Tokyo Round and that have been implemented beginning in 1980. Our findings are that the Tokyo Round will have small but beneficial effects on trade, domestic prices, and economic welfare in the United States and practically all the other major industrialized countries. Employment will rise and fall by small amounts in various industries and countries, with the United States posting a change that is positive but almost negligible in size. There will be small gains to some but by no means all of the major developing countries. We were unable to quantify many of the NTB codes negotiated in the Tokyo Round so that their likely effects cannot be evaluated unambiguously at present. By the same token, there were several important NTB's that were left intact in the Tokyo Round. Benefits from further liberalization of international trade could be substantial if these existing NTBs were reduced or removed.

APPENDIX: EXPLICIT FUNCTIONAL FORMS

The following are the differentiated versions of equations 1–4 and 9–1' of Table 1. The operator e represents the differential of the natural logarithm of the variable that follows it. That is, for any variable x,

$$ex = d(\ln x) = dx/x.$$

$$eS_{ij}^X = [\varepsilon_{ij} + \delta(1 - b_{ij}^O)/b_{ij}^O]ep_{ij}^X - [\varepsilon_{ij} + \delta(1/b_{ij}^O)] \times \sum_{k=1}^{n'} b_{ikj}(\theta_{ik}^H ep_{ik}^H + \theta_{ik}^M ep_{ik}^M) - \varepsilon_{ij} b_{ij}^O ew_{ij} + eK_{ij}^X. \quad \text{(A1)}$$

$$eS_{ij}^H = [\varepsilon_{ij} + \delta(1 - b_{ij}^O)/b_{ij}^O](ep_{ij}^H + et_{ij}^H) - [\varepsilon_{ij} + \delta(1/b_{ij}^O)]$$
$$\times \sum_{k=1}^{n'} b_{ikj}(\theta_{ik}^H ep_{ik}^H + \theta_{ik}^M ep_{ik}^M) - \varepsilon_{ij} b_{ij}^O ew_{ij} + eK_{ij}^H, \qquad \text{(A2)}$$

where

ε_{ij} = Supply elasticity of industry j, country i,

b_{ikj} = Input-output coefficient for use of good k as input to industry j in country i,

b_{ij}^O = Value-added share of industry j, country i,

θ_{ik}^M, θ_{ik}^H = Initial shares of demand in country i for imported and home-produced products of industry j, and

$$\delta = \begin{cases} 1 \text{ for Cobb-Douglas technology} \\ 0 \text{ for Fixed Coefficient technology.} \end{cases}$$

$$eD_{ij}^M = -\theta_{ij}^H \sigma_{ij}(ep_{ij}^M - ep_{ij}^H) - [(1 - \delta)v_{ij}^O + \delta](\theta_{ij}^H ep_{ij}^H + \theta_{ij}^M ep_{ij}^M)$$
$$+ v_{ij}^O eE_i + \sum_{k=1}^{n'} v_{ijk}[\gamma_{ik}^X (eS_{ik}^X + \delta ep_{ik}^X) \qquad \text{(A3)}$$
$$+ (1 - \gamma_{ik}^X)(eS_{ik}^H + \delta ep_{ik}^H)] + eG_{ij}.$$

$$eD_{ij}^H = -\theta_{ij}^M \sigma_{ij}(ep_{ij}^H - ep_{ij}^M) - [(1 - \delta)v_{ij}^O + \delta](\theta_{ij}^H ep_{ij}^H + \theta_{ij}^M ep_{ij}^M)$$
$$+ v_{ij}^O eE_i + \sum_{k=1}^{n'} v_{ijk}[\gamma_{ik}^X (eS_{ik}^X + \delta ep_{ik}^X)$$
$$+ (1 - \gamma_{ik}^X)(eS_{ik}^H + \delta ep_{ik}^H)] \qquad \text{(A4)}$$
$$- (\theta_{ij}^M/\theta_{ij}^H) eG_{ij},$$

where

σ_{ij} = Elasticity of substitution in country i between imported and home-produced products of industry j,

v_{ijk} = Demand by industry k for products of industry j as a share of total demand for industry j in country i,

ν_{ij}^{Q} = Share of final demand in total demand for industry j in country i, and
γ_{ij}^{X} = Share of exports in total production of industry j, country i.

$$et_{ij}^{Meq} = et_{ij}^{M} + [\theta_{ij}^{QM}/\eta_{ij}(1 - \theta_{ij}^{QM})](eQ_{ij}^{M} - eD_{ij}^{M}), \tag{A9a}$$

$$eD_{ij}^{M} = \frac{1}{M_i}\sum_{k=1}^{n}[X_{ik}eS_{ik}^{X} + (X_{ik} - M_{ik})ep_k^{W} + dB_i^{KO}], \tag{A9b}$$

$$et_{ij}^{Xeq} = et_{ij}^{X} + [\theta_{ij}^{QX}/\varepsilon_{ij}(1 - \theta_{ij}^{QX})](eQ_{ij}^{X} - eS_{ij}^{X}), \tag{A10a}$$

where

θ_{ij}^{QM}, θ_{ij}^{QX} = Shares of imports and exports of industry j subject to quantitative restrictions in country i,
η_{ij} = Price elasticity of demand for imports of good j in country i,
M_i = Total imports of country i, and
X_{ik}, M_{ik} = Values of exports and imports of industry k, country i.

$$\begin{aligned} eD_{ij}^{L} = {} & \gamma_{ij}^{X}\{[1/(1 + \delta/b_{ij}^{O}\varepsilon_{ij})\theta_{ij}^{L}]\,[eS_{ij}^{X} + \delta(ep_{ij}^{X} - ew_{ij})] \\ & - [(\theta_{ij}^{K} - \delta\theta_{ij}^{L}/b_{ij}^{O}\varepsilon_{ij})/(1 + \delta/b_{ij}^{O}\varepsilon_{ij})\theta_{ij}^{L}]eK_{ij}^{X}\} \\ & + (1 - \gamma_{ij}^{X})\{[1/(1 + \delta/b_{ij}^{O}\varepsilon_{ij})\theta_{ij}^{L}]\{eS_{ij}^{H} + \delta(ep_{ij}^{H} - ew_{ij})] \\ & - [(\theta_{ij}^{K} - \delta\theta_{ij}^{L}/b_{ij}^{O}\varepsilon_{ij})/(1 + \delta/b_{ij}^{O}\varepsilon_{ij})\theta_{ij}^{L}]eK_{ij}^{H}\}, \end{aligned} \tag{A11}$$

where

θ_{ij}^{L}, θ_{ij}^{K} = Labor and capital shares of value-added in industry j, country i.

Equation A9a is derived as follows. Let a typical import demand depend on the tariff equivalent, with elasticity η, and a list, λ, of other variables including price:

$$eD^{M} = \eta et^{Meq} + \lambda. \tag{B1}$$

Define an implicit tariff, t^{QM}, that would hold imports to a given quantity, Q^M, in (B1):

$$eQ^{M} = \eta et^{QM} + \lambda, \tag{B2}$$

and define t^{Meq} as the weighted average of t^M and t^{QM}:

$$et^{Meq} = (1 - \theta^{QM})et^{M} + \theta^{QM}et^{QM}. \tag{B3}$$

Eliminating t^{QM} and λ, B1-B3 can be solved to yield A9a. Equation A10a can be derived similarly.

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