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OPTIMAL TARIFF CALCULATIONS IN ALTERNATIVE TRADE MODELS AND SOME POSSIBLE IMPLICATIONS FOR CURRENT WORLD TRADING ARRANGEMENTS[1]

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I. Introduction

In this paper we report the results of calculations of optimal tariffs with and without retaliation in a sequence of simplified two good, two country trade models. We consider both pure exchange models and models with production; we use conventional functional forms for preferences and production sets and crudely calibrate parameter values chosen to our interpretation of current 'empirical' knowledge. We relate our calculations to earlier calculations by Johnson [1954], Gorman [1957] and Kuga [1973] and discuss whether there is anything in our calculations which is of relevance to current world trade policy issues.

We motivate our calculations as follows.

(1) In the literature on the optimal tariff we have only been able to find three pieces in which calculations of post retaliation Nash equilibria are reported. In two of these, (Johnson and Gorman) two country, two good pure exchange trade models with constant elasticity excess demand functions are used to produce cases in which one country can be better off in a Nash equilibrium compared to free trade. In the other, Kuga [1973] considers a three country two good case and constructs a payoff matrix involving 27 pure strategies and calculates a Nash equilibrium involving non-pure strategies for at least one country. Nowhere in the literature on the optimal tariff, as far as we are aware, has there been any attempt to examine tariff rates associated with Nash equilibria in light of either existing or historical levels of protection among major trading areas. There is discussion of the apparent large size of first step optimal tariffs in Kahn [1947] and de Graaf [1949] but since this exchange there appears to be no attempt to relate optimal tariff calculations directly to policy issues.[1]

[1] Many economists would probably argue that this is a hopeless attempt. Indeed, the general consensus at the present time as to the relevance of optimal tariff analysis for the evaluation of protection in the industrialized world would appear to be that (a) for major industrialized countries, post Kennedy

(2) The two well known pieces by Johnson and Gorman consider constant elasticity excess demand functions in both countries which have the property that optimal tariffs for each country are independent of the retaliation of the other country. It is widely acknowledged that constant elasticity excess demand functions imply strong (and to some, unpalatable) restrictions on preferences and the pattern of initial endowments.

(3) We are able to compute Nash equilibria for a wider class of models than are used in existing literature. We do not require excess demand functions to be of constant elasticity form and we also incorporate production into some of our calculations. While we maintain the restriction to two good, two country models we explicitly use functional forms for preferences and production sets drawn from the widely used CES/LES family. We determine the changes occurring in elasticities of excess demand functions as our calculations proceed, and for many of our formulations this takes us some distance from the Johnson-Gorman assumptions.

(4) By varying preference weighting parameters, implicit own price elasticities of demand functions, and the relative size of countries, we are able to loosely characterize alternative representations of various bilateral trade scenarios. We suggest that such bilateral trade cases as US-Canadian, US-EEC, US-Japan, North-South and OPEC-Non OPEC, all differ in

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(and eventually post Tokyo) Round tariffs are low averaging significantly less than 10% for manufactured products and therefore probably some distance from 'optimal' tariffs (b) for industrialized, developing, and less developed countries, non-tariff barriers (quotas, standards, health and sanitary restrictions, government procurement and the like) are much more important than tariffs as protective devices and while they all could correspond or exceed 'optimal' tariff protection they remain largely unquantifiable and (c) what tariffs exist are more appropriately viewed as the political outcome of lobbying efforts by narrowly defined interest groups (textile unions, steel unions and the like) rather than the result of a rational centralized calculation involving maximization of a national welfare function.

We take the view that (i) the analytical tariff literature is dominated by the same kind of framework we use and (ii) given the relative lack of numerical calculation, some numerical investigation seeking to extend current theory in a quantitative direction may be useful even if performed with a healthy dose of skepticism.

one or more of the characteristics of relative size of trading blocs, degree of specialization, and price elasticities determining trade. We analyze a number of cases in which these characteristics vary and compare free trade, Nash equilibria, and first step optimal tariff outcomes for each country.

(5) In light of our calculations, we are able to discuss what form a non-cooperative outcome in world trade could take if current multilateral trade agreements under the GATT and bilateral arrangements (such as the US-Canadian auto pact) were to be removed or break down. We explore the relative size of calculated and current levels of protection and also briefly discuss protection in the 1930's which appears, in the light of our calculations, as possibly being roughly consistent with a non-cooperative Nash solution.

(6) Our calculations also provide some indications as to what elements of structure in some of the larger scale 'empirical' general equilibrium models of trade are important for the fairly strong terms of trade effects sometimes found, and we suggest that the so-called "Armington" assumption, which implies a form of complete specialization, may be responsible for this.

The extension of our calculations beyond the 2 x 2 framework we regard as non-trivial for computational reasons. We are forced to approximate the offer surfaces derived from conventional utility functions by piecewise linear segments and we repeatedly refine these linear approximations in the neighbourhood of the Nash equilibria we compute. The determination of the 'with tariff' offer surfaces involves a prior assumption as to the direction of trade. More goods complicates matters due to both of these problems; more countries complicates the programming of the retaliatory processes. While these are not insuperable difficulties it is our current judgement that significant extension in dimensionality considerably extends the complexity of code with no clear enrichment of structure. In a final section we report some results indicating ranges for first step optimal tariffs in a larger scale 'realistic' general equilibrium trade model assembled by Whalley [1979] and discuss the relation to the simpler 2 x 2 models discussed in the main part of the paper.

II. The Johnson-Gorman-Kuga Discussion of the Optimal Tariff Problem

In two pieces in the 1950's, Johnson [1954] and Gorman [1957] analyze the optimal tariff problem in the two country two good pure exchange case. Johnson's piece was subsequently amended in light of Gorman's paper when it was reprinted in Johnson [1961]. Kuga [1973] attempts an extension of the Johnson-Gorman analysis beyond the two good, two country case.

The motivation for the original Johnson piece comes from the earlier literature on optimal tariffs. The rediscovery by Kaldor of Bickerdike's earlier argument that a tariff can improve domestic welfare had led to Scitovsky's suggestion in 1941 that repeated retaliation by each country in a two good model to changes in the other country's tariff would result in a situation where both countries are worse off as a result of a retaliatory trade war. Johnson sets out to demonstrate that this need not be the case. He shows that one country can be better off even after the retaliatory process is completed and attempts to simulate conditions under which a particular country will gain or lose. This involves the numerical determination of characteristics of a Nash equilibrium associated with the implicit two person non-zero sum game which characterizes the optimal tariff model.

The simplifying device which Johnson uses to analyze his model is to assume that offer surfaces are of constant elasticity form. The main feature of such an assumption is that the optimal tariff of each country is determined directly from the assumed elasticity of the other country's offer surface. Retaliation by either country leaves the optimum tariff of the other unaffected and so the Nash equilibrium is easy to determine. In his original paper Johnson suggests that there is only a single functional form for offer surfaces consistent with such an assumption, a proposition which Gorman demonstrates to be false, and in his later revision presents a model incorporating this class of preferences.

Johnson assumes two countries I and II each characterized by a social welfare function (or equivalently a single consumer's utility function) defined on the net trades (imports and exports) of the form

$$U^{I} = f^{I}(kX^{\frac{a}{k}} - A^{\frac{a}{k}} Y^{a}) \qquad (1 \le a \le k) \tag{1}$$

$$U^{II} = f^{II}(jY^{\frac{b}{j}} - B^{\frac{b}{j}} X^{b}) \qquad (1 \le b \le j) \tag{2}$$

where X is the imported good and Y the exported good for country I. The f's are monotonic functions which for purposes of ranking bundles of goods associated with different equilibrium outcomes can be ignored. A and B are unit parameters. k and j are parameters which determine the elasticities of the offer surfaces; a and b determine the way the offer surfaces are displaced by any given tariff.

For country I the first order conditions to (1) yield the offer curve

$$X = A(1 + t_{I})^{\frac{k}{a}} Y^{k} \tag{3}$$

where t_I is the tariff in country I ($t_I = 0$ if there is free trade). This offer curve is of elasticity k, where its elasticity, following Johnson, is defined by $\frac{dX}{dY} \cdot \frac{Y}{X}$. It follows directly that the optimal tariff for country II is the elasticity of I's offer curve minus one, or k-1; similarly the optimal tariff for I is given directly by j-1.

Johnson suggests that the parameters a and b may be interpreted as controlling the way in which the offer surfaces in countries I and II will be displaced as each country changes its own tariff. He considers four cases; $a/b = 1/j$, $a/b = k/j$, $a/b = 1$, $a/b = k$ giving an interpretation for each. The case $a/b = k$, for instance, he suggests corresponds to the situation where imports are a pure luxury and exports a pure necessity in country I, while imports are a pure necessity and exports a pure luxury in country II. These different cases all imply properties of the excess demand functions which can be stated in terms of income elasticities, a notion more completely formalized in Gorman's paper.

The numerical solution for the Nash equilibria proceeds in Johnson's paper by substituting between the excess demand functions in the two cases of free trade ($t_I = t_{II} = 0$) and the post retaliation equilibrium given by the optimal tariffs ($t_I = j - 1$, $t_{II} = k - 1$). Each optimal tariff is calculated directly as the elasticity of the foreign offer curve minus one. Substituting the resulting quantities into the utility functions he obtains the expressions

(4)
$$\frac{U_t^I}{U_o^I} = \frac{(\eta_1 + \eta_2 - 1)}{\eta_2} \left(\frac{(\eta_1 - 1)}{\eta_1}\right)^{\frac{(\eta_1 - 1)\cdot\eta_2\cdot a/b}{\eta_1 + \eta_2 - 1}} \cdot \left(\frac{\eta_2 - 1}{\eta_2}\right)^{\frac{(\eta_1 - 1)(\eta_2 - 1)}{\eta_1 + \eta_2 - 1}}$$

$$\frac{U_t^{II}}{U_o^{II}} = \frac{(\eta_1 + \eta_2 - 1)}{\eta_1} \left(\frac{(\eta_1 - 1)}{\eta_1}\right)^{\frac{(\eta_1 - 1)(\eta_2 - 1)}{\eta_1 + \eta_2 - 1}} \cdot \left(\frac{\eta_2 - 1}{\eta_2}\right)^{\frac{(\eta_2 - 1)\eta_1 b/a}{\eta_1 + \eta_2 - 1}}$$

where $\eta_1 = k/(k-1)$ and $\eta_2 = j/(j-1)$, and U_t^I (U_t^{II}) and U_o^I (U_o^{II}) denote the utility index in country I (II) under the optimal tariff retaliation and free trade respectively. η_1 can be interpreted as the price elasticity of demand for imports in I and η_2 as the import price elasticity in II.[1]

By numerical calculation Johnson proceeds to determine combinations of values for the parameters η_1 and η_2 such that country I would gain from a tariff war, country II would gain, and both would lose. We reproduce his diagram here as our Figure 1 for the four cases corresponding to the combinations of a/b

[1]See Johnson [1961], p. 50.

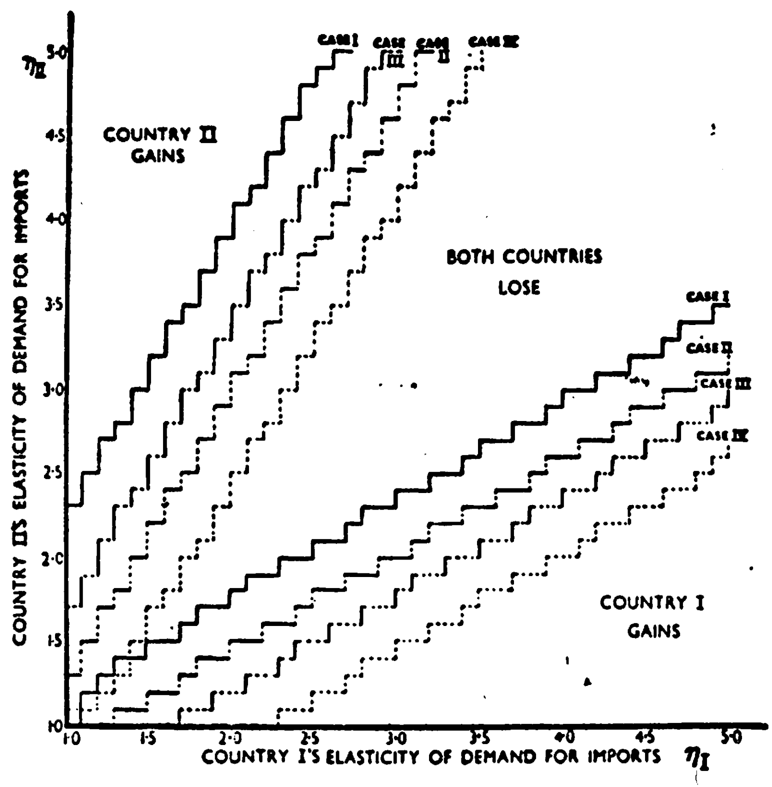
listed earlier. His conclusion is that a country is only likely to gain in a tariff war if its import price elasticity is significantly higher than that in the other country, and the scope for this gain is greater the closer its export good approximates to a pure luxury in world consumption. The cases he considers also show that it is not a necessary condition for a country to gain from optimal tariff retaliation that its price elasticity of demand for imports should exceed the import price elasticity of the other country. A country could gain if both import price elasticities are low and the country's exports are a luxury item in world consumption (income elasticity for imports above unity in the foreign country).

Gorman extends Johnson's original paper by formalizing the properties of preference functions implied by the restriction of excess demand functions to constant elasticity form (or, equivalently, constant price elasticity of the import demand functions). Gorman obtains the somewhat surprising result that if neither good is inferior and the demand for each is elastic, the volume of trade in each is about three times as great under free trade as in the final tariff equilibrium, being e ($\simeq$ 2.72) times as great as the import price elasticity approaches infinity in both countries. Like Johnson, Gorman also analyzes numerically the issue of conditions under which countries gain from a tariff war analyzing situations which he characterizes as involving 'Europe' and the 'Commonwealth'.

The paper by Kuga [1973] contrasts with those by Johnson and Gorman in that he begins by providing a general statement of existence of tariff distorted equilibria which had been missing from earlier literature. He then proceeds to use this result to prove the existence of a Nash equilibrium supported by retaliatory tariffs in an M country N good world. By way of illustration, he considers as a numerical example a two good pure exchange model with nested Cobb-Douglas preferences, and for a particular numerical specification assumed solely

Figure 1

Johnson's Diagram of 'Boundary Lines' denoting gaining and losing situations after a tariff war.



Reproduced from Johnson [1961], p. 52.

Case I : a/b = 1/j

Case II : a/b = k/j

Case III: a/b = 1

Case IV : a/b = k.

for illustrative purposes, he constructs a payoff matrix involving twenty-seven pure strategies. He then arithmetically calculates a Nash equilibrium, the main characteristic of which is that it involves non-pure strategies for at least one country. The calculation is not related to the Johnson/Gorman calculations nor to any set of 'realistic' parameters for the model.

We note the following points in connection with these calculations.

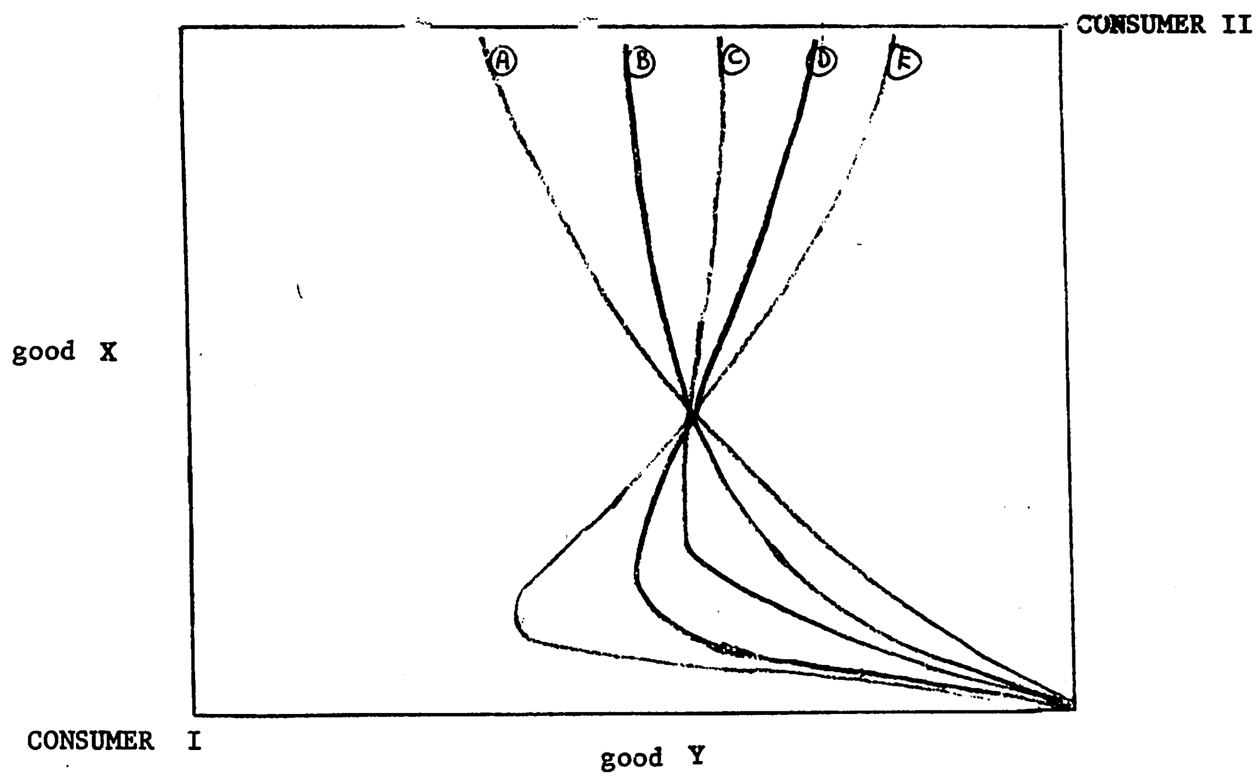
(i) Neither in the papers by Johnson and Gorman, nor subsequently, is there substantive discussion of the reasonableness or otherwise of the assumption of constant elasticity of offer surfaces. For a simple two good, pure exchange, general equilibrium model, it is not difficult to construct cases in which the elasticity of each country's offer curve varies substantially, or changes sign, as one moves along the offer curve. We present in Figure 2 diagrams which describe the offer curves generated from CES utility functions for a number of different parameter specifications where the endowment point is in the 'corner' of the Edgeworth box. As is apparent from the diagram, the assumption of constant elasticity offer surfaces is some distance from what is implied by the use of CES utility functions in these cases; and the same would hold for the Cobb-Douglas or LES functions. This problem is made more complicated by the presence of production since it is difficult to devise a set of production and utility functions giving constant elasticity excess demand functions which incorporate a production response.

(ii) There is no clear indication given in these papers how some of the more widely recognized 'parameters of trade' can be incorporated into the analysis. Characteristics such as the degree of specialization in each country in the presence of trade and the relative sizes of the countries involved will affect the size of tariffs and yet no obvious way exists of introducing these into the Johnson-Gorman framework except by varying elasticities of offer surfaces.

Figure 2

Diagrammatic Representation of Offer Curves Generated from CES Utility Functions

A. Five Offer Curves all generated from CES preference functions, for country I which pass through same initial endowment point (the corner of the box) and constructed to cross a 45^{0} line from the endowment point at the same point



B. Characteristics of the Offer Curves.

Offer Curve	Elasticity of Substitution in CES Function	Elasticity of the Offer Curve along ray 2X=Y through endowment point	Elasticity of the Offer Curve along ray X = Y through endowment point	Elasticity of the Offer Curve along ray X=2Y through endowment point
A	2.5	0.301	0.511	0.671
B	1.25	0.147	0.218	0.291
C	0.75	-0.090	-0.033	0.014
D	0.5	-0.332	-0.230	-0.171
E	0.25	-0.797	-0.171	-0.395

(iii) There is little discussion in the presentation of these calculations of further characteristics of the Nash equilibria involved except the qualitative welfare comparison to the free trade equilibrium for each country. Optimal tariffs and their relation to existing protection in world trade are not discussed. In addition little or no attention is given as to what values for trade elasticities might be realistic in these calculations in the light of current empirical evidence.

We thus seek to expand on these earlier calculations through the construction of a sequence of 2 x 2 numerical general equilibrium trade models incorporating full preference and production functions. Using conventional CES/LES functional forms we are able to numerically determine Nash, free trade, and autarky equilibria. We compare these equilibria and calculate optimal tariffs with and without retaliation. We also attempt an evaluation as to whether there is anything of significance in these calculations for current discussion of policy issues in the world economy.

III. The Computation of Nash Equilibria in the Models we Discuss

In this section we describe the sequence of models we consider and outline the methods we have used to numerically solve for the various equilibria we report. We assume two countries each characterized on the demand side by a single consumer. We consider alternative models with and without a production structure in each economy. We initially use general notation to represent the solution concepts in the models we have used and later describe the specific functions we adopt.

Following Shoven and Whalley [1974] we recognize that market demand functions in the presence of revenue generating distortions must be defined as functions of both prices and the revenue assumed generated by the distortion. For given ad valorem tariffs in country k on imported goods, denoted by the vector t^k, we write the market demand function for commodity i in country k as $\xi_i^k(\pi,R^k)$. π denotes the vector of world (net of tariff) prices, R^k denotes the tariff revenue distributed on the demand side of the economy in country k, and the index i denotes the commodity i. Demand functions are assumed to satisfy a domestic version of Walras Law. In those cases where production enters we assume the domestic production set to be represented by a transformation frontier defined over the vector of domestic outputs X. We write the transformation frontier for each country as $F^k(X)$; the case of a pure exchange economy involves the fixed endowment vector w as the function F^k.

We consider the following alternative solution concepts (in addition to the autarky solution) which we state for the pure exchange variant of these models

(1) Free Trade Equilibrium ($t^k=0 \quad \forall k, \quad R^k=0 \quad \forall k$)

Equilibrium is defined by a vector of world market prices π^* such that market demands are less than equal to supplies with strict equalities holding where corresponding prices are strictly positive.

$$\sum_k \xi_i^k(\pi^*) \leq \sum_k w_i^k \quad \forall_i \ (= \text{if } \pi_i^* > 0)$$

A property of such an equilibrium following from the assumption of Walras Law holding separately in each country is that external sector balance prevails for each country.

(2) 'First step' Optimal Tariff for country k (all countries but k have zero tariffs; $t^\ell = 0 \quad \ell \neq k$, $R^\ell = 0 \quad \ell \neq k$)

Equilibrium is defined by a vector of world market prices π^* such that country k maximizes the social welfare function

$$U^k(\xi^k(\pi^{k*},R^{k*}))$$

subject to the equilibrium conditions

$$\xi_i^k(\pi^{k*},R^{k*}) + \sum_{\ell \neq k} \xi_i^{\ell}(\pi^*) \leq \sum_{\ell \neq k} w_i^{\ell} + w_i^k \quad (= \text{ if } \pi_i^* > 0)$$

and equilibrium prevails. π^{k*} denotes the vector of consumption prices in country k, and equilibrium is supported by the vector of optimal tariffs $\frac{\pi^{k*} - \pi^*}{\pi^*}$. Two properties which will hold in equilibrium are government budget balance, $R^{k*} = \Sigma(\pi_i^{k*} - \pi_i^*)\ \xi_i^k(\pi^{k*},R^{k*})$, and external sector balance, $\sum_i \pi_i^*(\xi_i^k(\pi^{k*},R^{k*}) - w_i^k) = 0$.

(3) <u>Post retaliation (Nash Equilibrium) optimal tariff outcome for all countries</u>.

Equilibrium is defined by vector of world market prices π^* such that all countries maximize their social welfare function

$$U^k(\xi^k(\pi^{k*},R^{k*})) \qquad \forall k$$

subject to the equilibrium conditions

$$\sum_{\ell} \xi_i^{\ell}(\pi^{\ell*},R^{\ell*}) \leq \sum_{\ell} w_i^{\ell} \quad (= \text{ if } \pi_i^* > 0)$$

and equilibrium prevails. π^{k*} denotes the vector of consumption prices in country k, and equilibrium is supported by the vector of optimal tariffs $\frac{\pi^{k*} - \pi^*}{\pi^*}$ in each country. Government budget balance and external sector balance both hold in equilibrium.

The interpretation of each of these solution concepts in a two country model proceeds as follows. In a free trade equilibrium we determine a set of equilibrium prices such that all markets clear. In a 'first step' optimal tariff equilibrium, the country imposing the optimal tariff will determine their optimal tariff by maximizing utility subject to the excess demand functions of the other country. In a post retaliation (Nash) equilibrium each country simultaneously maximizes utility subject to the tariff distorted excess demands of the other country; the optimal tariffs determined for each country are consistent with the values assumed by the other country in determining their optimal tariff.

In order to compute equilibria of these types in a two good two country framework we consider piecewise linear approximations to the excess demand functions in both countries in solving the non-linear programming problem yielding an optimal tariff. We derive excess demand functions from maximization of conventional CES/LES type preference functions subject to the endowment or production constraint in the economy. The excess demand functions change as different domestic tariffs are levied and the piecewise linear approximations change accordingly. We assume a predetermined direction of trade which is treated as remaining unchanged in the face of tariff retaliation. We follow the process of retaliation through which optimal tariffs are calculated by each country and revised in light of any changes in tariffs adopted by the other country. When no further retaliation occurs an approximation to the Nash equilibrium is achieved. We determine a Nash equilibrium given the degree of approximation assumed in the linear segments for the excess demand functions and repeatedly refine the approximation in the neighbourhood of our approximate solution until a solution within a satisfactory tolerance is obtained. Convergence appears to be rapid in all the cases we have examined and the amounts of execution time involved are small. A procedure of explicitly using the fixed point mapping in strategy space which characterizes a Nash equilibrium and using a fixed point computational procedure could be followed but is, in our opinion, unnecessary for the cases we consider.

The demand functions derived from CES/LES type preference functions can be written in the form

$$X_i^k = C_i^k + \frac{\alpha_i^k \left(I^k - \sum_j P_j^k C_j^k\right)}{P_i^{k\,E^k} \cdot \sum_j \alpha_j^k P_j^{k\,1-E^k}} \qquad i=1,2;\ k=1,2$$

where the X_i^k's denote quantities demanded of good i in country k. The C_i^k's denote required purchases of good i in country k, and the α_i^k are weighting parameters in the preference functions. P_i^k indicates the consumer price for good i in country k, and E^k is the elasticity of substitution in the preference function. Where tariffs operate the price terms P_i^k are gross of tariffs and the income term I^k includes the tariff revenue.

We choose values for the parameters C_i^k to calibrate to point estimates of income elasticities of demand functions; values of E^k are set to calibrate to point estimates of import price elasticities. Alternative values of the parameters α_i^k are considered and affect both the volume of trade in a free trade equilibrium and the extent of specialization.

We also consider variations on pure exchange models in which production enters. We assume constant elasticity transformation surfaces between the two goods and specify alternative values for the elasticity of transformation. As this elasticity approaches zero the production model reverts to a pure trade specification. These functions are written as

$$Y = \left[\sum_i b_i^k X_i^k{}^{\frac{(\sigma^k-1)}{\sigma^k}} \right]^{\frac{\sigma^k}{(\sigma^k-1)}} \qquad (k=1,2)$$

where σ^k is the elasticity of transformation in country k, b_i^k define weighting parameters in country k's transformation function, and Y is a constant. The X_i^k denote the output levels of good i in country k.

We consider a number of different numerical specifications of these functions for which we compute Nash equilibria. We compare these equilibria to free trade and autarky equilibria and report values for the associated optimal tariffs.

IV. Trade Elasticities and the Optimal Tariff Problem

The formulations of the optimal tariff problem by Johnson and Gorman are concerned primarily with the qualitative proposition that it is possible for a country to gain through a retaliatory tariff war. They demonstrate this by numerical examples which are especially easy to solve.

Whether such occurrences are likely depends on trade elasticities (each country's import price and income elasticities), and these elasticities in turn are critical parameters in determining the size of optimal tariffs (either as first step or post retaliation solutions). Neither Johnson nor Gorman were able to relate their calculations to empirical literature since at the time the literature was sparse. Even though more literature is now available these estimates remain contentious; nevertheless, to provide more basis for evaluation of our results which follow we now briefly review this literature.

The most complete set of estimates of trade elasticities is the recent compendium compiled by Stern, Francis, and Schumacher [1976]. They briefly summarize the results of approximately 150 empirical studies from the period 1960-1975 which estimate trade elasticities by product and by trading area. They report the main findings of each study and produce central tendency tables from which they extract "best guess" estimates which we reproduce in Table 1. They suggest that there is little basis on which to produce "best guess" estimates on a more detailed product classification than the single digit SITC categories shown in Table 1 and they also stress the small sample size for estimates for countries other than the US.

There are several striking features of these estimates

(1) The total estimates for both import and export price elasticities strike many people as surprisingly low. Crudely averaging across all countries, numbers in the range of -1 are obtained. There has been extensive discussion of bias in estimates based on time series data following Orcutt's well known

Table 1

Central Tendency Trade Elasticities Reported by Stern, Francis, and Schumacher [1976]

Uncompensated Own Price Elasticity of Import Demand				Total	Country	Uncompensated Own Price Elasticity of Export Demand				Total
SITC 0 + 1	SITC 2 + 4	SITC 3	SITC 5 - 9	(Trade Weighted Average)		SITC 0 + 1	SITC 2 + 4	SITC 3	SITC 5 - 9	(Trade Weighted Average)
-0.80	-0.47	-0.96	-1.84	-1.66	United States	-0.85	-0.86	n.a.	-1.24	-1.41
-0.80	-0.58	-0.52	-2.06	-1.30	Canada	n.a.	n.a.	n.a.	n.a.	-0.79
-0.66	-0.91	-0.57	-1.42	-0.78	Japan	n.a.	n.a.	n.a.	-1.77	-1.25
-0.58	-0.80	-1.11	-2.36	-1.08	France	n.a.	n.a.	n.a.	n.a.	-1.31
-0.78	-0.25	-1.17	-2.53	-0.88	W. Germany	n.a.	n.a.	n.a.	n.a.	-1.11
-0.87	-0.25	-0.44	-1.22	-0.65	United Kingdom	n.a.	n.a.	n.a.	-2.00	-0.48
-1.06	-0.22	-1.35	-1.34	-0.83	Belgium-Luxembourg	n.a.	n.a.	n.a.	n.a.	-1.02
-1.52	-0.47	-1.00	-2.61	-1.05	Denmark	n.a.	n.a.	n.a.	n.a.	-1.28
-1.59	-0.93	-0.44	-2.64	-1.37	Ireland	n.a.	n.a.	n.a.	n.a.	-0.86
-0.96	-0.50	-1.16	-1.02	-1.03	Italy	n.a.	n.a.	n.a.	n.a.	-0.93
-0.26	-0.94	-0.01	-0.88	-0.68	Netherlands	n.a.	n.a.	n.a.	n.a.	-0.95
n.a.	-0.27	n.a.	-0.74	-1.32	Austria	n.a.	n.a.	n.a.	n.a.	-0.93
-0.09	-0.50	-0.33	-0.99	-0.50	Finland	n.a.	n.a.	n.a.	n.a.	-0.78
-0.58	-1.15	-1.36	-1.65	-1.19	Norway	n.a.	n.a.	n.a.	n.a.	-0.81
-0.47	-0.52	-0.24	-1.05	-0.79	Sweden	n.a.	n.a.	n.a.	n.a.	-1.96
-0.15	-0.17	-2.78	-1.21	-1.22	Switzerland	n.a.	n.a.	nn.a.	n.a.	-1.01
-0.73	n.a.	n.a.	n.a.	-0.42	Australia	n.a.	n.a.	n.a.	n.a.	-0.74
-1.12	-0.75	-0.34	-1.23	-1.12	New Zealand	n.a.	n.a.	n.a.	n.a.	-0.70

Source: Stern, Francis, Schumacher [1976], p. 20. n.a. indicates not available.

SITC 0 + 1 = Food, Beverages and Tobacco
SITC 2 + 4 = Crude Materials; oils and fats
SITC 3 = Mineral Fuels
SITC 5 - 9 = Manufactured goods.

paper [1950] and a further paper by Kemp [1962] has provided an argument as to why trade elasticities might be biased towards -1. Some authors argue for and use substantially higher trade elasticities based on so called 'tariff elasticities' [Balassa and Kreinin [1967] for instance use sharply higher elasticities (in absolute value)]. Some recent literature has suggested that the problems of bias first raised by Orcutt may not be as serious as once supposed and estimates in the range reported by Stern et al. remain both widely accepted and widely used.

(2) Reported estimates of export price elasticities do not appear to follow the ranking one would expect from the relative sizes of countries. If one argues that small economies are price takers they should face export price elasticities which are larger in absolute value than for larger price making countries. Thus the values of -1.41 for the US versus -0.79 for Canada, and -1.25 for Japan versus -0.70 for New Zealand or -0.74 for Australia seem a little counter intuitive.

(3) The estimates for import price elasticities suggest strongly that current tariffs are not consistent with optimal tariffs. If an optimal tariff is being pursued it must equal one over the foreigner's import demand elasticity minus one.[1] Thus if one examines US-Canadian trade and treats this as bilateral trade excluding all other countries, optimal tariffs of approximately 300% for the US and 133% for Canada would seem to be consistent with a post retaliation Nash equilibrium. These tariff levels are dramatically larger than post Kennedy Round tariffs of less than 10%. Given similar import price elasticities in other US trading partners this rough calculation is not much altered by aggregating all non-US countries into the 'rest of the world' for a US-Rest of the world bilateral calculation.

(4) A number of countries have import price elasticities in absolute value less than one, implying that if a two country optimal tariff equilibrium was involved the other country's optimal tariff would be negative. Thus not only are the values for most countries inconsistent with an optimal tariff outcome

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[1] See Johnson [1961] Appendix to Chapter 2, pp. 56-58.

as a description of current tariffs in world trade, they are also inconsistent with a constant elasticity offer curve formulation of the optimal tariff problem since negative tariffs would always result. We argue that this observation gives further weight to the case for calculations of the type we report.

(5) No central tendency tables are provided for import income elasticities by Stern et al. but there are a number of studies summarized in which import income elasticities are greater than unity. Houthakker and Magee [1969] for instance, report an income elasticity of import demand on the US of 1.51.

Our procedure, in light of this evidence, is to incorporate a capability of prespecification of import demand price and income elasticities in our calculations at some chosen point on the offer curve for each country (typically, the free trade equilibrium). Given the non-constant elasticity nature of the offer curves we use, we are able to work backwards to the implied elasticities of substitution and other parameters in the preference and production frontier functions. We perform calculations for a range of values and then appeal to the estimates reported in Table 1 to provide a guide as to which cases are more plausible than others.

An important point of interpretation with these estimates arises in the case of models which incorporate production. We suggest the appropriate interpretation of estimates of import demand elasticities are as elasticities of excess demand functions (demand less supply) with respect to prices. Thus low import price elasticities imply a low sum of transformation and demand elasticities in the models with production. The interpretation of such estimates in a general equilibrium trade model with production would be that the production response of the economy would also appear in the data generating the estimated functions. In models incorporating production we therefore suggest the natural interpretation of the Stern, Francis and Schumacher results is as the composite of demand and supply elasticities, rather than as demand side elasticities alone. It should also be squarely noted that this interpretation is critical for some of our later conclusions.

An important recent paper by Goldstein and Kahn [1978] reports high export supply elasticities for some countries in a simultaneous equations approach to estimation of export demand and supply functions. Effectively infinite supply elasticities for Japan are found, values in the neighbourhood of 5.0 are found for the US and W. Germany, and values closer to 1.0 for smaller economies such as Belgium. A difficulty in relating such estimates to traditional trade models is that there is not a supply function for exports as such in these models but a supply function for exportables. The market is in the homogeneous product which is consumed in both countries rather than a market in the product consumed abroad. Traditional trade models with linear homogeneous production will yield partial equilibrium supply elasticities of exportables which approach infinity in the sense that profit maximizing producers who face equilibrium prices for which zero profit conditions hold are indifferent as to what quantity they sell. To the extent that one is willing to interpret estimated supply elasticities in this way, no necessary contradiction exists with low transformation elasticities.

V. Some Numerical Results from a Sequence of Simple Trade Models

In this section we report calculations from a number of different formulations with alternative numerical specifications for each. All cases involve two goods and two countries; for each we specify an autarky point, preference function parameters, and (for cases involving production) parameters of the production transformation frontier. The specification of our first model may be summarized as follows

Specification #1

1) Pure Trade Only - No production is considered in either country.
2) CES preference functions with all $C_i^k = 0$; this is equivalent to specifying unitary income elasticities in all demand functions.
3) Endowment points, are (75,25) in country 1, (25,75) in country 2. The dimension of the pure exchange Edgeworth Box is 100 x 100 in quantity terms.
4) The α_i - weighting parameters in preference functions - are set at .5 in both countries. This places the contract curve (locus of free trade equilibria) along the diagonal of the Edgeworth box.
5) Elasticities of substitution in preferences are set so as to calibrate the excess demand functions to specified values of import price elasticities at free trade; import price elasticities vary between cases and thus elasticities of substitution also vary between cases.
6) By construction; free trade prices are unity; utility levels of each country at free trade are 100.0; free trade is characterized by consumption vectors of (50,50) in each country and trade of 25 in each commodity.

Table 2 reports results from a sequence of cases which follow specification #1 and which only deviate one from another in the setting of import price elasticities at free trade. For each case we report utility levels at free trade, autarky, and post retaliation (Nash) equilibria. We also report

Table 2

Results from Alternative Cases Using Specification No. 1[1]

Import Price Elasticity at Free Trade		Utility at Autarky		Utility at Free Trade Equilibrium		Utility at Post Retaliation (Nash) Equilibrium		First Step Optimal Tariff in Country 1	Post Retaliation (Nash Equilibrium) Optimal Tariffs		Volume of Trade at Free Trade		Volume of Trade at Nash Equilibrium	
Country 1	Country 2	Country 1	Country 2	Country 1	Country 2	Country 1	Country 2		Country 1	Country 2	Exports of Good 1 to Country 1	Exports of Good 2 to Country 2	Exports of Good 1 to Country 1	Exports of Good 2 to Country 1
-1.0	-1.0	75.3	75.3	100.0	100.0	91.8	91.8	318.8	222.0	222.0	25.0	25.0	10.6	10.6
-2.0	-1.0[2]	91.2	75.3	100.0	100.0	106.9	84.1	236.6	193.1	40.5	25.0	25.0	16.7	7.8
-3.0	-1.0[2]	94.7	75.3	100.0	100.0	109.5	82.7	219.6	191.9	24.9	25.0	25.0	18.0	7.4
-4.0	-1.0[2]	96.3	75.3	100.0	100.0	110.7	82.0	213.3	185.3	26.2	25.0	25.0	18.7	7.2
-2.0	-2.0	91.2	91.2	100.0	100.0	97.8	97.8	58.4	41.8	41.8	25.0	25.0	12.0	12.0
-3.0	-2.0[2]	94.7	91.2	100.0	100.0	100.5	95.9	53.8	42.4	22.8	25.0	25.0	13.0	11.2
-4.0	-2.0[2]	96.3	91.2	100.0	100.0	101.6	95.2	51.9	42.6	15.5	25.0	25.0	13.4	10.9
-3.0	-3.0	94.7	94.7	100.0	100.0	98.6	98.6	31.4	24.1	24.1	25.0	25.0	11.6	11.6
-4.0	-3.0[2]	96.3	94.7	100.0	100.0	99.8	97.8	30.2	24.3	15.7	25.0	25.0	12.1	11.4
-4.0	-4.0	96.3	96.3	100.0	100.0	99.0	99.0	20.6	16.1	16.1	25.0	25.0	12.1	12.1
-5.0	-5.0	97.1	97.1	100.0	100.0	99.3	99.3	16.4	12.0	12.0	25.0	25.0	12.4	12.4
-6.0	-6.0	97.6	97.6	100.0	100.0	99.4	99.4	12.2	10.0	10.0	25.0	25.0	12.0	12.0
-7.0	-7.0	98.0	98.0	100.0	100.0	99.5	99.5	10.2	8.0	8.0	25.0	25.0	12.6	12.6

[1] The characteristics of this specification are given in the text.

[2] Since the countries are symmetric in all respects cases such as (-2,-1) or (-3,-1) are identical to (-1,-2) and (-1,-3).

post retaliation optimal tariffs, first step optimal tariffs in country 1, and the volume of trade at free trade and the post retaliation equilibrium. While Table 2 contains a substantial amount of detail some of the major features can be highlighted as follows

(i) The indications from the Johnson/Gorman calculations as to conditions under which one country may gain even after a tariff war appear to be similar between this table and Johnson's original calculations. In Figure 3 we summarize our results and those of Johnson for a four by four grid of cases reporting who gains and who loses. The comparison indicates a similarity to the Johnson/Gorman findings although the results are not identical.

(ii) The assumption of constant elasticity of the offer surfaces in the Johnson/Gorman calculations is departed from quite noticeably in a number of the cases reported in Table 2. If a constant elasticity offer curve prevailed in both countries the optimal tariff would be the same for the imposing country regardless of retaliation by the other country. With import price elasticities at free trade set at -2 in both countries for instance, country 1 has a first step optimal tariff of 58% but a post-retaliation optimal tariff of 42%. Other cases also confirm the non-constant elasticity nature of the offer surfaces.

(iii) The level of post retaliation tariffs calculated for the smaller values of import price elasticities are surprisingly large. For the (-2,-2) case post retaliation optimal tariffs above 40% are produced. The initial indication is that in light of the empirical evidence on trade elasticities a worldwide tariff war would produce tariffs significantly above existing tariffs in the world economy. Tariffs in the region of the 50% and higher which prevailed in the 1930's in the US for many (but not all) commodities might thus not be unrealistic as optimal tariffs. We comment later on the relation between the post retaliation optimal tariffs reported and current protection in world trade.

Figure 3

Representation of gainers and losers
Between Nash equilibrium and free Trade in Table 2
Comparison to the calculations by Johnson

Import price elasticity in country 1	Table 2	Johnson Case 1	Table 2	Johnson Case 1	Table 2	Johnson Case 1	Table 2	Johnson Case 1
-4.0	1 gains 2 loses	1 gains 2 loses	1 gains 2 loses	1 gains 2 loses	Both lose	1 gains 2 loses	Both lose	Both lose
-3.0	1 gains 2 loses	1 gains 2 loses	1 gains 2 loses	1 gains 2 loses	Both lose	Both lose	Both lose	Both lose
-2.0	1 gains 2 loses	1 gains 2 loses	Both lose	Both lose	2 gains 1 loses	Both lose	2 gains 1 loses	Both lose
-1.0	Both lose	Both lose	2 gains 1 loses	Both lose	2 gains 1 loses	2 gains 1 loses	2 gains 1 loses	2 gains 1 loses
	-1.0		-2.0		-3.0		-4.0	

Import price elasticity in country 2

[1]See Figure 1, p. 8 reproduced from Johnson [1961].

(iv) Table 2 also provides some findings relevant to the Gorman result that with constant elasticity offer curves the volume of trade in a Nash equilibrium compared to free trade is related by the ratio 1/e. As the import price elasticities increase, the ratio of trade seems to approach a limit of 1/2 rather than 1/e and the approach is far from being monotone; increasing and then decreasing.

The results in Table 2 are expanded on through a number of further calculations. We first examine cases incorporating production into Specification #2.

Specification #2

As for specification #1, except for the following

(a) rather than a pure trade case, we consider production possibilities in each country to be given by constant elasticity transformation frontiers. The transformation elasticities differ between cases and are listed in Table 3. In each variant the production possibility frontier is constructed to pass through the endowment point from the corresponding pure exchange case and have a slope of minus one at this point. Because of the use of .5 weighting parameters in each country and the (25,75), (75,25) endowment points used in Table 2, the free trade equilibrium prices and utilities are the same in all cases in Table 3 and equal to those of the corresponding pure exchange variant.

(b) We fix the free trade import price elasticities at (-2,-2) and (-2,-4) respectively in two blocs of results we report.

In Table 3 we report results from these cases. The cases in Table 3 differ in the values which are specified for elasticities of transformation for the production possibility frontier in each country. In each reported case both countries have identical transformation elasticities, although this is not necessary for the computations performed.

Table 3

Results from cases using specification No. 2[1] (specification No. 1[1] but with production)

A. Import price elasticities at free trade set at -2 in both countries

Elasticity of Transformation in Production in Each Country: Country 1	Country 2	Utility at Free Trade Equilibrium: Country 1	Country 2	Utility at Post Retaliation (Nash) Equilibrium: Country 1	Country 2	First Step Optimal Tariff in Country 1	Post Retaliation (Nash Equilibrium) Optimal Tariffs: Country 1	Country 2
.25	.25	100.0	100.0	98.0	98.0	60.2	35.9	35.9
.33	.33	100.0	100.0	98.1	98.1	37.5	34.1	34.1
.5	.5	100.0	100.0	98.3	98.3	32.3	31.1	31.1
1.0	1.0	100.0	100.0	98.6	98.6	36.3	24.4	24.4
3.0	3.0	100.0	100.0	99.2	99.2	17.9	13.4	13.0
5.0	5.0	100.0	100.0	99.5	99.5	12.9	9.0	9.0
10.0	10.0	100.0	100.0	99.7	99.7	6.9	5.0	5.0
[(Comparable Pure Exchange Case from Table 2)		100.0	100.0	97.8	97.8	58.4	41.8	41.8]

B. Import price elasticities at free trade set at -2 in country 1 but -4 in country 2

Elasticity of Transformation in Production in Each Country: Country 1	Country 2	Utility at Free Trade Equilibrium: Country 1	Country 2	Utility at Post Retaliation (Nash) Equilibrium: Country 1	Country 2	First Step Optimal Tariff in Country 1	Post Retaliation (Nash Equilibrium) Optimal Tariffs: Country 1	Country 2
.25	.25	100.0	100.0	96.0	101.2	25.2	15.1	35.8
.33	.33	100.0	100.0	96.2	101.1	2.4	14.9	34.0
.5	.5	100.0	100.0	96.6	100.9	22.2	14.3	30.9
1.0	1.0	100.0	100.0	97.4	100.5	22.4	12.8	24.2
3.0	3.0	100.0	100.0	98.7	100.0	14.6	8.9	13.0
5.0	5.0	100.0	100.0	99.2	99.9	8.3	6.8	6.8
10.0	10.0	100.0	100.0	99.6	99.8	5.5	4.3	5.0
[(Comparable Pure Exchange Case from Table 2)		100.0	100.2	95.2	101.6	24.8	15.5	42.6]

[1] These specifications are described more fully in the text.

As would be expected, results in Table 3 indicate that as the elasticity of transformation gets smaller the results from the corresponding pure exchange case are approached. As the elasticity of transformation approaches infinity optimal tariffs would approach zero since no terms of trade effects from tariffs are possible since the production surfaces are linear. With transformation elasticities at one half the demand side elasticities, optimal tariffs in a post retaliation equilibrium are approximately one half of the pure exchange case values. A striking result is that the (1.0,1.0) production case result using (-2.0,-2.0) as import price elasticities is approximately the same as the (-3.0,-3.0) pure exchange case. This suggests a plausible approximation that the sum (in absolute value terms) of the final import demand and transformation elasticities gives a total import demand elasticity which in turn can be approximated by a pure exchange variant. Given that estimated import demand elasticities are total elasticities incorporating both demand side and production side responses, a given 'estimated' import demand elasticity can be calibrated to in these models either through an implied demand side substitution elasticity alone or through demand and production side elasticities whose sum meets the specified condition.

Table 3 also provides some indications as to the quantitative impact of increasing values of supply side elasticities on computed optimal tariffs. With transformation elasticities of 10.0, optimal tariffs in the (-2,-2) case fall from over 40% in the pure exchange case (or zero transformation elasticity) to around 5%. Five percent tariffs are approximately the range in which post Tokyo Round tariffs[1] will be after 1987 for major industrialized countries. An argument can be made that these tariffs do not differ too sharply from optimal tariffs because of a high elasticity of the production side response.

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[1] But not the ad valorem equivalents of NTB's.

As already noted this is not the interpretation of empirical evidence on trade elasticities which seems to us most natural.

In Specification No. 3 we consider the effects of allowing income elasticities to depart from unity for the (-2,-2) case considered in Table 2 and we report our results in Table 4. We vary the values of the C_i^k in the LES/CES demand functions and determine the income elasticities of import demand at the free trade equilibrium in each case.

Specification No. 3

As for specification No. 1, except that

(a) values for the C_i^k are set at nonzero values by product and by country and the implied point estimates of income elasticities for imports at free trade calculated (these differ from unity as in the earlier specifications).

(b) The C_i^k and the weighting parameters in demands are set so that the free trade equilibrium is the same in each case. The autarky equilibria differ between cases.

(c) For reasons of restriction of the number of possible cases, we only consider cases in which the free trade import price elasticities are -2 in each country.

Results from Table 4 indicate that relatively small differences in income elasticities do not produce a situation where one country gains when this is not the case in a unit income elasticity environment. In fact, computed post retaliation optimal tariffs are largely insensitive to variations in income elasticities except when these elasticities become small. With income elasticities of .7 and 1.7 in country 1 and 2 respectively, country 2 does not gain at a Nash equilibrium compared to free trade, the same outcome as with unit income elasticities. Post-retaliation tariffs vary from 47% to 35% as

Table 4

Results from cases using Specification No. 3[1] (Specification No. 1[1] but with import income elasticities displaced from unity)

Import Price Elasticities at Free Trade set at -2 in both Countries

Income Elasticity of Demand for Imports, Country 1	Country 2	Minimum Requirements, Country 1, Good 1	Country 1, Good 2	Country 2, Good 3	Country 2, Good 4	Autarky Utilities, Country 1	Country 2	Free Trade Utilities, Country 1	Country 2	Post Retaliation Nash Equilibrium Utilities, Country 1	Country 2	1st Step Optimal Tariff, Country 1	Post Retaliation Nash Equilibrium Tariffs, Country 1	Country 2	Elasticity of Substitution in Demand, Country 1	Country 2	Volume of Trade at Nash Equilibrium, Good 1	Good 2	Preference Weighting Parameters constructed to yield the same free trade outcome in each case, Country 1, Good 1	Country 1, Good 2	Country 2, Good 1	Country 2, Good 2
0.5	0.5	25.0	-25.0	-25.0	25.0	81.1	81.1	100.0	100.0	95.3	95.3	86.4	77.8	77.8	2.4	2.4	7.0	7.9	0.25	0.75	0.75	0.25
0.6	0.6	20.0	-20.0	-20.0	20.0	88.3	88.3	100.0	100.0	96.7	96.7	70.3	55.5	55.5	2.1	2.1	9.8	9.8	0.3	0.7	0.7	0.3
0.7	0.7	15.0	-15.0	-15.0	15.0	89.7	89.7	100.0	100.0	97.2	97.2	64.1	47.8	47.8	1.8	1.8	10.8	10.8	0.35	0.65	0.65	0.35
0.8	0.8	10.0	-10.0	-10.0	10.0	90.4	90.4	100.0	100.0	97.4	97.4	61.7	45.5	45.5	1.7	1.7	11.1	11.1	0.4	0.6	0.6	0.4
1.0	1.0	0.0	0.0	0.0	0.0	91.2	91.2	100.0	100.0	97.7	97.7	58.4	41.9	41.9	1.5	1.5	12.0	12.0	0.5	0.5	0.5	0.5
1.1	1.1	-5.0	5.0	5.0	-5.0	91.4	91.4	100.0	100.0	97.8	97.8	57.6	41.0	41.0	1.5	1.5	12.3	12.3	0.55	0.45	0.45	0.55
1.2	1.2	-10.0	10.0	10.0	-10.0	91.6	91.6	100.0	100.0	97.9	97.9	58.5	41.1	40.8	1.5	1.5	12.4	12.4	0.6	0.4	0.4	0.6
1.4	1.4	-20.0	20.0	20.0	-20.0	92.0	92.0	100.0	100.0	98.0	98.0	57.4	40.2	40.2	1.6	1.6	12.8	12.8	0.7	0.3	0.3	0.7
1.5	1.5	-25.0	25.0	25.0	-25.0	92.2	92.2	100.0	100.0	98.1	98.1	58.9	38.6	38.6	1.7	1.7	13.3	13.3	0.75	0.25	0.25	0.75
1.7	1.7	-35.0	35.0	35.0	-35.0	92.9	92.9	100.0	100.0	98.4	98.4	54.4	34.9	34.9	2.3	2.3	14.1	14.1	0.85	0.15	0.15	0.85
1.5	1.1	-25.0	25.0	5.0	-5.0	92.2	91.4	100.0	100.0	98.1	97.7	60.6	44.3	37.4	1.7	1.5	12.7	12.4	0.75	0.25	0.45	0.65
1.5	1.3	-25.0	25.0	10.0	-10.0	92.2	91.8	100.0	100.0	98.1	97.9	58.5	41.7	38.4	1.7	1.5	12.9	12.8	0.75	0.25	0.4	0.6
1.7	1.1	-35.0	35.0	5.0	-5.0	92.9	91.4	100.0	100.0	98.8	97.4	61.7	46.5	30.1	2.3	1.5	13.6	12.8	0.85	0.15	0.45	0.55
1.7	1.2	-35.0	35.0	10.0	-10.0	97.9	91.6	100.0	100.0	98.8	97.6	59.4	44.0	30.5	2.3	1.5	12.3	13.2	0.85	0.15	0.4	0.6
1.5	0.9	-25.0	25.0	-5.0	5.0	92.2	90.6	100.0	100.0	98.1	97.5	62.6	46.8	36.7	1.7	1.6	12.5	12.1	0.75	0.25	0.55	0.45
1.7	0.7	-35.0	35.0	-15.0	15.0	92.9	89.7	100.0	100.0	99.2	96.5	67.3	55.7	26.9	2.3	1.8	13.3	12.0	0.85	0.15	0.65	0.35

[1] These specifications are explained more fully in the text.

income elasticities in both countries vary between .7 and 1.7. As elasticities change from .7 to .5 in both countries, optimal tariffs rise to 78%.

The sensitivity of optimal tariff rates to further changes in specification is investigated in cases in which the endowment point in a pure trade case is systematically varied. These cases are represented by Specification No. 4.

Specification No. 4

As for specification No. 1 except that the endowment point (75,25), (25,75) is varied as described. We examine cases in which import price elasticities are preserved at (-2,-2) in both countries and income elasticities are unity.

Results in Table 5 indicate that the relative sizes of the two countries makes a substantial difference as to whether a country will gain from a retaliatory tariff war and also to the size of calculated optimal tariffs.

In the first set of results in Table 5 we systematically vary the relative size and endowment mix of the two countries. As we move from a situation of equal size to dominance by country 1 for unchanged point estimates of import price elasticities at free trade, 1 becomes a gainer in a trade war. Interestingly, the post retaliation optimal tariffs in 1 first rise and then fall as the relative size of country 1 increases. In the second set of results we move the endowment point in our pure trade example along a diagonal of the Edgeworth box towards the contract curve. As we approach the contract curve optimal tariffs fall and on this basis we are able to relate optimal tariffs to the degree of specialization which trade produces. Thus with the value of trade being 10% of the value of endowments optimal tariffs of 8% result, but with trade being 90% of the value of endowments optimal tariffs of 130% result.

Table 5

Results from cases using specification #4[1]
(Variations in the endowment point of pure exchange case)

Import price elasticities at free trade equal -2 in both countries, unit import income elasticities

Endowment Configuration				Utility at Free Trade		Utility at Post Retaliation (Nash Equilibrium)		First Step Optimal Tariff in	Post Retaliation (Nash Equilibrium) Optimal Tariffs	
Country 1		Country 2		Country 1	Country 2	Country 1	Country 2	Country 1	Country 1	Country 2
good 1	good 2	good 1	good 2							
99	1	1	99	100.0	100.0	82.3	82.3	281.6	200.0	200.0
99	5	1	95	104.0	96.0	94.9	76.0	277.5	205.8	131.9
99	10	1	90	109.0	91.0	105.6	69.7	270.8	209.4	96.3
99	15	1	85	114.0	86.0	114.3	64.2	266.7	213.2	74.8
99	20	1	80	119.0	81.0	121.6	59.4	261.2	213.4	61.9
99	25	1	75	124.0	76.0	128.3	54.9	256.2	212.3	51.8
99	50	1	50	149.0	51.0	155.6	35.5	222.9	198.2	23.7
99	75	1	25	174.0	26.0	178.1	18.6	172.3	168.2	8.6
95	5	5	95	100	100	88.4	88.4	191.7	133.3	133.3
85	15	15	85	100	100	94.6	94.6	103.0	74.5	74.5
75	25	25	75	100	100	97.6	97.6	60.7	44.1	44.1
65	35	35	65	100	100	99.3	99.3	31.7	22.0	22.0
55	45	45	55	100	100	99.9	99.9	10.2	8.1	8.1

[1]This specification is described more fully in the text.

Table 5 also indicates that with increasing degrees of specialization in free trade larger post-retaliation optimal tariffs are involved which, in turn, reflect progressively stronger terms of trade effects. This suggests that empirically based general equilibrium trade models which use the so-called 'Armington' assumption of treating products as heterogeneous by trading area may be incorporating stronger terms of trade effects into such models than may be the case in practice. Such models use this assumption due to the empirical observation of cross-hauling in trade data, and an assumed complete specialization is involved.

Using a further variation in specification (Specification No. 5) we report additional results from cases in which the relative sizes of the two countries vary in Table 6. In these cases the size of country 1 is systematically increased while 2 remains unchanged.

Specification No. 5

As for Specification No. 1 except we vary the sizes of the countries by varying their endowments one to another while preserving their relative endowments across commodities.

Table 6 confirms the importance of relative country size in the determination of optimal tariffs, as suggested by Table 5. With countries both of equal size, both lose through a trade war; where country 1 is double the size (all other parameters unchanged) country 1 gains from a trade war. Post retaliation tariffs change from (44%, 44%) in the equal size case to (61%, 28%) where one country is double the size, to (89% to 9%) in the 10-1 case. The ratio of optimal tariffs is approximately equal to the relative sizes of countries of all other parameters (including import price elasticities) being the same across countries.

Tables 3-6 thus provide indications as to the behavior of post retaliation optimal tariffs in a sequence of 2 x 2 trade models and in the next section we attempt to loosely relate some of the more striking suggestions drawn from these calculations to issues with current protection in world trade.

Table 6

Results from cases using Specification No. 5[1] (changes in relative country size)

Import price elasticities at free trade in both countries set at -2, unitary import income elasticities

Endowments				Utility at Autarky		Utility at Free Trade		Utility at Post Retaliation (Nash) Equilibrium		First Step Optimal Tariff	Post Retaliation Optimal Tariffs		Volume of Trade at Free Trade		Volume of Trade at Post Retaliation (Nash Equilibrium)	
Country 1		Country 2		Country 1	Country 2	Country 1	Country 2	Country 1	Country 2	Country 1	Country 1	Country 2	Country 1 imports	Country 2 imports	Country 1 imports	Country 2 imports
25	75	75	25	91.0	91.0	100.0	100.0	97.6	97.6	60.7	44.1	44.1	25.0	25.0	11.6	11.6
30	90	75	25	109.3	91.0	118.3	101.6	116.7	98.0	63.7	47.8	38.9	26.4	28.1	12.9	12.9
35	105	75	25	127.5	91.0	136.3	103.2	135.7	98.4	68.8	50.9	34.5	27.8	31.2	14.1	14.1
40	120	75	25	145.7	91.0	154.6	104.2	154.5	98.6	69.8	54.9	32.3	28.9	33.6	14.6	14.6
45	135	75	25	163.9	91.0	172.8	105.3	173.0	98.8	74.1	56.9	31.9	29.9	36.0	15.0	15.2
50	150	75	25	182.1	91.0	190.7	106.5	192.0	98.9	75.1	60.7	28.1	30.3	37.8	15.8	15.8
125	375	75	25	455.2	91.0	461.2	115.9	468.9	100.1	88.7	77.7	15.5	34.8	55.3	20.1	20.5
250	750	75	25	910.4	91.0	914.3	121.5	926.3	100.4	95.1	88.7	9.1	36.9	65.9	22.3	22.3

[1]This specification is described more fully in the text.

VI. Synthesis and Interpretation of Results from Section V and Their Relevance to the Evaluation of Protection in the Modern World Economy

It is unrealistic to claim a precise set of policy conclusions on the basis of the calculations reported in Section V. There are, however, suggestions in our results for trade policy evaluation in the modern world economy which we find striking and these we stress. We also feel our calculations are of interest even if their interpretation is restricted simply to an extension of existing calculations for analytical models incorporating optimal tariff analysis. We list our synthesis of results in point form but emphasize that these should be construed as approximate working hypotheses from current analytics and empirical evidence, rather than definitely proven findings.

(1) Given current empirical evidence on import price elasticities, and interpreting this as evidence on elasticities of excess demand functions, the indications from our calculations are that in a post retaliation trade war environment tariffs among major world trading areas (US, EEC, Japan) could be significantly higher than is currently the case. One could argue that existing nontariff barriers by industrialized countries substitute for these high retaliatory optimal tariffs but the lack of reliable estimates of ad valorem equivalents for NTB's causes us to hesitate in advocating this position too strongly.

(2) We feel that a 'best guess' set of post retaliation tariffs are indicated to be in excess of 50% (and possibly significantly higher) for the US and the EEC, while being somewhat less for Japan due to its relative size. We also suggest that tariffs of 50% plus which occurred in the early 1930's might not be too far out of line with post retaliation optimal tariffs.

(3) We suggest that if a sequence of 2 x 2 trade models were constructed in which each country traded with a 'Rest of the World' treated as a single cooperating coalition, the size of any country's optimal tariff would be proportional to their relative size to the rest of the world. This involves calibrating parameters of excess demand functions to estimated import price elasticities as point estimates at free trade. This calculation would suggest that, for instance, Canada's tariff would be 1/10 of that of the US, other things being equal.

(4) We do not believe that incorporation of income elasticities for imports other than unity into these calculations dramatically changes this overall picture. Our calculations indicate that income elasticities for imports have to be considerably dissimilar to significantly change results, more disparate than seems to be indicated by currently available evidence.

(5) Results suggest that a worldwide tariff war between major trading areas could result in a loss in world wide welfare in the region of 3% assuming that full employment were to apply throughout the trade war.

(6) A possible view of world protection suggested by our calculations would be that tariff rates in the mid 1930's following the depression were of the order to magnitude suggested by our post retaliation tariff calculations. International agreements since that date, and in particular under the GATT, have successfully exploited cooperative reductions

in the level of protection since this period and thus current protection is significantly below post retaliation tariffs. This suggests that a major role for GATT negotiations such as the Kennedy and Tokyo Rounds is the preservation of cooperative arrangements in world trade policies.

We have sought to offer some elaboration on these findings by examining alternative tariff scenarios in a large-scale general equilibrium model of world trade involving the (9 member) EEC, the US, Japan, and a residual rest of the world constructed by Whalley [1979] which uses data for 1973. This model incorporates production, demand and trade data on 33 products in each trading area and determines alternative equilibria as policy variations are introduced into the model. The model equations are specified so that the model calibrates to the 1973 data used which in turn is transformed to accommodate general equilibrium conditions. The import price elasticities in the model rely on the Stern, Francis, Schumacher values discussed earlier. Since these are close to unity for these trading areas large optimal tariffs result from these.

We consider alternative uniform tariffs separately in each trading area and calculate the sum of compensating and equivalent variation within each trading area between the benchmark equilibrium in 1973 data and the hypothetical equilibrium calculated in the presence of the uniform tariffs in the trading area concerned. We report these welfare measures as a percent of GNP in each trading area to make them more easily interpretable.

Table 7 reports the computer runs involved with this large dimensional model. Because of the expense of repeated solution we are unable to compute a

Table 7

Crude Calculations of 'First Step Optimal' Tariffs in a larger-scale general equilibrium model of EEC-US-Japanese trade due to Whalley [1979][1]

(All results refer to Compensating and Equivalent variation as a % of GNP by area.[2])

		EEC		US		Japan		Rest of the World		Total	
		CV as % of GNP	EV as % of GNP	CV as % of GNP	EV as % of GNP	CV as % of GNP	EV as % of GNP	CV as % of GNP	EV as % of GNP	CV as % of GNP	EV as % of GNP
A. EEC replacement of existing tariffs by uniform tariff at	125%	2.0	1.6	-0.3	-0.3	0.2	0.3	-2.5	-3.0	-0.1	-0.4
	150%	2.1	1.6	-0.3	-0.4	0.3	0.3	-2.8	-3.4	-0.2	-0.5
	175%	2.1	1.5	-0.3	-0.4	0.3	0.3	-0.3	-3.7	-0.3	-0.6
	200%	2.1	1.4	-0.4	-0.4	0.3	0.4	-3.1	-4.0	-0.3	-0.8
B. US replacement of existing tariffs by uniform tariff at	125%	-0.8	-0.4	2.2	1.6	-1.2	-1.4	-1.6	-1.8	-0.2	-0.5
	145%	-0.8	-0.9	2.2	1.6	-1.3	-1.5	-1.7	-2.0	-0.2	-0.6
	160%	-0.8	-1.0	2.3	1.6	-1.3	-1.6	-1.7	-2.1	-0.2	-0.6
	180%	-0.9	-1.0	2.2	1.5	-1.4	-1.7	-1.8	-2.2	-0.3	-0.7
C. Japanese replacement of existing tariffs by uniform tariffs at	150%	-0.1	-0.1	-0.3	-0.4	2.3	1.3	-0.8	-0.9	-0.1	-0.2
	175%	-0.1	-0.1	-0.4	-0.4	2.4	1.2	-0.9	-0.9	-0.1	-0.3
	200%	-0.1	-0.1	-0.4	-0.4	2.4	1.1	-0.9	-1.0	-0.1	-0.3
	225%	-0.1	-0.1	-0.4	-0.5	2.4	0.9	-1.0	-1.0	-0.2	-0.4
D. Simultaneous adoption of uniform tariffs at rates of	175% in EEC 160% in US 200% in Japan 178% in Rest of the World	-5.0	-6.8	-2.2	-2.3	-5.1	-6.7	-1.4	-1.6	-3.2	-4.0
E. Simultaneous adoption of uniform 60% tariffs in all trading areas		-2.1	-2.3	-0.3	-0.4	-2.1	-2.3	-0.1	-0.0	-1.0	-1.1

[1] Tariff rates reported are uniform ad valorem rates on all imports and operate in addition to domestic taxes, and quantified ad valorem equivalents of selected NTB's considered in the model.

[2] +ve indicates a gain and -ve indicates a loss.

Nash equilibrium in the presence of retaliatory tariffs for this model but we have crudely calculated a 'first step' optimal tariff for each. These tariffs are substantially above the regions for optimal tariff levels from our earlier 2 x 2 which we feel is primarily due to the trade elasticity values used. The welfare loss from the combined imposition of all calculated 'first step' optimal tariffs (with an arithmetic average imposed for the rest of the world) produces a worldwide loss in the region of 3% of worldwide GNP, roughly consistent with the figure mentioned above.

VII. Conclusion

In this paper we report calculations of optimal tariffs both with and without retaliation in a sequence of 2 x 2 trade models. We extend the earlier calculations by Johnson [1954, 1961] and Gorman [1957] which assume constant elasticity offer surfaces by using functional forms from the Cobb-Douglas/CES/LES family for utility functions and by also incorporating production into our calculations. We suggest the most critical parameters in any such calculations are the import price elasticities and we briefly survey the empirical evidence as to their values. Our major conclusion is that these models confirm the suggestion from casual inspection of reported trade elasticities that current levels of tariff protection are some distance from optimal tariffs and that the margin for tariff retaliation in a worldwide trade war is potentially large. Our interpretation of our calculations suggests that such a trade war could yield a worldwide welfare loss of 3% of worldwide GNP assuming full employment were to be maintained in all trading areas. Other implications of the results are explored in the text.

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