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General Equilibrium Analysis Of The Effects Of Multilateral And Canadian Trade Liberalization: I Multilateral Trade Liberalization Ii Canadian Trade Liberalization Iii Systematic Sensitivity Analysis Of Model Results

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GENERAL EQUILIBRIUM ANALYSIS OF THE EFFECTS OF MULTILATERAL AND CANADIAN TRADE LIBERALIZATION

I. Multilateral Trade Liberalization
II. Canadian Trade Liberalization
III. Systematic Sensitivity Analysis of Model Results

by

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ABSTRACT

The thesis is comprised of three essays which analyze trade liberalization on a multilateral basis and in the Canadian context. Essay I concerns multilateral liberalization, Essay II concerns Canadian liberalization, and Essay III presents extensive systematic sensitivity analysis of the results of Essays I and II.

The extension of short-run wage rigidities is found to markedly reduce the welfare gains from multilateral liberalization under some circumstances, while extending sector-specificity of capital has a much smaller impact on welfare and adjustment effects of multilateral liberalization.

In Essay II, Whalley's (1985) model of global trade is revised with the incorporation of economies-of-scale features, in a way similar to Harris and Cox (1984). It is found that both unilateral liberalization or bilateral liberalization with the U.S. cause Canada to suffer small welfare losses. Liberalization may still be in the interest of Canada if compensation by the U.S. is possible. The contrast of these results, with those of Harris and Cox is investigated, but only part of the discrepancy is resolved. The indirect calibration procedure adopted by Harris and Cox is identified as a potential source of the discrepancy.

Extensive conditional and unconditional systematic sensitivity analysis conducted in Essay II yields the following results with regard to systematic sensitivity analysis of NGE model results:

(i) Unconditional procedures on selected elasticities yield more diffuse distributions of the results than conditional procedures on all of the elasticities.

(ii) Pagan-Shannon approximations of unconditional results are often very accurate, resource saving substitutes for the unconditional analysis.

The results of all three essays suggest a simple relationship between the elasticity configuration of the model, and the resulting welfare effects of multilateral or bilateral trade liberalization.

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INTRODUCTION AND OVERVIEW

This thesis evaluates the effects of some multilateral and bilateral trade liberalization experiments using modified versions of John Whalley's 7- and 8-bloc numerical general equilibrium models. Attention is paid to the factor reallocations and temporary unemployment effects of trade liberalization. Policymakers are interested in these short-run adjustment and unemployment effects, particularly as they compare to the corresponding welfare effects.

Essay I analyzes the effects of two multilateral tariff liberalization experiments, focussing particularly on the U.S. adjustment effects. The adjustment effects are compared to the effects of neutral technological progress estimated by using the same numerical general equilibrium model. This approach confirms the findings of Krueger (1980), that technological progress is responsible for much larger factor adjustment effects than modest changes in trade policy. It is also found that while there are substantial aggregate long-run gains to multilateral liberalization, these may be dramatically reduced in the short-run if real wage rigidities exist.

Essay II evaluates the effects of U.S.-Canada tariff abolition, using a revised version of Whalley's model of global trade. Firstly, it is found that neither unilateral nor bilateral tariff abolition with the U.S. is in Canada's interest. The contrast of these results with those of Harris and Cox is investigated in some detail, and the benchmarking procedure used by Harris and Cox is identified as a possible source of the discrepancy.

Essay III conducts systematic sensitivity analysis of the effects of liberalization discussed in Essays I and II. The intensive conditional and unconditional sensitivity analysis suggests some rules of thumb for sensitivity analysis, and allows an approximation technique due to Pagan-Shannon to be evaluated. Essay III also suggests some rules of thumb about the relationship between the size of welfare effects from liberalization and the elasticity configuration of the model.

I.1 INTRODUCTION

In some earlier work, Whalley and Wigle (21) model the adjustment to various trade policy changes in a numerical general equilibrium framework. Two alternative models of adjustment were considered, to contrast with the "long-run" assumptions incorporated into Whalley's (19) 7-bloc model of world trade. First, real wage rigidity was incorporated into the model and second, capital was modelled as being sector specific to a subset of industries. In both cases, the short-run formulations were introduced in the U.S. alone for comparison with other earlier work. It was found that the existence of these rigidities lead to smaller aggregate gains to trade liberalization than under the long-run assumptions of perfect wage flexibility and free inter-sectoral mobility of capital. It was also found that larger terms of trade effects tended to result in the short-run variants.

This essay evaluates the effects of multilateral tariff liberalization, first, using a modified version of the 7-bloc model where the rigid wage formulation is present in all blocs in the model, and subsequently using a modified version of the 7-bloc model where capital is sector-specific throughout the developed world. The extension of these short-run formulations was expected to generate a further reduction in the short-run gains to trade liberalization (or increases in the short-run losses).

This essay also generates estimates of the size of factor reallocations and unemployment costs associated with two multilateral trade liberalization experiments. Estimates of two types of unemployment costs are presented. In the case where wages are rigid, some workers may be willing to work, but unable to find work. Income losses attributable to this unemployment are calculated for the rigid wage formulation. Even if wages are flexible, it will take some time for workers laid off by a declining industry to be rehired by an expanding one. The income (or equivalently output) losses attributable to this reallocation are calculated as a reallocation cost. The size of these effects will be compared both to previous estimates of these reallocations and costs and subsequently to the effects of technological progress evaluated using the same model.

The debate over the relative size of factor reallocations from trade-related matters and ongoing domestic phenomena has been carried on largely in terms of econometric or "accounting" studies. Krueger (12) and Frank (7) come to the conclusion that technological progress and domestic demand changes are dramatically more important than import penetration as a cause of employment changes. The numerical general equilibrium context is particularly well suited to addressing a related question: "Are the 'adjustment' effects of a significant multilateral tariff reduction larger or smaller than the effects of ongoing technological progress?".

Multilateral tariff reductions generate much larger reallocation and unemployment effects than previous estimates under the rigid wage formulation. In addition, the income losses due to unemployment may be larger and more concentrated than previously estimated. In spite of this, the reallocations and unemployment effects are found to be smaller than a lower bound estimate of the effects of ongoing technological progress. In all cases, the labour reallocation effects are found to be very small. Less than 1/2 of 1% of those employed would be required to move between industries as a result of any of the experiments studied.

The extension of the rigid wage formulation does alter the short-run policy implications of some of the experiments studied, while the specific factors formulation has a very small quantitative impact in all cases.

I:2 THE ADJUSTMENT ISSUE

While it is usually agreed that long-run gains to multilateral trade liberalization exist, opposition to trade liberalization is often based on the fear that the short-run effects (displacement of workers in particular) of trade liberalization may be unacceptable. Trade liberalization would be undesirable if the short-run unemployment costs outweighed the long-run welfare gains from freer trade.

A second issue relevant to trade liberalization is the issue of compensation. Even in cases where the long-run gains to liberalization exceed the short-run costs, some groups may stand to lose from liberalization. In the event that a group stands to lose from liberalization, it may be possible to gather support for liberalization from this group by introducing a compensation scheme to offset the losses incurred.

In the United States, the Trade Adjustment Assistance (TAA) program was introduced in 1974 in an attempt to win support for the Tokyo Round of tariff cutting. Under this program, supplementary unemployment benefits, retraining grants and counselling services were made available to workers who were displaced largely as a result of the tariff cuts. Determination of worker eligibility for the program was a major problem. Since tariff rates were relatively low, and cuts were due to take place over a five to ten year period, it was rarely clear that observed employment reductions were due to new import penetration. This problem is exacerbated by interdependence in the economy, which clouds the link between a broad range of (domestic and foreign) tariff cuts and changes in domestic industry employment.

The issues of compensation and adjustment promotion are closely linked in the case of the TAA and similar Canadian programs such as the Industry and Labour Adjustment Program and the Automotive Adjustment Program. These programs provide financial compensation to those firms and workers who relocate, retrain or retool (in the case of firms) to "adjust" to liberalization. In other cases, notably the textile industry, promotion of adjustment to liberalization seems absent.

The wisdom of compensating trade affected individuals is a political rather than an economic issue. Tying compensation to effective adjustment appears to be advisable where it is feasible. The results discussed below contribute to the discussion of these issues only insofar as they suggest that compensation of the losers by the gainers from trade liberalization would be possible.

I.3 LITERATURE DISCUSSION

Particular attention is given to the adjustment issue in work by Cline et al. (6), and Baldwin, Mutti and Richardson (2) on the impacts of trade policy changes in developed countries. Both studies assume that the long-run equilibrium is attained after a transitional period. Adjustment costs are estimated using explicit measures of unemployment duration and reduced utilization rates for capital.

Baldwin et al. (2) consider a 367 sector input-output model of the U.S. Fixed coefficient intermediate production is assumed and fixed labour and capital coefficients. Final demands by the U.S. for imports and export demands by foreigners depend on the gross of tax and tariff commodity prices. A multilateral tariff reduction reduces import prices to U.S. consumers and increases import volumes both directly and indirectly through the input-output structure. Decreased tariffs abroad increase the demand for U.S. exports. No full employment condition is assumed and both labour and capital use can rise or fall in response to tariff reductions. The implicit assumption is that sufficient un- or underemployment exists so that increased factor demands can be met from previously idle supplies available. Similarly, unemployment arising from the policy change is treated as an addition to the existing pool of resources.

Baldwin et al. (2) identify those industries with contracting and expanding employment as a result of any trade policy change. They assume that expanding employment merely reduces unemployment while contracting employment adds to the level of existing unemployment. They calculate the net addition to unemployment and treat this as a once-and-for-all adjustment cost.[1] The net addition to unemployment is calculated as the sum of the net changes in employment by industry times the (sector-specific) average duration of unemployment. The average duration of unemployment varies by sector due to demographic differences in the labour force by sector. A similar treatment is adopted for capital, with the net contraction of capital assumed to be idle for 18.5 days on a once-and-for-all basis.

Baldwin et al. (2) calculate static welfare gains accruing to the U.S. from a 50% multilateral reduction in tariffs. They discount the flow of welfare gains accruing to the U.S. from a 50% multilateral reduction in tariffs using a 10% discount rate and conclude that the value of the long-term gains to the U.S. from such a policy change is approximately $1.I billion using 1967 data. Their estimated adjustment cost is $0.037 billion, substantially less than the discounted welfare gains.

Cline et al. (6) use a similar structure to that of Baldwin et al. (2) but simultaneously consider all 11 OECD countries plus the rest of the world, linked through foreign trade. Thus, rather than explicitly writing an export demand function for the U.S., export demands are generated from the import demands of the other countries in the model.

The impacts of trade policy changes are evaluated with or without consideration of exchange rate changes necessary to maintain the original trade balance in each country. The appropriateness of exchange rates in a model of this type has been questioned by Whalley and Yeung (22). They argue that the calculated "exchange rates" have little in common with financial exchange rates. As in Baldwin et al. (2), no full employment conditions exist and total factor employments change in response to trade policy changes. Although total factor income changes as a result of liberalization, this is not reflected in the welfare calculations presented by either Baldwin et al. (2) or Cline et al. (6).

Using an international price-taking formulation for each country, they evaluate the net gains to each country from participation in the proposed Tokyo Round tariff reductions. Among the cases they consider is the full U.S. tariff-cutting authority (effectively a 60% multilateral tariff cut). For this case they evaluate the long-term welfare gains and the short-run adjustment costs. They reach a similar conclusion to Baldwin et al. (2), in that the adjustment costs are small compared to the welfare gains, but the absolute measures of both gains and costs are much higher in Cline et al. (6)

In estimating adjustment costs, Cline et al. (6) consider only labour adjustment costs, and capital reallocations are ignored. Unlike Baldwin et al. (2), they do not calculate the change in unemployment. Cline et al. (6) calculate the sum of increases in employment for increasing sectors and the sum of decreases in employment for decreasing sectors and use the largest of these two as a measure of the value of labour reallocated. Since full employment is not assumed, either of these may be larger. The adjustment costs are then calculated, citing Bale's (4) estimate of a mean unemployment duration of 31 weeks for trade displaced workers under the

Kennedy Round. The combination of duration and labour reallocation (in value terms) leads to an estimate of the adjustment costs of approximately $0.61 billion, almost twenty times the cost estimate of Baldwin et al. (2).

To estimate the discounted present value of the welfare gains, they generate an annual welfare gain estimate in a similar way to Baldwin et al. (2). This estimate is then multiplied by a factor of 5 to reflect the ratio of "dynamic" to "static"[2] gains. They then discount these gains at 5% to provide an estimate of the present value of the welfare gains to the U.S. from a 60% multilateral tariff cut. Their estimate is that the U.S. would experience a welfare gain of approximately $49 billion, almost fifty times the calculation of Baldwin et al. (2).

Deardorff and Stern (3) use a multi-country model to evaluate the effects of multilateral tariff liberalization. They assume that <u>nominal</u> wages are rigid in the short-run, and calculate the change in employment resulting from liberalization. Their best guess is that the U.S. would suffer a reduction in employment of 20,400 workers as a result of a 50% multilateral tariff reduction.

Contrasting with these results, Whalley and Wigle (21) find that welfare losses accrue to the U.S. from the 50% multilateral tariff cut. The annual welfare effect is estimated to be in the range of $1.1 billion to $2.9 billion, with labour adjustment costs of an additional $.36 billion[3]. This result is true in all formations studied. The 7-bloc model is used under three alternative equilibrium assumptions:

1. Long-Run (Reallocation Cost)
2. Rigid Wage
3. Specific Factors

The long-run equilibrium solution corresponds to the usual equilibrium assumptions used by Whalley (19). All relative prices are flexible and capital is internationally immobile but mobile between industries. Adjustment costs in this case were calculated as foregone income to workers temporarily displaced as a result of trade liberalization. Employees who move between sectors are assumed to be unemployed for 31 weeks, using Bale's (4) estimate of the average duration of unemployment for U.S. trade displaced workers.[4]

TABLE 1: Welfare and Adjustment Calculations: Selected Studies of Multilateral Tariff Liberalization

Study	Annual Welfare Gain	Present Value at 5%	Adjustment Costs	Ratio of Net Welfare to Adj. Cost
Baldwin, Mutti and Richardson (1980)	.18	3.6	.07	51
Cline, Kawanabe, Kronsjo and Williams (1978)	2.80	56.0	.70	80
Whalley and Wigle (1985) (Long-Run)	-1.07	-21.4	2.20	-10

Note: All calculations are presented in Billions of 1977 U.S. $.

The welfare losses calculated for the U.S. in all three Whalley and Wigle (21) formulations reflect both deterioration in the terms of trade and changes in factor incomes resulting from liberalization. In the case of the rigid wage calculations, income losses due to unemployment are an important contributor to the calculated welfare losses. The calculations in Whalley and Wigle (21) focus on adjustment in the U.S., hence the introduction of the short-run formulations to the U.S. alone. The results of the alternative formulations mentioned above are presented in Table 2 along with some alternative calculations for both Baldwin et al. (2) and Cline et al. (6). Table 2 also presents the calculated welfare and unemployment effects of Deardorff and Stern (3) which lie between those of Baldwin et al. (2) and Cline et al. (6).

TABLE 2: Alternative Welfare and Income Loss Calculations

Study	Formulation	Annual Welfare Change	Annual Income Loss Due to Unemployment
Baldwin et al. (1980)	Treating addition to unemployment as permanent	.11	.07
Cline et al. (1978)	Treating addition to unemployment as permanent	2.10	.70
Whalley & Wigle (1985)	Rigid Wage	-2.90	1.10
	Specific Factors	-1.53	N.A.
Deardorff and Stern (1979)	Rigid Nominal Wage	1.20	.31

Note: All calculations are in Billions of 1977 U.S. $.

Whalley and Wigle (21) conclude that short-run adjustment costs may be larger than previously expected, and that the short-run gains to trade liberalization may be smaller than previously thought.[5] They also find (as in other work by Whalley) that significant factor reallocations occur between the traded and non-traded sectors.

I.4 THE MODEL

I.4.1 Thumbnail Sketch of Whalley's 7-Bloc Model of World Trade

The formulations used to model short-run responses to liberalization are introduced into Whalley's (19) model of world trade. Seven blocs are modelled, and they trade in five commodities. There is a sixth non-traded commodity. The model adopts the Armington structure, assuming that products produced in different regions are qualitatively different. The regions modelled are the E.E.C., the United States, Japan, other developed countries (O.D.), O.P.E.C., newly industrialized countries (N.I.C.) and less developed countries (L.D.C.).

The six commodities are (i) agriculture and food (Ag & Food), (ii) mining, (iii) energy, (iv) non-mechanical manufacturing (M1), (v) equipment and vehicles (M2) and (vi) services and non-traded.

The model is calibrated to a 1977 micro-consistent data set using best guess estimates of the important trade elasticities provided by Harrison (10) and estimates of the elasticities of capital-for-labour substitution estimated for some related work (see Appendix B).

Production exhibits constant returns to scale, with substitution in intermediate use and between the two non-produced factors capital (K) and labour (L). Production and utility functions are CES.

Producers in each bloc are assumed to maximize profit given producer prices of output and inputs. Consumers are assumed to maximize utility given consumer prices and incomes, the latter depending on the input prices and applicable factor taxes. The supplies of K and L available to each region are fixed.

Whalley computes a long-run equilibrium of the model in which four sets of equilibrium conditions hold:

(i) Supply equals demand for all goods.

(ii) Supply equals demand for all factors.

(iii) Excess profits are zero.

(iv) All blocs' external balances are zero.

The model is described in greater detail in Appendix A. Whalley (19) gives an extensive specification of the model.

I.4.2 Modelling of Short-Run Adjustments

The two short-run formulations analyzed here and in Whalley and Wigle (21) correspond closely to the theoretical models of Brecher (5) and Jones (11) respectively. In these models, short-run adjustment is hampered by "price" and "quantity" rigidities respectively.

Brecher (5)[6] assumes that real wages (particularly as measured by the wage/rental ratio) are downward rigid in the short-run. This rigidity may be attributable to minimum wages, unions or long-term contracts. In the presence of this "price" rigidity, changes in trade policy which would otherwise lead to reductions in the wage/rental ratio lead to endogenous unemployment.

The rigid wage solution is computed on the assumption that the real wage measured in terms of the marginal product of capital cannot fall below the value associated with the pre-policy equilibrium. If wage rigidities exist because workers attempt to maintain their earnings relative to other incomes, the choice of a downward rigid wage/rental ratio is particularly appropriate to the 7-bloc model since there are only two sources of factor income, capital and labour.

To solve for a long-run equilibrium of his world trade model, Whalley (19) searches for a set of factor prices and government-to-consumer transfers which lead to equilibrium in all factor and output markets and a balanced budget. Given the wage rate (W_i) and rental rate (R_i) paid in each region (i), and all applicable factor taxes, the producer's factor cost per unit and per unit factor requirements can be calculated. Given this plus the input-output structure, the equilibrium (zero-profit or cost-covering) prices can be computed, and thus the consumers' prices. Consumer incomes are calculated simply, given W_i, R_i and the transfer passed to consumers in each region (T_i) as:

$$Y_i = W_i L_i^O + R_i K_i^O + T_i \quad (1)$$

L_i^O and K_i^O represent the endowment of labour and capital, respectively.

The consumers maximize utility given income Y_i. This leads to final demands x_i^j for good (j) by consumer (i). Total demand for goods (and thus industry activity levels, q_i^j) can be calculated as:

$$Q = [I-A]^{-1} X \quad (2)$$

, where Q(X) is the vector of industry activity levels (final demands), I is the identity matrix and A is the intermediate requirements matrix.

The total demands for factors corresponding to a given vector (W_1, R_1, T_1, ..., W_7, R_7, T_7) can be calculated by multiplying the per unit factor requirements by all industries in region i by the industry activity levels.

$$K_i^d = \sum_{j=1}^{6} q_i^j k_i^j \qquad (3)$$

$$L_i^d = \sum_{j=1}^{6} q_i^j \ell_i^j \qquad (4)$$

, where $k_i^j(\ell_i^j)$ are the per unit requirements of capital (labour) and $K_i^d(L_i^d)$ are the total demands for capital (labour) in region i. The excess demands for K and L are written:

$$\begin{aligned} Z_i^K &= K_i^d - K_i^o \\ Z_i^L &= L_i^d - L_i^o \end{aligned} \qquad (5)$$

The final excess demand is an excess demand for transfers, and equals the excess of total government receipts of taxes and tariffs over the transfer used originally (T_i) to generate consumer income in the region.

To solve for a rigid wage equilibrium, an artificial wage variable (ϕ_i^W) replaces the wage rate on the unit simplex. This "wage" variable is interpreted differently depending on whether the "wage"/rental ratio exceeds its original value. In the case that the wage/rental ratio exceeds its original value, the same steps as before are used to evaluate the excess demands for factors. If, however, the "wage"/rental (ϕ_i^W/R_i) ratio in one bloc is less than its original value, the wage rate W_i assumed to prevail is equal to the new rental rate times the old wage/rental ratio. In this case, it is necessary to know the unemployment rate to calculate total income. This unemployment rate, u_i is determined from ϕ_i^W as follows:

$$u_i = 1 - [\frac{\phi_i^W}{R_i} (\frac{\overline{R}_i}{\overline{W}_i})] \qquad (6)$$

($\overline{W}_i$ and $\overline{R}_i$ are the original wage and rental rates.). As can be seen, if the wage rental rate is unchanged, the unemployment rate is zero.

Total income is calculated similarly to before, as:

$$Y_i = \phi_i^W L_i^O + R_i K_i^O + T_i \qquad (1')$$

If the rigid wage is binding, some unemployment is assumed in the calculation of total income, and as a result the calculation of excess demands for labour are also changed. The factor demands are calculated exactly as before, using ϕ_i^W as W_i if (ϕ_i^W/R_i) is greater than $(\overline{W}_i/\overline{R}_i)$, and using R_i times $(\overline{W}_i/\overline{R}_i)$ as W_i if not. The excess demand for labour is changed however since the excess demand for "employed labour" must now be calculated. The excess demands for factors can be written:

$$Z_L = L_i^d - L_i^O(\phi_i^W/W_i)$$

$$(5')$$

$$Z_K = K_i^d - K_i^O$$

The problem of finding an equilibrium when the rigid wage formulation binds in some blocs amounts to solving for an equilibrium level of unemployment in those blocs, given a fixed factor price. This amounts to finding a vector $(\phi_1^W, R_1, T_1, \ldots, {}_7^W, R_7, T_7)$ at which the excess demands for factors defined by (5') are zero, and the government budget balance condition is satisfied.[7] Note that the incomes generated will reflect losses due to unemployment.

Policy changes that would otherwise depress the wage/rental ratio have the effect of generating endogenous unemployment.

The specific factors formulation is similar to the Jones (11) specific capital model.[8] In the Heckscher-Ohlin model, capital is assumed to be intersectorally mobile but internationally immobile. In Jones's model, capital is assumed to be specific to its current industry of use. If a major effect of the trade policy is to reallocate factors between industries, then a major portion of the adjustment to freer trade is precluded in a specific capital model. The potential gains from increased specialization may also be reduced.

In the specific factors formulation, capital is assumed to be immobile between the primary and non-primary industries. Type 1 capital is mobile between the agriculture and food; mining and energy industries, while type 2 capital is mobile between the manufacturing industries and the service and construction industry. The specific factors formulation is solved by using an added element on the simplex to correspond to a rental rate for each new type of capital introduced.

I.5 THE EFFECTS OF MULTILATERAL TARIFF REDUCTIONS

The effects of three trade policy experiments have been evaluated using the extended short-run formulations described above. These include:

(i) a 50% multilateral tariff reduction by the developed blocs (E.E.C., U.S.A., Japan and the other developed bloc) on all of their imports.[9]

(ii) a 50% multilateral tariff reduction by all blocs on all of their imports.

(iii) neutral technological change.

Evaluation of the effects of neutral technological change was undertaken to contrast the size of these reallocation and unemployment effects with those of the multilateral liberalization experiments. Although others have repeatedly made the point that trade policy changes have a relatively small impact on unemployment and employment, the point has not been investigated in a short-run numerical model.

Real growth in national income over five years of the blocs considered was attributed to factor and product neutral technological change, where the rates of change differ by region only. The rates of growth used are presented in

Table 12 below. The five year period was chosen since multilateral tariff cuts such as those modelled here have been phased in over at least five years in the past.

I.5.1 50% Multilateral Tariff Reduction by Developed Blocs

The welfare and terms of trade effects of a 50% multilateral tariff reduction by developed countries are reported in Table 3 for the long-run equilibrium and the rigid wage formulation (in the U.S. alone). These results differ somewhat from earlier results in Whalley and Wigle (21) due to the use of revised elasticity estimates.

TABLE 3: 50% Multilateral Tariff Reduction by Developed Blocs

	Long-Run		Rigid Wage Formulation in U.S.	
	Welfare[1]	Terms of Trade[2]	Welfare	Terms of Trade
E.E.C.	-.21	-.40	-.20	-.40
U.S.	-.99	-.62	-2.54	-.61
Japan	.84	.84	.84	.77
O.Dev.	1.06	.05	1.04	.04
O.P.E.C.	.23	.04	.22	.03
N.I.C.	.50	.25	.49	.25
L.D.C.	.26	.11	.25	.11
World	1.69		.10	

[1] Reported as Hicksian EVs in billions of 1977 U.S. $.

[2] Reported as the proportionate change in the commodity terms of trade.

As with other models of this type, the long-run solution suggests that the U.S. would lose from a 50% multilateral tariff cut by the developed blocs.[10] Other models with constant returns to scale technology and endogenous relative commodity prices also generate deterioration of the U.S. terms of trade. Since tariffs are primarily on manufactures, tariff reductions lead to an improvement in the terms of trade of countries who export primarily manufactures in exchange for agricultural commodities. The same logic helps explain the deterioration of the U.S. terms of trade in both cases. Two notable differences exist between the two formulations in Table 3. First, the U.S. experiences dramatically larger welfare losses. Second, the world (sum of the EVs) experiences a dramatically reduced welfare gain.

The reduced aggregate gains and increased welfare losses by the U.S. are largely attributable to income losses from unemployment. In response to liberalization, a very small amount of unemployment would occur in the U.S. (less than one tenth of one percent) but the corresponding income loss is $1.1 billion. This accounts for most of the difference between the two columns of welfare effects.

Table 4 presents the labour adjustment figures for the long-run and rigid wage formulation (U.S. only). Most notable is the fact that such a small proportion of employment moves between sectors in any of the blocs in response to these tariff reductions. Less than 1 in 1,000 workers would be required to move between sectors. The small size of these reallocations is not so surprising given the relatively low

TABLE 4: 50% Multilateral Tariff Reduction by Developed Blocs

Labour Reallocation and Unemployment

	Long-Run	Rigid Wage (U.S. Only)	
	Labour Reallocation[1]	Labour Reallocation[1]	Unemployment[3]
E.E.C.	.10	.10	
U.S.	.08	+.07 (-.16)[2]	.09
Japan	.03	.03	
O.Dev.	.06	.06	
O.P.E.C.	.01	.01	
N.I.C.	.01	.01	
L.D.C.	.06	.06	

[1] % of employment which reallocates between sectors.

[2] For the U.S., since the rigid wage binds, employment expands in increasing sectors by .07% of total employment, while employment falls in declining industries by .16% of total employment. The difference between these numbers accounts for a $1.1 billion direct income loss due to unemployment.

[3] % of employment which become unemployed as a result of trade liberalization.

level of tariffs. In the case of the U.S., when the rigid wage formulation is present, the sum of the decreases in employment by declining industries is more than twice as large as the sum of increases in increasing industries.

I.5.1.1 Extension of Rigid Wage Formulation

Extending the rigid wage formulation to other blocs had virtually no effect on the welfare effects of a 50% multilateral tariff reduction. This unexpected result is due to the fact that the real wage rigidity does not cause significant unemployment in any other of the trading blocs. It was expected that it might bind in at least one of the other developed blocs. In fact, the rigid wage did not bind anywhere other than the U.S. ($1.1 billion income loss from unemployment). In the less developed bloc, the demand and supply of labour are equated with no unemployment at the original wage/rental rate. This highlights two features of this modelling approach. First, unemployment need not occur in all the blocs where the downward wage rigidity is present. In the simple two-by-two-by-two variant of this model with identical production technologies, we would expect one bloc to experience unemployment as a result of liberalization. Second, the effects of the binding wage rigidity are largely confined to the bloc where the rigidity binds. This is highlighted in Table 5 where alternative configurations of the rigid wage formulation were considered. This is true of both welfare effects and factor reallocation effects. The labour allocation effects for the case where the rigid wage formulation is present in all blocs are identical to column two of Table 4.

The policy implications of results from the "extended" model are identical to those of the original work. If policymakers weigh short-run concerns most heavily, and real wages are rigid, there may be little incentive to engage in multilateral cuts of the type detailed here. In the rigid wage version, there are NO gains that can be divided among

TABLE 5: 50% Multilateral Tariff Reduction by Developed Blocs

Welfare Effects[1]

	Long-Run Equilibrium	Rigid Wage Formulation in:			
		All Blocs	Developed Blocs	Developing Blocs	U.S.
E.E.C.	-.21	-.20	-.20	-.21	-.20
U.S.	-.99	-2.54	-2.54	-.99	-2.54
Japan	.84	.84	.84	.84	.84
O.Dev.	1.06	1.04	1.04	1.06	1.04
O.P.E.C.	.23	.22	.22	.23	.22
N.I.C.	.50	.49	.49	.50	.49
L.D.C.	.26	.24	.25	.26	.25
World	1.69	.10	.10	1.70	.10

[1] Welfare effects are reported as Hicksian EVs in billions of 1977 US $.

the developed countries. (The developed countries as a group experience an annual welfare loss of $860 million per year as long as the wage rigidity is present.)

Methods discussed in detail in Essay III were used to evaluate the sensitivity of the results to respecification of the model (in terms of its elasticities). The procedure, briefly, involves solving the model many times for different reasonable values of the elasticities of interest. The resulting mean is a weighted average of solutions corresponding to elasticity configurations at varying distances from the means.

The point estimate of the world annual welfare gain is very close to zero, and systematic sensitivity analysis suggests that the expected world annual welfare gain is indeed negative (although very small). Systematic sensitivity results for the welfare results are presented in Table 6.[11]

TABLE 6: 50% Multilateral Tariff Reduction by Developed Blocs

Systematic Sensitivity of Welfare Results[1,2]

	Rigid Wage Formulation in All Blocs				
	Point Estimate	Mean	Minimum Value	Maximum Value	Probability of Gain
E.E.C.	-.20	-.40	-4.12	2.68	.39
U.S.	-2.54	-2.72	-6.53	.17	.00
Japan	.85	.77	-.14	1.38	.99
O.Dev.	1.04	1.32	-2.94	6.47	.75
O.P.E.C.	.22	.16	-.33	.38	.89
N.I.C.	.43	.45	-.32	1.02	.98
L.D.C.	.24	.17	-.84	.85	.73
World	.10	-.26	-3.22	1.39	.43

[1] Results of a Pagan Shannon interpolation of a 5 value unconditional systematic sensitivity analysis on the import elasticities for the E.E.C., U.S., and O.D. bloc, and the common export price elasticity. The maximum perturbation is 1.4 standard errors.

[2] Reported as Hicksian EVs in billions of 1977 U.S. $.

I.5.1.2 Extension of Specific Factors Formulation

The effects of a 50% multilateral tariff reduction by the developed countries were evaluated using the specific factors formulation, first in the U.S. and subsequently in all of the developed blocs. The results are presented below in Table 7. The most striking observation is the small impact of introducing and extending the specific capital formulation. Extending the specific capital formulation does reduce the welfare gains from the multilateral reductions by less than $1/3 billion. The small impact of the specific

TABLE 7: 50% Multilateral Tariff Reduction by Developed Blocs

Welfare Effects[1]

	Long-Run Equilibrium	Specific Factors Formulation In U.S.	Specific Factors Formulation In All Blocs
E.E.C.	-.21	-.25	-.07
U.S.	-.99	-.96	-.94
Japan	.84	.87	.79
O.Dev.	1.06	1.08	.58
O.P.E.C.	.23	.23	.24
N.I.C.	.50	.51	.53
L.D.C.	.26	.25	.26
World	1.69	1.70	1.40
		Terms of Trade	
E.E.C.	-.40	-.43	-.38
U.S.	-.62	-.64	-.62
Japan	.84	.81	.79
O.Dev.	-.05	.05	-.05
O.P.E.C.	.04	.03	.05
N.I.C.	.25	.26	.28
L.D.C.	.11	.10	.11

[1] Welfare effects reported as Hicksian EVs in billions of 1977 U.S. $.

capital formulation is in line with earlier findings by Fullerton (8) who finds that welfare gains to corporate tax integration in the U.S. are decreased by 3% by the implementation of sector-specific capital in a dynamic sequencing framework.

The terms of trade were virtually unaffected by the extension of the specific capital formulation.

I.5.1.3 Summary

Extending the short-run formulations studied in Whalley and Wigle (21) has very little impact on the evaluation of the effects of the 50% multilateral tariff reduction by the developing countries. In the case of extending the rigid wage formulation, no unemployment is caused in other blocs. In at least this case, extension of either short-run formulation does not change the policy implications of the analysis.

I.5.2 50% Multilateral Tariff Reduction By All Blocs

The consequences of extending the rigid wage formulation are pronounced for the evaluation of a 50% multilateral tariff reduction by all blocs. In the long-run solution, all of the developed blocs gain from worldwide tariff reductions. These gains are sizable, but are partially offset by large losses in the developing world. The L.D.C. and N.I.C. blocs suffer welfare losses for two reasons. First, the developing blocs have substantially higher average tariffs so that a 50% cut implies a larger absolute cut in tariffs. Secondly, the exports of the developing blocs are relatively high in non-manufactures. As before, since tariffs are largely used against manufactures, the terms of trade effects resulting from liberalization also go against these blocs.

The welfare and terms of trade effects are unchanged by introduction of the rigid wage formulation to the U.S. alone. This occurs since the rigid wage does not bind. Extending the wage rigidity to the developed blocs (E.E.C.,

TABLE 8: 50% Multilateral Tariff Reduction by All Blocs

Welfare Effects[1]

	Long-Run Equilibrium	Rigid Wage Formulation in: All Blocs	Developed Blocs	Developing Blocs
E.E.C.	10.27	9.93	10.27	9.98
U.S.	3.39	3.19	3.39	3.25
Japan	6.11	5.92	6.05	5.97
O.Dev.	2.36	2.17	2.31	2.11
O.P.E.C.	3.00	2.40	3.00	2.90
N.I.C.	-8.29	-13.00	-8.23	-12.86
L.D.C.	-5.90	-9.21	-5.86	-9.12
World	10.94	1.40	10.90	2.20

[1] Reported as Hicksian EVs in billions of 1977 U.S. $.

U.S., Japan, and OD) leads to a trivial change in the welfare effects generated. This is due to the fact that the rigid wage binds only in Japan and there it leads to unemployment of only .01% of employment. The results change dramatically when the developing blocs are subject to the rigid wage formulation. In this event, the evaluation of the 50% global cut is dramatically altered. Total world welfare gains are reduced from almost $11 billion to less than $1.5 billion and the welfare losses accruing to the developing blocs are increased. The direct income loss attributable to unemployment in the N.I.C. bloc is almost $4 billion and this accounts for most of the increased welfare loss to that bloc. Similarly, income losses due to unemployment in the L.D.C. bloc of $3.5 billion are very close to the difference in welfare effects between the rigid wage and long-run formulation.

The terms of trade effects are not very sensitive to the labour market formulation. Terms of trade in the L.D.C. and N.I.C. blocs deteriorate, partially due to the fact that tariffs in these blocs are substantially higher than in the developed blocs.

For the purposes of analyzing the effects of a global 50% tariff reduction, the important feature is the modelling of the developing bloc labour markets. Obviously, it is only important to have the rigid wage formulation in those blocs which experience a reduction in the real wage as a result of the tariff cut. Perhaps less obviously, the effects of these rigidities are largely confined to the region where the wage binds.

A clear pattern emerges in the labour reallocation figures (Table 9). In the case of the long-run equilibrium, the amount by which employment falls in declining industries is exactly equal to the amount by which employment increases in expanding industries (.13% of the labour force for the U.S.). If the rigid wage binds, this need not be the case. In all cases where the rigid wage binds, the sum of decreases in employment in declining industries is larger under the rigid wage formulation than in the long-run equilibrium. Similarly, the sum of increases in employment in expanding industries is smaller under the rigid wage formulation than in the long-run equilibrium.

TABLE 9: 50% Multilateral Tariff Reduction by All Blocs

Labour Reallocations[1] and Unemployment Effects

	Long Run Equilibrium	Rigid Wage Formulation in All Blocs		
	Labour Reallocation	Labour Reallocation	U rate[2]	Income Loss[3]
E.E.C.	.13	.13		
U.S.	.13	.13		
Japan	.10	.10	.01%	.04
O.Dev.	.08	.08		
O.P.E.C.	.35	.35		
N.I.C.	.23	(+.05, -1.75)[4]	1.7%	3.96
L.D.C.	.23	(+.10, -.66)[4]	.6%	3.54

[1] Measured as percentage of total labour force which changes sectors as a result of trade liberalization.

[2] Ratio of unemployment to pre-policy employment.

[3] In U.S. $billion 1977

[4] In cases where the rigid wage formulation binds, the increases in employment in expanding industries will be less than the reduction in employment in declining industries. In these cases both figures are shown.

The observed pattern of labour reallocations is easily understood if we think in terms of the simple supply and demand analysis in Figure I.

If the economy-wide wage were rigid at W_0, a reduced demand in a typical contracting sector leads to reduced employment of $L_0^c - \bar{L}_1^c$, which is greater than the reduction in employment when the wage rate falls $(L_0^c - L_1^c)$. In a similar way, the increased employment in a typical expanding sector is larger $(L_1^e - L_0^e)$ when wages are downward flexible than when they are downward rigid $(\bar{L}_1^e - L_0^e)$.

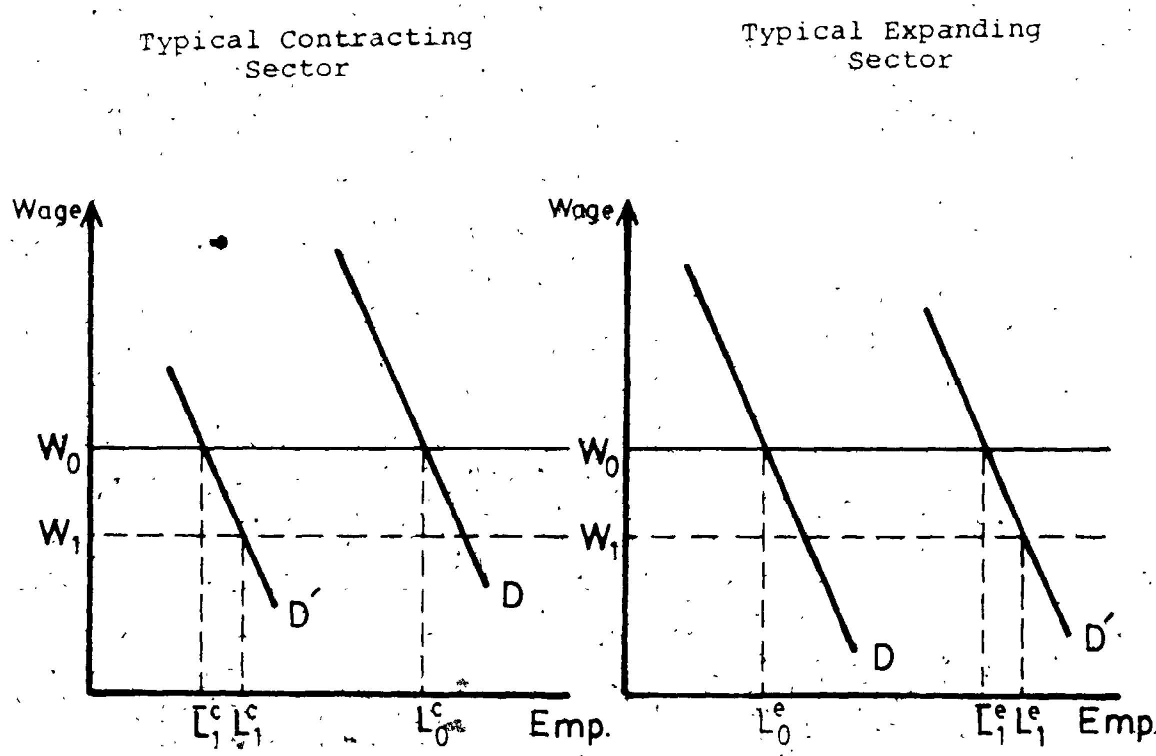

FIGURE I

Systematic sensitivity analysis of these results suggests that the qualitative story associated with extending the rigid wage formulation is not sensitive to reasonable re-specification of the elasticity structure of the model[12] (see Table 10). One point is emphasized however: the gains to the world from liberalization are dramatically reduced, to the point that the expected worldwide gain (in the short-run) is very close to zero.

TABLE 10: 50% Multilateral Tariff Reduction by All Blocs

Systematic Sensitivity Results[1,2]

Rigid Wage Formulation in All Blocs					
	Point Estimate	Mean	Minimum Value	Maximum Value	Probability of Gain
E.E.C.	9.93	9.92	3.15	16.49	1.00
U.S.	3.19	3.06	.48	5.19	1.00
Japan	5.92	5.86	4.52	6.85	1.00
O.Dev.	2.17	2.76	-3.65	10.98	.88
O.P.E.C.	2.40	2.27	1.42	2.67	1.00
N.I.C.	-13.00	-13.49	-18.54	-9.73	.00
L.D.C.	-9.21	-9.61	-15.12	-5.32	.00
World	1.40	.77	-7.79	7.17	.64

[1] Results of a Pagan Shannon interpolation of a 5-value unconditional systematic sensitivity analysis on the import elasticities for the E.E.C., U.S. and O.D. bloc, and the common export price elasticity. The maximum perturbation is 1.4 standard errors.

[2] Welfare reported as Hicksian EVs in billions of 1977 U.S. $.

I.5.2.1 Extension of Specific Factors Formulation

The effects of a 50% multilateral tariff reduction by all blocs was also evaluated using the specific factors formulation in the U.S. alone and subsequently in all of the developed blocs. These results appear in Table 11. As in the case of the multilateral tariff reduction by the developed blocs, the effects of the specific capital formulation are small on both welfare effects and the terms of trade.[13] Once again, this result suggests that the specific factors formulation has limited impact on the evaluation of trade policy experiments.

TABLE 11: 50% Multilateral Tariff Reduction by All Blocs

Welfare Effects[1]

	Long-Run Equilibrium	Specific Factors Formulation In U.S.	In All Developed Blocs
E.E.C.	10.27	10.26	9.96
U.S.	3.39	2.87	3.10
Japan	6.11	6.15	5.59
O.Dev.	2.36	2.45	2.48
O.P.E.C.	3.00	3.00	2.96
N.I.C.	-8.29	-8.33	-8.26
L.D.C.	-5.90	-5.94	-5.86
World	10.94	10.60	10.00
		Terms of Trade	
E.E.C.	5.33	5.39	5.38
U.S.	2.45	2.32	2.45
Japan	8.43	8.51	8.24
O.Dev.	2.78	2.86	2.95
O.P.E.C.	2.00	1.99	2.01
N.I.C.	-10.08	-10.13	-10.07
L.D.C.	-9.88	-9.90	-9.86

[1] Reported as Hicksian EVs in billions of 1977 U.S. $.

I.5.3 Technological Change

In an attempt to address the issue of the relative importance of trade policy and non-trade policy influences on labour reallocations and adjustment costs, factor reallocations from the two multilateral experiments described above were compared to a hypothetical example of technological change.

The technological change experiment evaluated is five years of neutral technological progress. It is assumed that all of the real growth observed in the blocs in the model was attributable to neutral technological change in all of the "value added" functions. A five-year period was used since significant tariff reductions like those analyzed above have been staged in over (at least) five years under G.A.T.T. arrangements. Using neutral technological change will also tend to understate the size of resulting inter-sectoral re-allocations particularly if actual rates of technological change differ by sector.

TABLE 12: Five-Year Real Growth Rates

E.E.C.	1.43
U.S.	1.20
Japan	1.48
O.Dev.	1.11
O.P.E.C.	1.58
N.I.C.	1.66
L.D.C.	1.63

Note: Real growth rates of GDP over the period 1975 to 1980 were calculated from U.N. data (18).

The labour reallocations associated with this technological improvement are compared to those from the trade policy experiments in Tables 13 and 14. The long-run allocations from the technological change are all quite small in absolute terms (less than 1/2 of 1% of those employed are required to move between industries). This is not surprising given the neutrality of technological change. There is neither factor bias nor product bias in the technological change. Factor reallocations result indirectly from higher incomes and associated growth of trade. Due to the differential in growth rates, terms of trade are also affected.[14]

TABLE 13: Long-Run Labour Reallocations[1]

	50% Multilateral Reduction by Developed Blocs	50% Multilateral Reduction by All Blocs	Five Years Neutral Technological Improvement
E.E.C.	.10	.13	.18
U.S.	.08	.13	.18
Japan	.03	.10	.08
O.Dev.	.06	.08	.43
O.P.E.C.	.01	.35	.39
N.I.C.	.01	.23	.26
L.D.C.	.06	.23	.15

[1] Percentage of employed required to move between industries as a result of the experiment considered.

TABLE 14: Comparison of Reallocation and Unemployment Effects (Rigid Wage Formulation in All Blocs)

Reallocation Effects[1]

	50% Multilateral Reduction by Developed Blocs	50% Multilateral Reduction by All Blocs	5 Years Neutral Technological Improvement
E.E.C.	.10	.13	.18
U.S.	(+.07, -.16)[2]	.13	(+.05, -.55)[2]
Japan	.03	.10	.08
O.Dev.	.06	.08	.43
O.P.E.C.	.01	.35	(+.31, -.54)[2]
N.I.C.	.01	(+.05, -1.75)[2]	(+.21, -.35)[2]
L.D.C.	.06	(+.10, -.66)[2]	(+.10, -.54)[2]

[1] Proportion of those employed who move between industries as a result of the experiment.

[2] In cases where the rigid wage binds the + number is the increase in employment (as a proportion of total employment) in expanding sectors, while the - number is the decrease in employment (as a percentage of total employment) released by declining sectors.

TABLE 14 (cont'd)

Annual Income Loss Due to Unemployment
(in Billions of 1977 $U.S.)

	50% Multilateral Reduction by Developed Blocs	50% Multilateral Reduction by All Blocs	5 Years Neutral Technological Improvement
E.E.C.	0.00	0.00	0.00
U.S.	1.15	0.00	6.50
Japan	0.00	0.04	0.00
O.Dev.	0.00	0.00	0.00
O.P.E.C.	0.00	0.00	0.17
N.I.C.	0.00	3.96	0.29
L.D.C.	0.00	3.54	2.81
Total	1.15	7.54	9.77

The short-run reallocations offer a more complex comparison, but the reallocation effects of the neutral technological change are with rare exception larger than either of the trade experiments considered. The total income loss due to unemployment caused by the technological change is also larger than those associated with the trade policy experiments.

These estimated effects do give support for the contention of Krueger (12) and Frank (7) that trade related issues have relatively small impact on factor reallocations in particular. At the same time, the "losers" (from an unemployment point of view) from trade liberalization may face larger losses from the trade policy experiments than the technological change. This is the case for the L.D.C. and N.I.C. blocs which suffer substantial income losses from unemployment as a result of the global tariff reduction.

I.6 SUMMARY AND CONCLUSIONS

This essay has extended two alternative short-run formulations in Whalley's 7-bloc model of world trade. The original long-run equilibrium corresponds to a flexible price equilibrium where all of the factor and product markets clear. The rigid wage formulation is a short-run equilibrium concept reflecting the short-run rigidity in a relative price (here the wage/rental rate). The specific factors formulation assumes that capital is not perfectly mobile between industries. These are findings relevant to both trade policy issues and methodological questions in numerical general equilibrium analysis.

The extension of the rigid wage formulation may suggest an altered policy perspective on multilateral tariff reductions. In the particular case of the multilateral tariff reduction by all blocs, extension of the rigid wage formulation virtually eliminates the short-run aggregate welfare gains from multilateral liberalization. In this example, the welfare losses of the developing blocs are dramatically increased by income losses due to unemployment. Of further interest is the fact that the unemployment effects tend to be concentrated in those countries who suffer the largest welfare losses even in the absence of rigid wages. The effect of the wage rigidity tends to be to concentrate the short-run losses more heavily. This is true in both of the tariff reduction cases studied.

This evidence gives some insight into the reluctance of some countries to liberalize. Although manufacturing is relatively labour intensive in the developed world, it is relatively capital intensive in the L.D.C. bloc. The relative price effects generated by tariff liberalization thus act to depress the long-run equilibrium wage/rental ratio, particularly in the L.D.C. bloc. If the wage/rental ratio is indeed rigid, the unemployment generated by global tariff liberalization would be concentrated in the developing world.

The reallocation effects of multilateral tariff reductions were subsequently compared to the reallocations from neutral technological change. The technological change experiment was chosen to generate a lower bound on the reallocations resulting from the amount of technological change likely to occur over five years. Substantial tariff reductions of the type discussed above have been staged in over periods of at least five years in previous G.A.T.T. rounds. The results indicate that these "lower bound" estimates of the unemployment and labour reallocation effects are (with few exceptions) substantially larger than the effects of either of the trade policy experiments.

While the reallocation effects presented here are larger than any of those surveyed earlier, it remains that in absolute size they are indeed very small. When it is appreciated that these reallocations would not likely occur over one year, but rather over five or more years, the absolute size of annual reallocations between industries becomes even smaller.

The exploration of these alternative formulations generates some useful insight into the modelling of short-run adjustment issues. Firstly, the results presented here suggest that treating capital as homogeneous is, for the purpose of evaluating terms of trade, welfare and adjustment effects, a useful simplification. This finding reinforces Fullerton's (8) findings of "small" impacts of going to sector-specific modelling of capital. The impact of the specific factors formulation is likely smaller than the rigid wage formulation because factors are not idle (as with the rigid wage formulation) but rather are merely unable to be "optimally" reallocated.

Finally, while the rigid wage formulation often generates large unemployment effects, the effects of the rigid wage formulation are largely confined to the bloc(s) where the rigid wage binds. As a result, if the focus of interest is one particular bloc, implementation of the rigid wage formulation in that bloc alone will generate a useful approximation of the effects on that bloc when the rigid wage formulation is in effect in all blocs.

In spite of the fact that "larger" short-run adjustment costs are found to be associated with multilateral tariff reductions, it still remains that these increased costs (or reduced short-term gains) are not sufficient to outweigh the aggregate gains from trade liberalization on a continuing basis. This is due to the fact that the "costs" associated with adjustment (temporary or "frictional" unemployment) are once-and-for-all costs while the benefits (once the adjustments have taken place) carry on as long as the liberalization remains in effect. Placing this horizon at even five years leads to substantial aggregate gains from either of the liberalization experiments considered here.

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APPENDIX A

Brief Overview of Whalley's 7-Bloc Model of World Trade[1]

The general equilibrium model incorporates seven trading blocs reflecting major participants in world trade; the (nine-member) EEC, the U.S., Japan, Other Developed Countries (including U.S.S.R. and Eastern Europe), OPEC, Newly Industrialized Countries (NICs), and Less Developed Countries (LDCs).

Six products produced in each bloc are considered and listed in Table A.1. Each of the first five goods are internationally traded with an assumed heterogeneity by trading area prevailing across production sources. The sixth commodity is non-traded for all blocs. The same

TABLE A.1: Product Classification Used in the Model

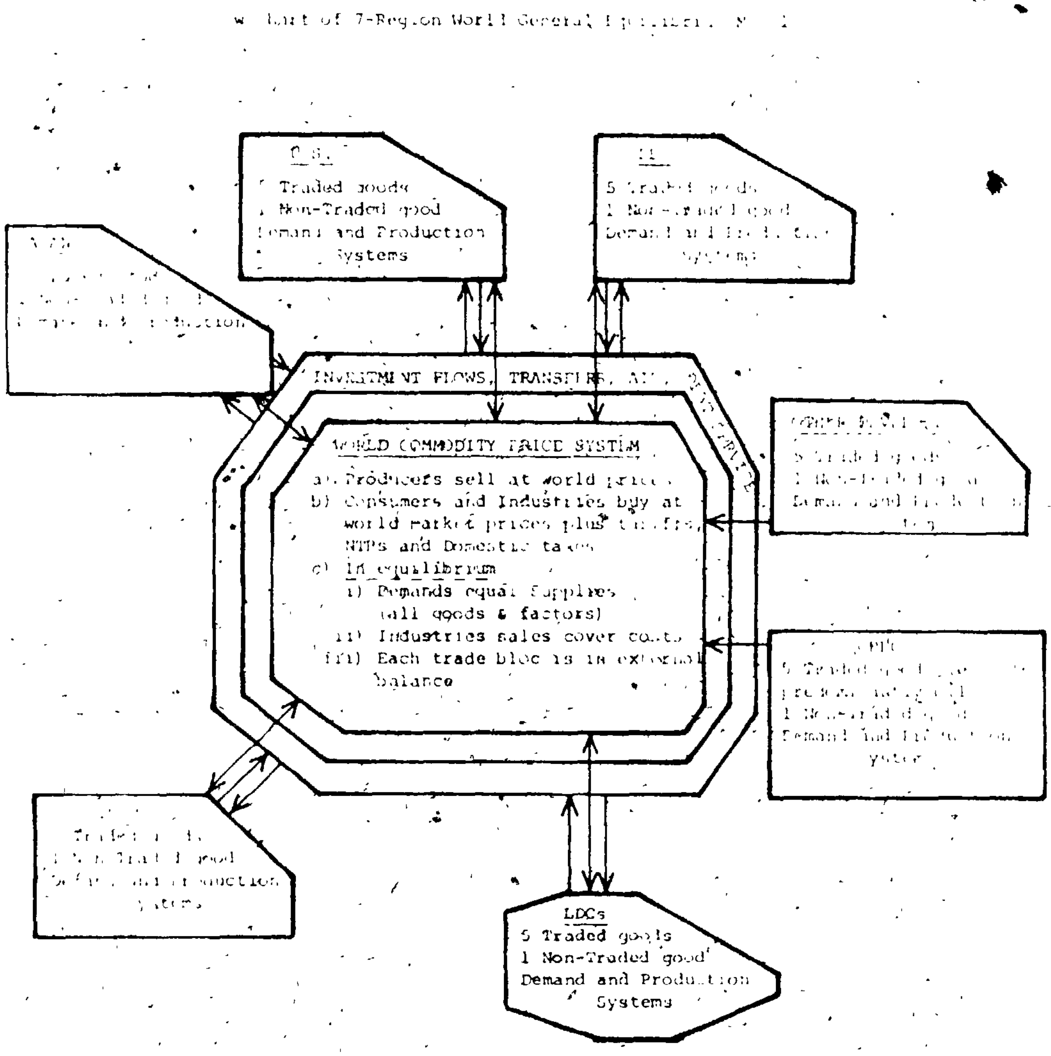
	SITC Headings
1. Agriculture and Food	0 + 1
2. Mineral Products and Extractive Ores	2 + 4
3. Energy Products (including oil)	3
4. Non-Mechanical Manufacturing	5,6,8,9
5. Machinery and Transport Equipment (including Vehicles)	7
6. Construction, Services, and Other Non-Traded	None

commodity classification is used for trade, domestic production, and final demand data, with an approximate concordance used between different classification systems in basic data. Problems of data availability for all blocs on this classification plus the larger dimensionalities involved in solution for a multi-trading bloc formulation have limited the model to six products and seven blocs: 42 products in total.

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

A schematic flow chart depicting the model is given in Figure A.1. Production and demand patterns in each of the trading blocs revolve around the domestic and world price systems. Explicit demand functions are used which are derived from hierarchical CES/LES preference functions,

FIGURE A.1


U.S.
Traded goods
1 Non-Traded good
Demand and Production
Systems
INVESTMENT FLOWS, TRANSFERS, AID
WORLD COMMODITY PRICE SYSTEM
a) Producers sell at world prices
b) Consumers and Industries buy at
world market prices plus tariffs,
NTPs and Domestic taxes
c) In equilibrium
i) Demands equal Supplies
(all goods & factors)
ii) Industries sales cover costs
iii) Each trade bloc is in external
balance
LDCs
5 Traded goods
1 Non-Traded good
Demand and Production
Systems

and CES functions characterize production sets. Producers maximize profits and competitive forces operate such that in equilibrium all supernormal profits are competed away.

TABLE A.2: 7-Bloc Model Data

	Proportion of Exports Which Are Primary	Value Added by Labour	Value Added by Capital
E.E.C.	13%	834	584
U.S.	28%	1298	336
Japan	3%	405	262
O.Dev.	39%	1394	450
O.P.E.C.	99%	79	145
N.I.C.	42%	233	170
L.D.C.	50%	629	97

For each product, the market price in the model is the price at point of production. Sellers receive these prices, purchasers (of both intermediate and final products) pay these prices gross of tariffs, NTB tariff equivalents, and domestic taxes; no transportation costs are considered. Investment flows, interest and dividends, and foreign aid enter the world market system with the second two of these being treated as income transfers. Foreign investment is treated as purchases of capital goods by agents located in the country of source of capital funds. The difference between investment flows and merchandise trade is that the capital goods acquired are not repatriated to the country of location of the purchaser, but remain in the source country to generate income in future time periods.

An equilibrium in the model is a situation where demands equal supplies for all products and in each industry a zero-profit condition is satisfied representing the absence of supernormal profits. In equilibrium, a zero foreign external sector balance condition (including investment flows, dividends, interest and transfers) applies for each country.

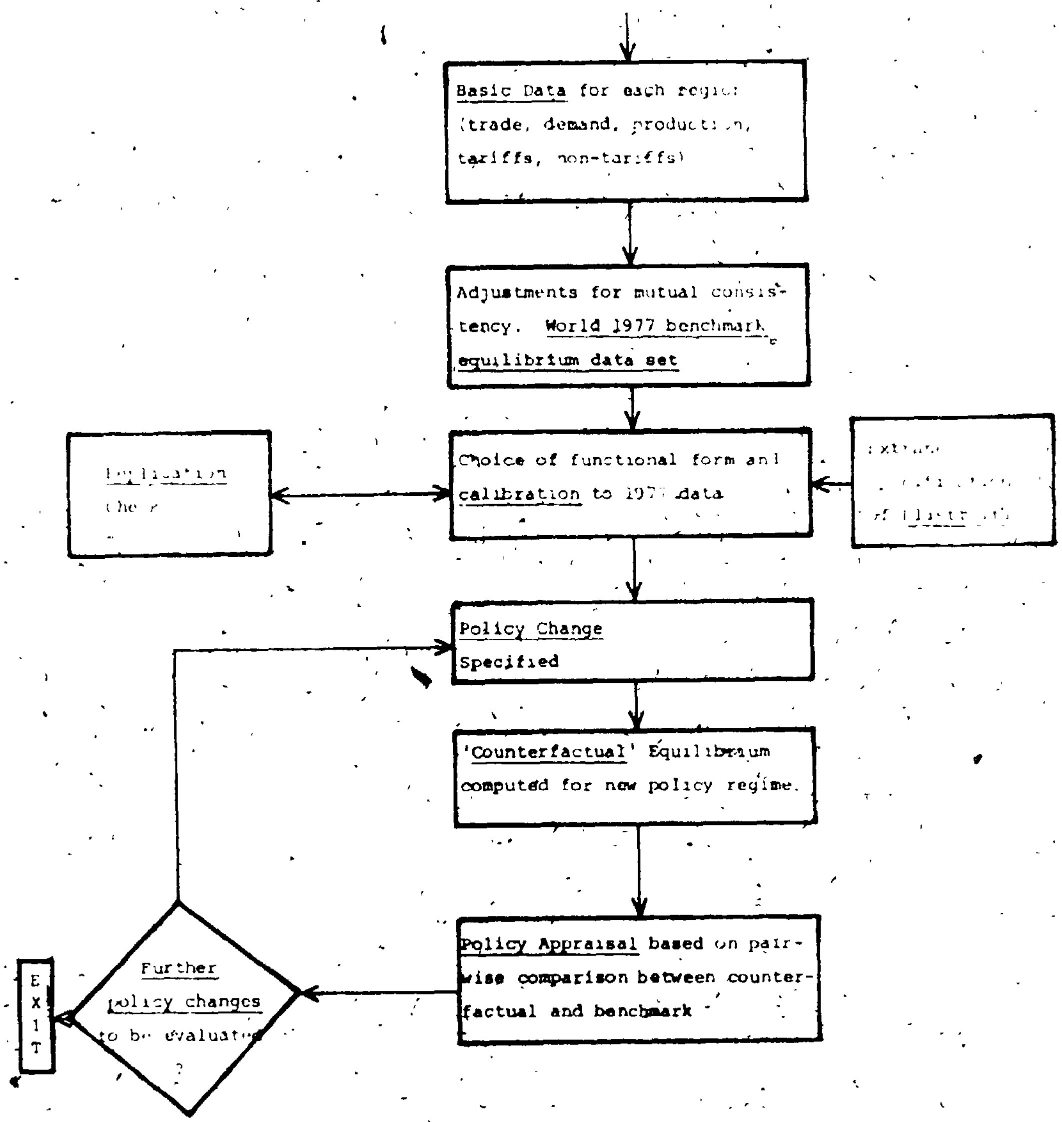
The model uses hierarchical CES/LES functions on both the production and demand sides of the model. The elasticities of substitution in these functions are the parameters which determine price elasticities in goods and factor demand functions. Because of the Armington product heterogeneity assumption, these elasticities also control import and export demand elasticities for any trading area.

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

The general equilibrium model is used for counterfactual equilibrium analysis following the procedures which have

FIGURE A.2

Model Flow Chart of Applied General Equilibrium Analysis Procedure in Using World Trade General Equilibrium Model



become widespread in recent applied tax and trade general equilibrium models. A flow chart outlining the procedure is given in Figure A.2. A worldwide general equilibrium constructed from 1977 data is assumed to hold in the presence of existing trade policies. The model is calibrated to the data set through a sequence of procedures which determine parameter values for the model functions consistent with the equilibrium restriction. Counterfactual analysis then proceeds for any specified policy change with a comparison between equilibria leading to the policy appraisal.

The calibration procedure involves first constructing a data set for a given year in a form which is consistent with the equilibrium solution concept of the model; a so-called benchmark equilibrium data set. Once assembled, parameter values for equations can be directly calculated from the equilibrium conditions using the calibration procedure described in Mansur and Whalley (13). The model specification is then capable of reproducing the benchmark data as an equilibrium solution to the model, and comparative statics can be performed with the model by computing new equilibria for alternative policy regimes and comparing new and benchmark equilibrium data. The benchmark equilibrium data set constructed for this purpose has the properties of a worldwide competitive equilibrium in that demands equal supplies for all products, no profits are made in any of the domestic industries, and each region is in zero external sector balance.

Once specified, the model is solved for a new general equilibrium for a policy or other change using a Newton method involving an estimate of the Jacobian matrix of excess factor demands and government budget imbalances. In using this approach to evaluate the effects of alternative model variants on the evaluation of trade policy changes, the benchmark equilibrium remains the same in all cases. For any given policy change, a full equilibrium is computed along with an equilibrium with the wage rate downward rigid at its value in the benchmark equilibrium, and an equilibrium with capital reallocation from the benchmark equilibrium values constrained. In each case, a pairwise comparison is made between the benchmark and counterfactual equilibria to provide the evaluation of the policy change; all evaluations are thus with respect to the same initial starting point.

APPENDIX B

TABLE B.1 Elasticity Values and Standard Errors Used

Elasticity	HWPE	Standard Error	JWPE
SIG(EC)	1.109	.3504	0.90
SIG(US)	1.413	.3412	1.66
SIG(J)	1.024	.3216	.78
SIG(OD)	.962	.4818	1.02
SIG(OPEC)	.897	.3833	.89
SIG(NIC)	1.365	.7892	1.38
SIG(LDC)	1.471	.7176	1.28
SIGI	1.082	.3256	1.50
SUB(1)	.945	.041	.693
SUB(2)	.426	.105	.800
SUB(3)	.293	.102	.800
SUB(4)	.939	.108	.879
SUB(5)	1.118	.075	.726
SUB(6)	1.988	.477	.990

ENDNOTES

1. This treatment is adopted even though the net addition to existing unemployment is calculated. Since an equilibrium in the presence of "equilibrium" unemployment is assumed, it would seem that a justification exists for treating these costs as a recurring cost (or benefit if unemployment fell), rather than a once and for all effect.

2. This factor of 5 is attributed to Balassa. Dynamic gains are gains due to increased competition and economies of scale which are not included in the static calculations. Balassa (1, p. 122) discusses dynamic effects, but does not mention a specific ratio.

3. Recomputed estimates of the welfare losses ($1.0 to $2.45 billion) and the adjustment costs ($1.2 billion) have been computed to correspond to the new trade elasticity estimates in Harrison (10) and new elasticities of substitution estimated in some related work.

4. See Bale (4).

5. In the case of the rigid wage formulation, world welfare falls in the short-run as a result of multilateral liberalization.

6. See also Neary (16, 17).

7. An unfortunate consequence of this is that the excess demand correspondences (for the rigid wage formulation) have a kink at the original wage/rental rate. The model is solved using a Newton algorithm which was unsuccessful at finding a solution when using Jacobian matrices generated from the rigid wage excess demands. It was possible to solve the model using a Jacobian matrix generated from the same model without the rigid wage formulation in place.

8. See also Mayer (14), Neary (15).

9. This includes imports from the developing and less developed blocs, in line with the generalized system of preferences.

10. Harrison (10) and Whalley and Wigle (20) both find that significant multilateral tariff reductions lead to welfare losses.

11. The methodology used is presented in detail in Essay III.

12. The methodology used is presented in detail in Essay III.

13. The specific factors specification was applied to the NIC and LDC blocs, with minute effects on the results. For this reason, extending the factor specificity to all blocs simultaneously was not pursued.

14. The small differences lead to sizable changes in the terms of trade. For comparison, doubling the efficiency parameters in all of the value added functions causes no change in the terms of trade.

Appendix

1. For further details see Whalley (10).

II.1 INTRODUCTION AND OVERVIEW

This essay reports the estimated effects of trade liberalization using a model incorporating economies of scale and industrial organization features in a way similar to Harris and Cox (6,12,13). The model is based on Whalley's (26) 8-bloc model of global trade.

The analysis concentrates on two proposals. The first, bilateral tariff abolition (BTA) involves the bilateral elimination of all tariffs by Canada and the U.S. This policy is evaluated because of its relevance to the current policy debate in Canada over freer trade. While the model used is similar in flavour to Harris and Cox, the results of BTA contrast with those of Harris and Cox, since bilateral tariff abolition leads to small welfare <u>losses</u> by Canada. Harris and Cox find that substantial Canadian welfare gains result from a proposal they refer to as multilateral free trade (MFT). This proposal involves the elimination by Canada of all trade barriers, while the rest of the world abolishes tariffs on Canadian imports only. The contrast in results of these similar policies, using similar models is examined in detail in section II.7 of the thesis.

Evaluating the effects of MFT with the revised Whalley model leads to dramatically smaller welfare gains for Canada than those found by Harris and Cox. The source of this discrepancy is discussed in section II.7 of the thesis. Differences in the trade elasticities used and the capital mobility assumptions are found to account for some of the difference in welfare effect. The indirect calibration procedure used by Harris and Cox is also identified as a possible source of the discrepancy.

The indirect calibration procedure adopted by Harris and Cox involves calculating a long-run equilibrium (or benchmark) data set from the observed base data set, before counterfactual experiments are conducted. In the process, substantial entry occurs, so that the benchmark data has many more firms than the base data. If some of these additional firms[1] are eliminated from the economy as a result of liberalization, they could account for part of the discrepancy in welfare results.

While the results presented here are different from those reported by Harris and Cox, the results still provide evidence in support of bilateral or multilateral liberalization by Canada. While small welfare losses may accrue to Canada as a result of BTA, it is always easy for the U.S. to compensate Canada for the small losses suffered.

II.2 LIBERALIZATION ISSUES IN CANADA

Over the last 20 years, Canada has pursued trade liberalization in both the multilateral forum, through the G.A.T.T. and on a bilateral basis with our largest trading partner (the U.S.). In recent months, particular interest has focussed on the potential for a bilateral trade agreement with the U.S. Recent work by Harris and Cox (6,12,13) provides evidence which supports Canadian trade liberalization, suggesting that substantial gains would accrue to Canada from either unilateral <u>or</u> multilateral trade liberalization. This section discusses some of the issues relevant to the Canadian free trade debate, with special attention given to the "Eastman-Stykolt" (E-S) hypothesis.[2]

The E-S hypothesis argues that Canadian manufacturing industries are inefficient due, in part, to the small size of the Canadian market relative to the minimum efficient scale (MES) of plant. Canadian tariffs exacerbate this problem by restricting access of more efficient foreign producers (in the U.S. in particular), who would otherwise challenge domestic producers. Foreign (especially U.S.) tariffs on Canadian exports serve to further reduce the available market for Canadian manufactures.

Two examples cited by E-S to illustrate the effects of high tariffs are the auto industry and the appliance industry. In both cases, high tariffs lead to small plants producing short production runs of a wide variety of similar products. Canadian tariffs on appliances were above 22%, while U.S. tariffs were between 10% and 17% in 1961. Tariffs on autos and vehicles in Canada were between 10% and 15%, with the U.S. tariffs between 5% and 13%.[3] As well as leading to short (and inefficient) production runs, the tariffs were also associated with inefficient management and organization (7, p. 106).

While this argument would suggest that greater gains could accrue to Canada from multilateral liberalization (since the available market could be increased to a maximum in this way), the attention to bilateral initiatives in Canada is natural. In both of the cases cited above, foreign (U.S.) ownership of the Canadian industries exceeded 60%, so that potential gains to liberalization existed for both U.S. firms, and Canadian consumers. As well, Canada-U.S. trade accounts for over half of Canada's trade.

The Canada-U.S. Auto Pact of 1965 lead to virtually free trade in autos and parts between Canada and the U.S. The rationalization effects hypothesized by E-S did occur, with each Canadian auto plant converted from the production of several varieties of cars (and trucks) to the production of one model. Trade in parts and autos rose dramatically as a result of the Auto Pact.

The E-S hypothesis also suggests that unilateral trade liberalization could be beneficial for Canada. Unilateral liberalization is usually accompanied by losses for the liberalizing country attributable to deterioration in the terms of trade.[4] Unilateral trade liberalization could generate sufficient rationalization gains to more than offset the terms-of-trade losses.

Another corollary of the hypothesis is that the factor reallocations occasioned by movements to freer trade would be largely intra-industry in nature, as manufacturers produce longer runs of a smaller selection of the goods currently produced in Canada. These reallocations contrast with those implied by factor-endowment considerations. Since Canada is resource rich, factor-endowment considerations would suggest that freer trade would bring about expansion of the primary sectors at the expense of the manufacturing industries.

If the pattern of adjustment to freer trade were indeed primarily intra-industry in nature, the associated costs of adjustment would be smaller than if equal inter-industry adjustments were necessary. Less retraining costs would be required and more machinery and equipment could be shifted from declining to expanding firms. It is also likely that less relocating costs would be incurred since manufacturing employment is concentrated in central Canada, while primary employment is in the West and the Atlantic provinces.

The possibility that industrial rationalization would be a major element of adjustment to trade liberalization changes the policy perspective on liberalization for two reasons. First, the adjustment costs are likely to be smaller, and second, the employment shifts are less likely to be regionally sensitive.

While the E-S hypothesis and its corollaries represent strong arguments in favour of liberalization from 1960s levels of protection, it is less clear that they are as quantitatively important today. Trade in vehicles and parts between Canada and the U.S. is virtually free of barriers and accounts for more than one third of Canada-U.S. trade in manufactures. Average tariffs on Canadian imports from the U.S. will be below 5% by the end of 1987.

The fact that current U.S.-Canada tariffs are so low makes the substantial gains reported by Harris and Cox surprising. They report welfare gains to Canada of 8.6% and 4.1% of GNP respectively (from 1976 levels of protection), as a result of multilateral and unilateral trade liberalization, respectively.

While substantial agreement appears to exist that bilateral liberalization with the U.S. would be beneficial for Canada, substantially less agreement emerges on the benefits to be derived from unilateral liberalization. Section II.3 reviews some of the models used to evaluate the quantitative effects of Canadian trade liberalization, and compares their results.

II.3 REVIEW OF NUMERICAL STUDIES OF CANADIAN TRADE LIBERALIZATION

Many studies exist which analyse the effects of bilateral (Canada-U.S.) or multilateral trade liberalization. These studies analyse different precise experiments, but all come to the conclusion that bilateral or multilateral liberalization is in Canada's interest. As will be seen, the size of the estimated welfare gain varies dramatically. Studies of unilateral trade liberalization are also analysed, and less agreement is seen to emerge from these. Recent studies by Williams (27) and Harris and Cox (6,12,13) have been the focus of current attention due to renewed interest in Canada-U.S. free trade. These studies will be considered in somewhat greater detail.

II.3.1 Studies of Bilateral or Multilateral Free Trade

II.3.1.1 Williams (1978)

Williams uses a linear programming model of Canada to analyse the effects of bilateral tariff abolition (accompanied by domestic commodity tax abolition).[5] Canada is assumed to face fixed U.S. terms of trade. There are 63 produced commodities which are either for export (E), import-competing (M), or for domestic consumption (D). There are 41 "resources" which are assumed to be in fixed supply. These resources include agricultural products, minerals, and labour. As a result, Williams's model precludes reallocations between the primary and manufacturing sectors. Firms are assumed to be perfect competitors which face constant costs, and industry output is constrained to change no more than 10%. As a result of the assumption of constant costs and perfect competition there are no "rationalization" gains as a result of liberalization. Williams's data is for 1961. Williams estimates that gains of almost $2 billion (1976) would accrue to Canada from bilateral tariff abolition combined with the removal of all commodity taxes. The calculated welfare gains of less than 4% of GNP are then adjusted to 10% of GNP to account for increasing returns to scale. This brings Williams's estimates very close to the figure suggested by Wonnacott and Wonnacott (28). Since the U.S. is not explicitly modelled it is impossible to calculate the welfare effects for the U.S. Williams estimates further that manufacturing employment would increase by a small amount while service sector employment would decline.[6]

II.3.1.2 Harris and Cox (1984)

The Harris and Cox (H-C) model is made up of 20 manufacturing industries and 9 non-manufacturing industries.

The non-manufacturing sectors have constant returns to scale, while the manufacturing sectors have fixed factor requirements per firm, with constant returns to variable factors. Decreasing average costs result from the existence of fixed costs, so that price-taking behaviour is no longer consistent with equilibrium. Instead, manufacturing firms are assumed to set prices in an effort to maximize profits.

Firms in the manufacturing sectors are assumed to follow one of two pricing schemes. Firms may collude up to the duty-paid consumers price for the imported product (E-S pricing) or they may set the profit maximizing price given a perceived elasticity of demand (monopolistic pricing). The H-C model thus allows for rationalization to occur as a result of free trade. Entry and exit of firms is allowed in response to policy changes. Since a similar market formulation to that of H-C is adopted below, more detailed discussion of the pricing mechanism is left to section II.4.

Canada is modelled as a small, open economy in two respects. First, Canada faces a fixed (U.S.) rental rate for capital, which is freely mobile between Canada and the rest of the world. Canada also faces fixed (U.S.) border prices for imports.

H-C first assemble a "base" data set for 1976,[7] which is assumed to be a short-run equilibrium in which excess profits exist in some sectors. A "benchmark" data set is then produced by allowing free entry and exit to remove any economic profits. H-C then use this benchmark data set as the starting point to estimate the long-run effects of the abolition of all protection (including tariff equivalents of non-tariff barriers) between Canada and all trading partners on a multilateral basis.

The benchmark data is similar to the base data as regards aggregate variables such as the wage and capital bill, and national income, but the benchmark data has 55% more firms in the manufacturing sectors, though manufacturing output falls slightly. In 11 of 20 of the manufacturing sectors, entry occurs but industry output falls. The ratio of fixed to variable factors in the benchmark data is much higher than in the base data. Further, average markup rates on marginal cost are in the order of 18% as opposed to less than 5% for the base data.

The estimated welfare gains to Canada from multilateral free trade are estimated to be large, ($13 billion in 1976 $) as are the estimated factor reallocations. Their suggested welfare gain of approximately 8.6% of GNP is again similar to the welfare gain estimated by the Wonnacotts (28). It must be remembered that the experiments considered are quite different. Wonnacott and Wonnacott consider bilateral tariff abolition with the U.S. from pre-Kennedy Round levels, while Harris and Cox consider a multilateral elimination of all trade barriers at 1976 levels.

TABLE 1: Labour Reallocations From Free Trade Experiments
Proportionate Changes in Employment by Industry

Industry	Category	Williams	Harris & Cox
Food and Beverage	Manuf.	-.2	-5.4
Tobacco	Manuf.	.0	-13.7
Rubber and Plastic	Manuf.	10.0	12.7
Leather	Manuf.	-9.8	-36.0
Textiles	Manuf.	.6	49.3
Knitting Mills	Manuf.	-9.4	-24.8
Clothing	Manuf.	-10.0	3.8
Wood	Manuf.	.0	-9.3
Furniture and Fixtures	Manuf.	-10.0	-39.1
Paper and Allied	Manuf.	.1	62.8
Printing and Publishing	Manuf.	10.0	11.4
Primary Metals	Manuf.	0.0	12.8
Metal Fabricating	Manuf.	1.4	-2.6
Machinery	Manuf.	-10.0	-25.4
Transportation Equip.	Manuf.	10.0	76.3
Electrical Equip.	Manuf.	8.3	-19.9
Non Metallic Mineral	Manuf.	-.4	4.1
Petroleum and Coal	Manuf.	.0	-.8
Chemical	Manuf.	-3.9	6.2
Misc. Manufacturing	Manuf.	5.7	-30.5
Agriculture	Primary	0.0	33.9
Forestry	Primary	0.0	20.4
Fishing	Primary	0.0	15.4
Mining	Primary	0.0	10.5
Construction	Non-traded	-.0	-8.7
Transportation	Non-traded	-.3	-8.4
Communications	Non-traded	-.0	-6.8
Electric Power & Gas	Non-traded	.0	-.3
Services	Non-traded	-.0	5.7

Notes:

(i) Williams analyses the effect of bilateral tariff abolition between Canada and the U.S. plus commodity tax abolition.

(ii) Harris and Cox report the effects of multilateral abolition of all protection on Canadian trade.

II.3.1.2 Comparison of Labour Reallocations

For the purpose of comparison, the reallocations of Williams were aggregated to the H-C level of aggregation (29 sectors). Labour reallocations resulting from the liberalization experiments are summarized in Tables 1 and 2. The patterns of labour reallocation are only similar to the extent that intra-industry reallocations within manufacturing are a large part of total reallocations. This is particularly true of Williams's results, which show more than $700 million worth of labour reallocated between sectors, but an increase of manufacturing employment of only $87 million. The manufacturing sectors grow in both cases.

H-C emphasize the importance of rationalization gains to their results as production runs grow in response to free trade. As suggested by the E-S hypothesis, free trade does lead to dramatic increases in the efficiency of the manufacturing sector.

Harris and Cox also come to the conclusion that large capital <u>inflows</u> are likely to result from multilateral free trade due primarily to the increased productivity of the manufacturing sectors.

II.3.2 <u>Studies of Unilateral Free Trade</u>

Boadway and Treddenick (2) and Pinchin (21) present numerical analyses of the effects of unilateral free trade

TABLE [illegible] Inter-sectoral and Inter-industry Reallocations

(Change in Value of Labour Employed in millions of $1976)

	Williams	Harris and Cox
Change in Manufacturing Employment	96.8	-2791.6
Change in Primary Employment	[illegible]	1041.9
Change in Non-Traded Employment	-38.2	225.3
Sum of Increases of Employment*	[illegible]	7234.9
Sum of Contractions of Employment**	[illegible]	3258.2

* The sum of increases of employment in expanding sectors.

** The sum of contractions of employment in contracting sectors.

Notes:

i) Williams's estimates were multiplied by the ratio of employment in Harris to employment in Williams for comparison. These values are in $1976 millions.

ii) The sum of contractions for contracting sectors is smaller than the sum of increases for increasing sectors in both cases. The Williams error amounts to .05 of 1% of the value of labour employed, while the Harris and Cox number is 5% of the value of labour employed. Both models have full employment conditions and the error of Williams is a rounding error. The discrepancy in Harris and Cox is much too large to be a rounding error, and has yet to be resolved.

for Canada. Pinchin finds that the employment effects of unilateral tariff abolition are so large that it would not be a preferred option. He estimated that manufacturing employment would fall by 19% as a result of unilateral free trade.

Boadway and Treddenick (2) use a computable general equilibrium model to evaluate the effects of unilateral tariff abolition. They conclude that welfare in Canada would be virtually unaffected by tariff abolition, but would fall due to adverse terms-of-trade effects. As a result of unilateral tariff abolition, one might have expected Canada's manufacturing sector to decline since it is protected with tariffs. The primary sectors, which are subject to few tariffs, would have been expected to expand. Boadway and Treddenick (2) calculate that the service sector would decline while the primary and manufacturing sectors would expand. Since their model is a constant returns to scale model, the result is difficult to understand.

Harris and Cox (12) also evaluate the effects of unilateral abolition of all protection. Their results differ from those of Boadway and Treddenick in several respects. First, they calculate that welfare gains of 4.1% of GNP would accrue to Canada. Secondly, their evaluation of the inter-sectoral factor reallocations necessary to bring about adjustment are much larger. After aggregating to the

Boadway and Treddenick (16 sector) aggregation, Harris and Cox estimate that 3.9 percent of workers would move between sectors in response to unilateral free trade. In response to unilateral tariff abolition, Boadway and Treddenick estimate that .35% of workers would move between sectors. Harris and Cox estimate that the service and primary sectors would decline while manufacturing would be expected to expand.

II.3.3 Summary

Agreement emerges from this work on some points. First, the benefits to bilateral free trade in Canada appear to be significant. This is reinforced by the findings that even unilateral movements to freer trade may prove welfare improving. There is little evidence to suggest that Canada would suffer large losses from a unilateral move to free trade.

Some agreement also exists about the importance of intra-industry adjustment as part of the adjustment process to freer trade. Substantially less agreement exists about the likely size of factor reallocations required in response to bilateral free trade.

II.4 THE MODEL

Whalley's 8-bloc model of world trade (26) was modified to address issues in Canada-U.S. trade liberalization. Canada is modelled explicitly in the 8-bloc model, rather than as a component of the other developed bloc, as in the 7-bloc model. The 8-bloc model is otherwise similar to the 7-bloc model detailed in Appendix A of Essay I, but scale economy features (and the associated market structures) are introduced into the Canadian manufacturing industries.

II.4.1 Basic Data

The basic data used correspond to 1977, except that Canada-U.S. protection is at its 1976 level. The commodity and country groupings are listed in Table 3.

TABLE 3: 8-Bloc Model Structure

Commodities	Blocs
1. Agriculture and Food (Ag. & Food)	1. E.E.C.
2. Mining	2. United States
3. Energy	3. Japan
4. Non-Mechanical Manufactures (M1)	4. Canada
5. Machinery and Equipment (M2)	5. Other Developed
6. Construction and Services (Non-traded)	6. O.P.E.C.
	7. Newly Industrialized Countries
	8. Less Developed Countries

The volumes of Canada-U.S. trade and protection are presented in Table 4, followed by Canadian value added by

TABLE 4: 8-Bloc Data

(i) Canada-U.S. Trade and Protection

	Cdn. Exports to U.S.*	U.S. Protection Tariffs	U.S. Protection NTBs**	U.S. Exports to Canada*	Cdn. Protection Tariffs	Cdn. Protection NTBs**
A&F	1.2	5.2%	31.1%	1.2	3.6%	51.0%
Min.	4.4	.0%	.0%	1.2	.0%	94.5%
En.	4.3	.5%	.0%	1.1	2.9%	.0%
M1	7.6	2.3%	7.5%	7.1	11.2%	7.5%
M2	11.6	1.1%	.0%	14.4	4.3%	1.2%

* These figures are in billions of $US (1977).

** NTBs are present as tariff equivalents of non-tariff barriers.

(ii) Canadian Value Added by Industry

	Output*	Labour*	Value Added*	Ratio of Other Value Added to Labour
A&F	22.3	5.6	7.8	.4
Min.	15.6	4.9	8.9	.8
En.	7.7	2.2	4.0	.8
M1	131.7	32.8	39.6	.2
M2	35.5	15.8	19.1	.2
NT	199.7	69.0	100.1	.5
		130.3	179.5	

* These figures are in billions of $US (1977)

industry.

Of some interest is the volume of U.S.-Canada trade in machinery and equipment (M2). Canada's exports to the U.S. amount to almost one-third of output. A large volume of trade in this sector is trade in autos and parts (covered by the U.S.-Canada Auto Pact) as well as trade in agricultural equipment. Canadian automotive exports to the U.S. have a higher "parts" content, while U.S. automotive exports to Canada have a higher "finished vehicles" content than Canadian exports. Both automobiles and parts enter Canada duty free. This leads to a much lower Canadian tariff rate on M2 than on non-mechanical (M1) imports from the U.S. As is ~~well known~~, the Canadian tariffs on manufactures are higher than the corresponding U.S. tariffs.

Many agricultural products are subject to quotas or prohibitions, and this fact is reflected in high non-tariff barriers. By way of example, trade in poultry and fresh dairy products is effectively precluded by policies on both sides of the border. Many fruits and vegetables are subject to import quotas which protect the domestic market for domestic producers when fresh produce is available. In the past, high tariffs were used to protect manufactures, while NTBs were used to protect agricultural commodities. For Canada-U.S. trade this is no longer accurate due to substantial progress on the elimination of tariffs on both multilateral and bilateral trade in manufactures. U.S. average tariffs are lower on manufactures than agricultural commodities, while Canadian tariffs are only slightly higher on manufactures than on agricultural commodities (6.5% and 3.6% respectively).

The Canadian manufacturing industries are the most labour intensive, while the energy and mining industries are least labour intensive.

Canada and the U.S. are assumed to have fixed supplies of capital and labour, and there is no international mobility of capital. New capital equipment is made up of a composite of domestic and foreign products in all regions. Thus, though there is international trade in capital goods, capital, once in place is no longer mobile. This contrasts with Harris and Cox's assumption of perfect capital mobility.

II.4.2 Decreasing Costs and Imperfect Competition

The E-S or rationalization hypothesis argues that some Canadian manufacturing industries are typified by too many firms operating at (correspondingly) inefficient levels of production. The hypothesis also argues that one method to increase the levels of production in Canadian manufacturing is to eliminate tariffs on imports of manufactures. This section describes the market behaviour implemented in Canadian manufacturing industries. The behavioural assumptions used are similar to those used by Harris and Cox (6,12,13).

Since individual firms are assumed to have decreasing average costs, price-taking behaviour as usually implemented in Whalley's global trade models is inconsistent with market equilibrium. Firms, instead, are assumed to follow a pricing rule to maximize profits.

Harris and Cox discuss two alternative pricing hypotheses, referred to as the E-S (or collusive) pricing hypothesis and the MC (or monopolistically competitive) pricing hypothesis. These two pricing hypotheses are discussed in detail in sub-sections II.4.2.1 and II.4.2.2, respectively, under the simplifying assumption that marginal cost is constant. All versions of the model used have constant marginal cost, which, together with fixed factor costs per firm, generates decreasing average cost. All variants, further, correspond to the non-product discrimination case, in which the total number of "lines" produced is unchanged as a result of trade liberalization.

II.4.2.1 Collusive Pricing

Firms in an imperfectly competitive industry may realize that their sales and profits depend on their own pricing policies, and on those of other firms in the industry. Existing firms in an industry may have incentive to collude to increase profits. This section discusses the E-S pricing rule. E-S pricing involves collusion by Canadian manufacturers around the gross of tariff price of imports of comparable imports from the U.S. Such collusion may increase profits in the long-run if barriers to entry exist, but if no such barriers exist, collusion can only temporarily increase profits.

Focal-point pricing is one form of collusive behaviour, by which all firms in the industry charge the "focal-point" price. A focal-point price for an industry should be readily observable and highly correlated with the industry's true profit-maximizing price.

Since costs are decreasing, industry profits are maximized by having <u>one</u> firm produce all output if the products are identical. If, on the other hand, there is symmetric product differentiation, each firm faces an identical demand curve for its distinct product, and maximizing the profit per firm is the same as maximizing total profit, given the number of product lines.

In the event that Canadian and U.S. firms produced the same array of products, or the products were identical, the landed price of U.S. imports might well be the industry profit-maximizing price. This is illustrated in Figure I below.

P_u^t represents the gross of tariff price of imports from the U.S.[8] D_c will represent total demand for the Canadian product. As long as the duty-paid price of Canadian products

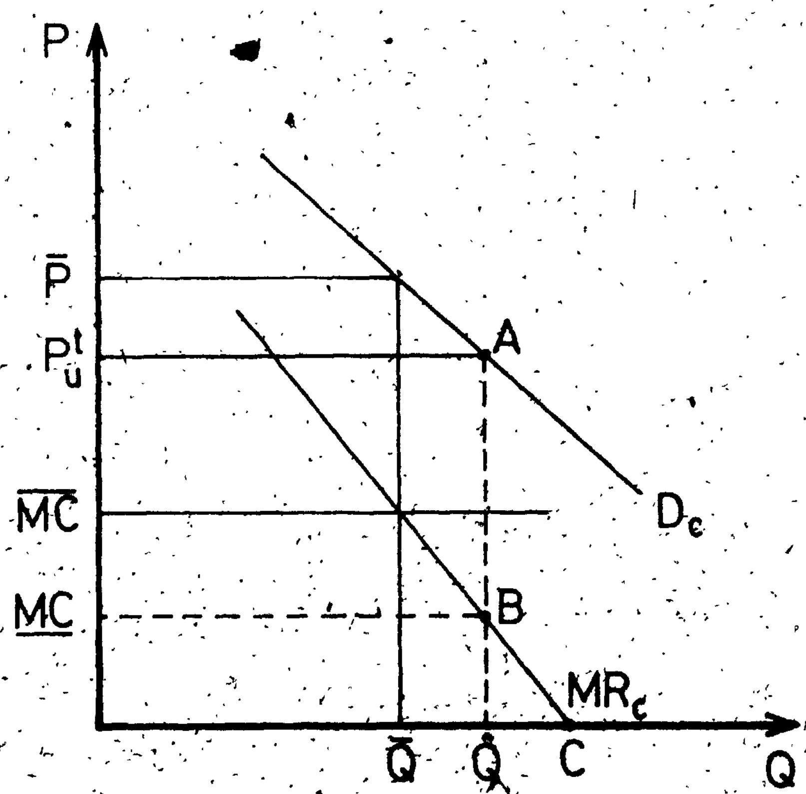


FIGURE 1: Industry Profit Maximization with Identical Product Lines in Canada and the U.S.

in the U.S. exceeds the U.S. producers' price, this total demand will correspond to Canadian market demand. Given Canadian marginal cost of $\overline{MC}$, the Canadian industry would maximize profits by setting price equal to P_u^t (in Figure 1) and selling quantity $\hat{Q}$. This corresponds to the marginal revenue curve P_u^t-A-B-C. Note that if the landed price of U.S. imports were above $\overline{P}$, Canadian firms would charge $\overline{P}$ and sell $\overline{Q}$. Finally, if Canadian marginal cost were below $\underline{MC}$, Canadian firms would set a price below P_u^t.

In the case that the Canadian "autarchy" price ($\overline{P}$) exceeds P_u^t, and marginal cost exceeds $\underline{MC}$, the industry profit-maximizing price will be P_u^t. This also supposes that Canadian producers ignore the U.S. market because their landed price in the U.S. exceeds the U.S. product's selling price there.

This analysis has assumed either (i) that Canadian products are perfect substitutes for the U.S. goods or (ii) that Canadian firms produce exactly the same product lines as U.S. producers. In any of the cases discussed, the Canadian industry would supply the entire Canadian market.

Neither of these assumptions are appropriate to the model used. Assumption (i) is inconsistent with the assumed imperfect substitutability between Canadian and U.S.-produced goods. Assumption (ii) is inconsistent with economic theory, since Canadian firms would not choose to produce the same lines as the U.S. firms given the lines produced by the U.S.

firms.

The examples discussed above, and illustrated in Figure 1 are illustrative only, and give a suggestion of conditions where the landed U.S. price would be an appropriate focal-point for Canadian producers' pricing behaviour. In the current model, Canadian and U.S. goods are imperfect substitutes. In this case, the landed price of U.S. imports will be a useful focal-point if the price is readily observable, and if it is correlated with the industry profit-maximizing price.

The comparative statics of Canadian tariffs are now analyzed, given E-S pricing behaviour and treating Canadian and U.S. imports as imperfect substitutes. In the model used Canadian and American manufactures are imperfect substitutes in both final demand and intermediate use.

With E-S pricing, the short-run and long-run comparative statics of Canadian tariffs are straightforward. Firms are assumed to use the same pricing rule in the short run as in the long run.[9] A result of this is that industry output will be the same in the long-run (partial) equilibrium as in the short-run (partial) equilibrium. In the model, general equilibrium considerations cause industry output to be different in the short run than in the long run.

In the short run, the introduction of a tariff on imports from the U.S., will cause Canadian firms to charge a higher price, equal to the new gross-of-tariff price of U.S. imports. The total demand for Canadian goods, in the model, is made up of U.S. and Canadian demand. As long as the own elasticity of demand in the Canadian market equals or exceeds the cross-price (U.S.) elasticity of demand for the Canadian market, total quantity demanded will fall as a result of the tariff. If the own and cross-elasticities are equal, the Canadian market quantity demanded will be unchanged, but the U.S. market will face a higher price, and the quantity sold there will fall.

Referring to Figure 2, the reduction in total quantity demanded is shown as $Q_o - Q_t$, where Q_o and Q_t are the pre- and post-tariff quantities. $D_c(P_c; P_u)$ and $D_c(P_c; P_u(1+t))$ are the pre- and post-tariff total demands for the Canadian made product.

Note that the new price in the market is known, given the producer's price of U.S. imports, P_u.

In the short run, output per firm falls from q_i^o (in the absence of the tariff), to Q^t/n, where n is the original number of firms in the industry. Note that originally (in the pre-tariff long-run equilibrium), profits were equal to zero, so that average cost was equal to P_u at the level of output q_i^o per firm. Each firm earns a short-run profit equal to $b(Q^t/n)$. In the long-run, free entry will cause the output per firm to fall to q_i^t, again yielding zero profits.

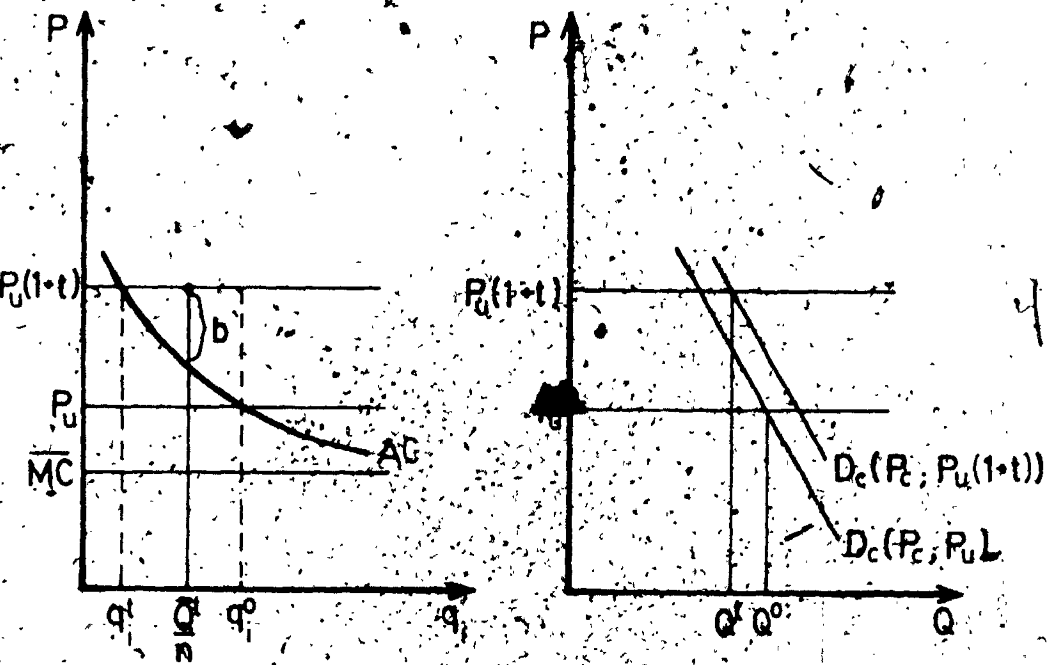


FIGURE 2: Comparative Statics of a Tariff (E-S Pricing)

With E-S pricing, an industry "supply" relation exists which is infinitely elastic at the landed price of U.S. imports. Output per firm will rise as the tariff rate falls in the long-run equilibrium. With E-S pricing, the tariff rate has an unambiguous inverse effect on the lengths of production runs. This results from the pricing behaviour which is assumed to apply to both new entrants and existing firms in the industry.

2

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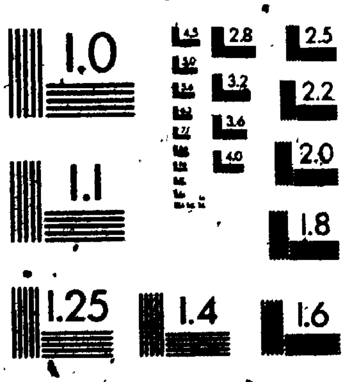

Collusive pricing could break down as a result of a tariff cut. For example, suppose that fixed costs account for a relatively small amount of total cost, while tariffs are quite high. In this case, abolition of the tariff either causes the industry to cease production or choose different pricing behaviour. This is illustrated in Figure 3 for the case where marginal cost is constant. In such cases, Eastman-Stykolt pricing cannot be sustained after the tariff is removed.

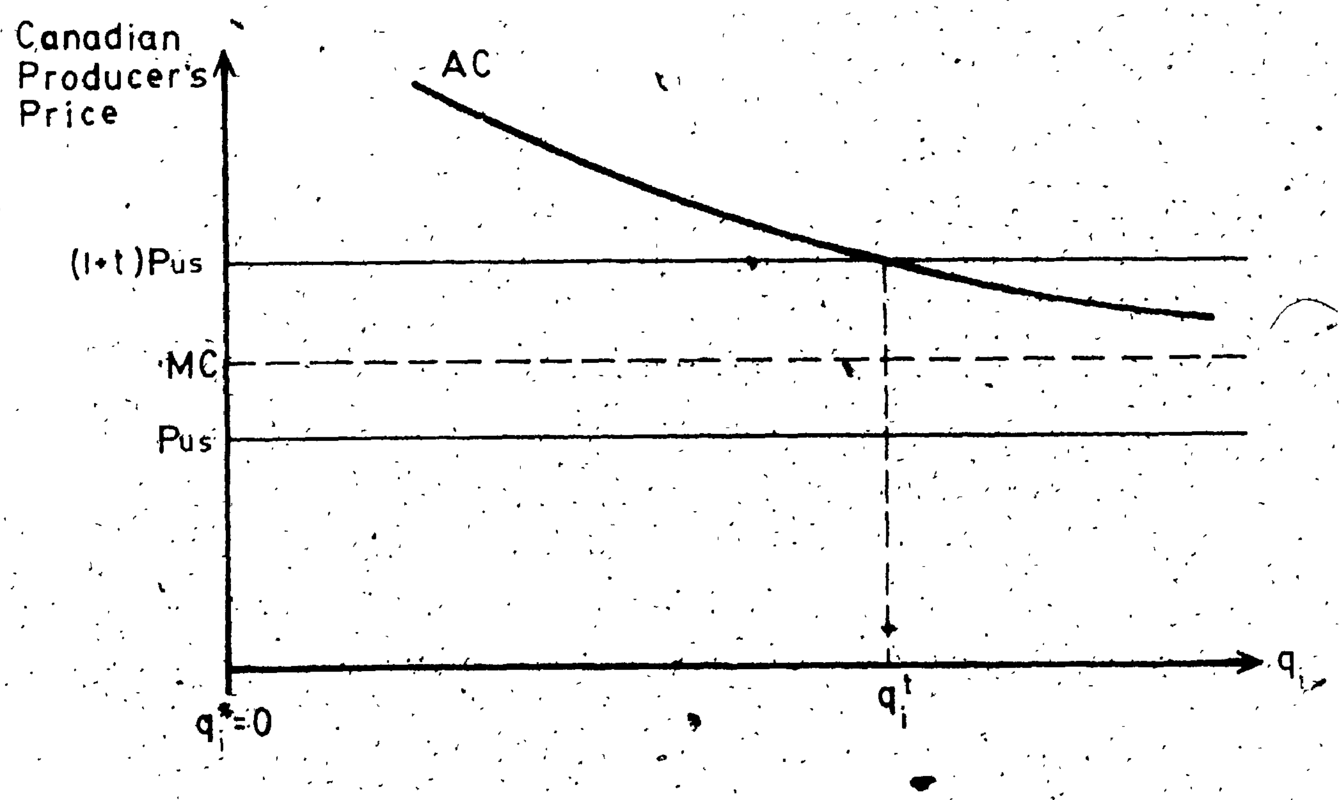

FIGURE 3: Tariff Removal Case (b)

As mentioned above, the landed price of U.S. imports may be an appropriate focal-point price for Canadian manufacturers, even where Canadian and U.S. products are qualitatively different. The partial equilibrium comparative statics of E-$ pricing are unambiguous in one respect: Increasing the tariff on U.S. imports must lead to shorter and less efficient production runs in Canada.

II.4.2.2 Monopolistically Competitive Pricing

The monopolistically competitive pricing rule used by Harris and Cox and here is based on Chamberlin's notion of a monopolistically competitive market.[10] Firms produce goods that are imperfect substitutes. In this way, the pricing behaviour is consistent with the implemented structure of market demand, whereby Canadian and U.S. produced goods are imperfect substitutes.

Firms are assumed to maximize profit, given the perceived elasticity of the (firm-specific) demand curve. The elasticity of each firm's demand will depend on the elasticity of total market demand, the ease of substitution between different products, and the pricing policies of the other firms in the industry. If the market demand is composed of foreign and domestic components which have different elasticities of demand, then the elasticity of market demand will also depend on the relative size of the domestic and foreign (export) components. In this section, all total demands correspond to the sum of the Canadian and foreign demands.

Given the prices of other firms' products, each individual firm is assumed to face a constant elasticity demand for its product.[11] If marginal cost is constant, the firm's profit maximizing pricing behaviour amounts to choosing the optimal mark-up of marginal cost. Algebraically, profit can be written:

$$P_i \cdot D(P_i) - D(P_i) \cdot \overline{MC} - F_o \qquad (1)$$

$D(P)$ is the (constant elasticity) demand for firm i's output, given the firm's price P_i, while $\overline{MC}$ is the (constant) marginal cost and F_o are fixed costs of production. $D'(P_i)$ is the derivative of the firm's demand with respect to its own price. The optimal pricing rule will satisfy:

$$\frac{P_i - \overline{MC}}{P_i} = \frac{-D(P_i)}{D'(P_i)P_i} \qquad (2)$$

Defining η_i to be the absolute value of the firm's "perceived" elasticity of demand, and m_i to be the proportional mark-up of marginal cost, equation (2) can be rewritten:

$$\frac{m_i \cdot \overline{MC}}{(1+m_i)\overline{MC}} = \frac{1}{\eta_i} \qquad (3)$$

The optimal mark-up rate can then be written:

$$m_i = \frac{1}{\eta_i - 1} \qquad (4)$$

Even the partial equilibrium comparative statics of tariffs with this type of pricing are unclear, and two examples are given to illustrate them for the cases where the perceived elasticity of demand is (i) constant and (ii) variable.

Suppose that introduction of a tariff causes the total demand curve for Canadian manufactures to be shifted to the right as domestic consumers substitute domestic for imported manufactures. Suppose further, however that the <u>elasticity</u> of total demand for the Canadian manufactures is unchanged. In this case (see Figure 4), the short-run effect of the tariff will be to increase total sales by Canadian firms (and thus sales per firm). If the tariff were introduced into a no-tariff long-run equilibrium, introduction of the tariff must lead to short-run excess profits.

D_i^o is the pre-tariff share of total demand for a typical firm i. Each firm produces q_i^o and there are no excess profits. The price charged by each firm is $(1+m_i)\overline{MC}$. After introduction of the tariff, if the firm's perceived elasticity of demand is <u>not</u> affected, the profit maximizing mark-up is unaffected, but each firm's demand has increased because of substitution by domestic consumers. In the short run each firm produces q_i^t and earns the short-run profit indicated in Figure 4. The original number of firms is n_o.

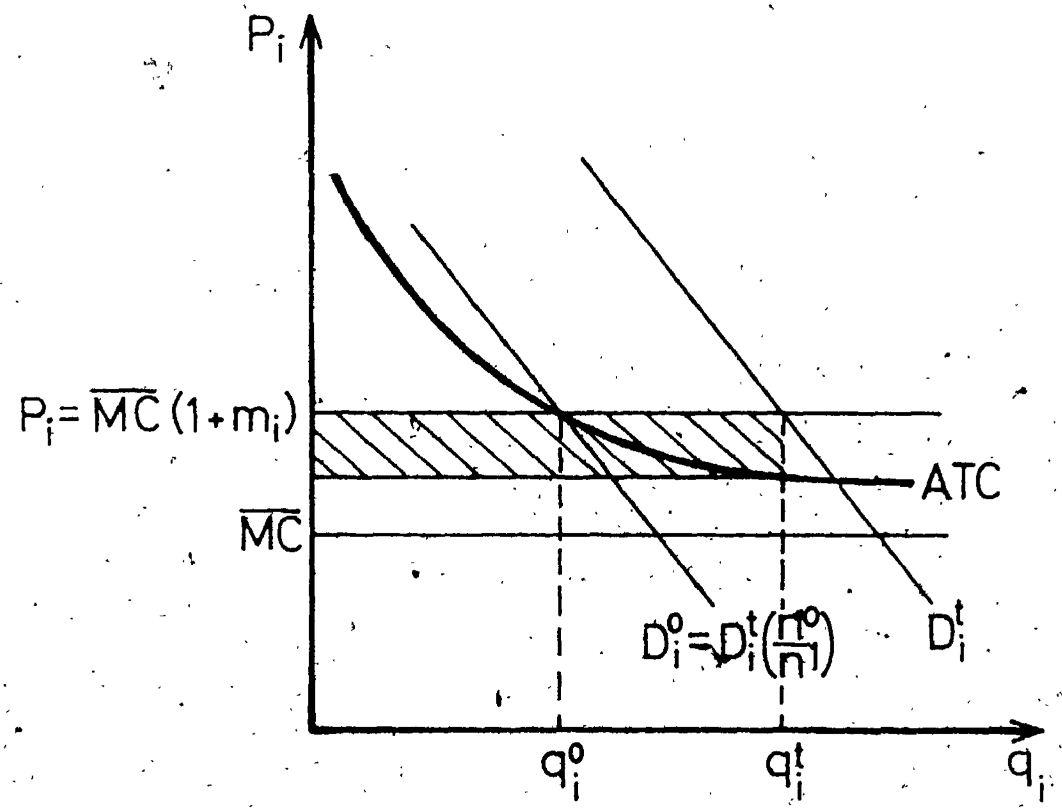

FIGURE 4: Comparative Statics of a Tariff (MC Pricing With Constant Elasticity)

As entry occurs, the demand per firm will be reduced, even though total quantity demanded (at the unchanged price) will be unchanged at $n_o q_i^t$. Entry will occur until output per firm is precisely q_i^o and all excess profits are eliminated. Note that if the perceived elasticity is unaffected by the tariff, the mark-up and the price charged will be unaffected by the tariff.[12] In this case, the tariff merely causes entry at the pre-tariff price and output per firm.

If the domestic demand is less elastic than the foreign demand, introduction of a tariff can have added effects. In this case, the perceived elasticity of demand faced by each firm may be lower in the new long-run equilibrium. This is true since domestic demand will be a larger share of total demand, so that the elasticity of total market demand falls. By equation (4), a higher mark-up will result, and thus a lower zero-profit (long-run) level of output per firm. In this case the long-run effects of the tariff are (i) to increase industry output, (ii) to cause entry, (iii) to reduce output per firm and (iv) to increase the price paid by consumers. This is illustrated in Figure 5.

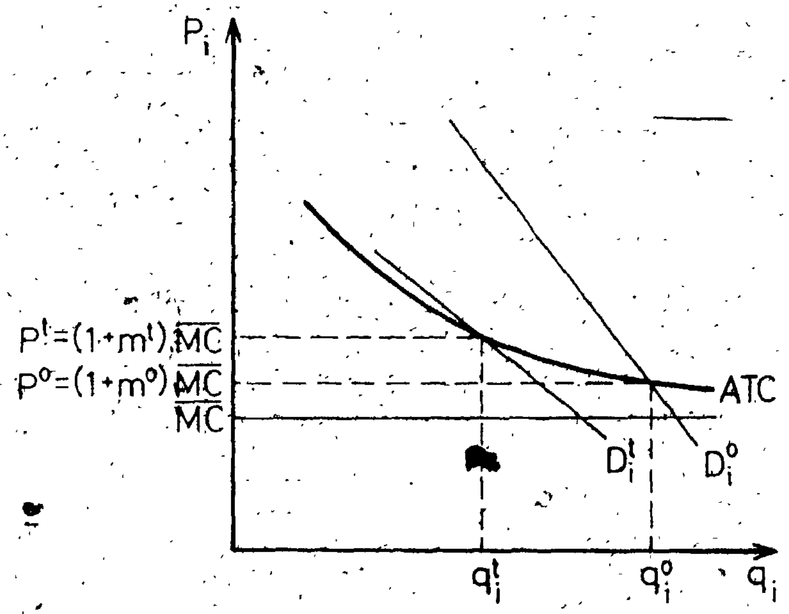

FIGURE 5: Comparative Statics of a Tariff (MC Pricing With Variable Elasticity)

The long-run post-tariff demand per firm (D_i^t) will cut average total cost (ATC) at q_i^t as a result of entry. This is the level of output where the fixed costs per firm exactly equal total mark-ups per firm. Algebraically:

$$q_i^t = \frac{F_o}{m^t \cdot \overline{MC}} \qquad (5)$$

m^t is the post-tariff optimal mark-up, which is higher than m^o due to the reduction in the perceived elasticity of demand. In this case, the tariff does cause a reduction in the length of production runs from q_i^o to q_i^t in the long-run.

In this case, the outward shift of market demand caused by the tariff is more than offset by entry so that demand per firm shifts in. If, on the other hand, the foreign component of total demand was dramatically less elastic than domestic demand, the tariff could have the counterintuitive effect of increasing the length of production runs! This would occur as a result of the impact of the tariff on the perceived elasticity of demand, as the less elastic component of total demand became a more important share of total demand.

The method of calculating the perceived elasticity of demand is discussed in detail in section II.4.3. Experience with the revised model suggests that very small changes in the perceived elasticities are likely to result from trade liberalization.

The comparative statics of tariffs with MC pricing are not clear-cut, as are those with E-S pricing, since they depend on the relation between tariff rates and the <u>elasticity</u> of demand, as well as the size of total demand. In the case where the perceived elasticity of demand is unaffected by the tariff, the length of production runs in Canada are unaffected by tariff rates.

II.4.3 Implementation of Decreasing Average Costs and Market Structure

This section outlines details of the implementation of decreasing average costs and market structure used. The formulation used is compared to that used by Harris and Cox (12, pp. 77-90).

The central case analyzed below involves MC pricing in the non-mechanical manufacturing industry (M1) and E-S pricing in the equipment and vehicles industry (M2).

MC pricing was assumed to hold in the M1 sector, since E-S pricing would break down in much of the sector, as a result of tariff abolition. Since Canadian tariffs are higher than the share of fixed costs in total cost in much of this sector, eliminating Canadian tariffs would cause the collusive price to be less than marginal cost. Under these conditions E-S pricing is likely to break down.

Collusion would seem most plausible where relatively few firms are involved in a market. Such is the case for the vehicles sector, which is the most important component of the equipment and vehicles sector.

The empirical basis for choosing one of these central case formulations over another is weak, and results corresponding to several alternative formulations are presented later.[13] There is no empirical evidence to aid in the choice of pricing hypotheses.

II.4.3.1 Production and Costs

In all industries other than Canadian manufacturing, production exhibits constant returns to scale in the inputs of primary factors (K and L) and intermediate use of produced inputs. The technology is of CES form, with hierarchical structure as outlined in Appendix A of Essay I.

In the Canadian manufacturing industries, production exhibits constant returns to scale in the <u>variable</u> inputs of primary factors and in the use of intermediates, but there is a fixed requirement of primary factors per firm. The fixed requirements of capital ($\bar{k}_i$) and labour ($\bar{\ell}_i$) lead to fixed costs of production per firm in the amount F, where:

$$F = W\bar{\ell}_i + R\bar{k}_i \qquad (6)$$

No substitution is permitted between capital and labour in fixed factors. As noted before, the existence of fixed costs means that average cost is a decreasing function of the quantity of output per firm.

Average cost for firms in the Canadian manufacturing industries can be written:

$$c(q_i) = W\ell_i + Rk_i + P \cdot a_i + (W\bar{\ell}_i + R\bar{k}_i)/q_i \qquad (7)$$

W and R are the producer's prices of labour and capital respectively. ℓ_i and k_i are the cost-minimizing per-unit factor requirements of labour and capital respectively. P is the (row) vector of producer's prices of the intermediates and a_i is the (column) vector of optimal per unit requirements of intermediates. In all industries other than the Canadian M1 and M2 industries, $\bar{k}_i$ and $\bar{\ell}_i$, the per-firm fixed requirements, are zero.

II.4.3.2 Perceived Elasticities of Demand

Firms in the Canadian M1 industry are assumed to engage in MC pricing, given a fixed number of product lines. To determine the optimal mark-up, it is necessary to know the perceived elasticity of demand η_i for the typical firm in that industry. Industry and firm demands are described by equations (8) and (9), respectively.

$$Q = \frac{Q_o}{n} \{ \sum_{i=1}^{n} P_i^{-\varepsilon} \} \qquad (8)$$

$$q_i = Q \cdot \frac{P_i^{-\alpha}}{\sum_{i=1}^{n} P_i^{-\alpha}} \tag{9}$$

Q is the industry output; q_i is the output of firm i and P_i is the price charged by firm i. n is the number of firms in the industry. Industry demand specified in this way has the property that total demand has constant elasticity ε, and the market share of any individual firm has a constant own price elasticity α, holding all other firms' prices constant. This specification has the following properties:

(i) Total demand is unchanged by adding more firms as long as all firms charge the same price.

(ii) In response to an increase in the price charged by one firm, total quantity demanded will fall by less than the fall in quantity demanded by the firm increasing the price, as long as α is greater than ε.

(iii) An increase in the price charged by one firm (j) will cause an increase in the quantity demanded by any other firm (i) as long as α is greater than ε.

An individual firm's perceived elasticity of demand η_i can be derived from (9), using (8). This elasticity will depend on:

(i) the number of firms in the industry

(ii) the elasticity of total demand (ε)

(iii) the elasticity of market shares (α)

Specifically, the firm's perceived elasticity of demand can be written:

$$\eta_i = \{\varepsilon[\frac{Q}{n}]P^{(\varepsilon-1)} - \alpha P^{(\alpha-1)}[\frac{1}{n} - 1]\} \frac{Q}{nP^{\alpha}} \cdot \frac{P \cdot n}{Q} \qquad (10)$$

In fact, the true demand for Canadian M1 manufactures is not likely to be of the constant elasticity variety, but this assumption seems a useful simplification. The data provide values for n, P, and Q for equation (10), but not values for ε and α. Once the substitution elasticities of the model are calibrated, ε can be approximated using the model. The elasticity of market demand for M1 was calculated by changing the price of M1 by 1% and determining the proportionate change in quantity demanded, holding all other prices constant.[14] This still leaves the "share" elasticity α and/or the perceived elasticity η_i which are unknown. Fortunately, knowledge of the scale elasticity of production, combined with the assumption of long-run equilibrium allows α and η_i to be determined during calibration.

II.4.3.3 Calibration

The share parameters of all of the utility functions and of the production functions outside of Canadian manufacturing were determined from the micro-consistent data, using a method outlined in Mansur and Whalley (15).[15] The methodology used in the Canadian manufacturing industry differs from that used by Harris and Cox.

Harris and Cox assume that their "base" data represents a short-run equilibrium, and they rely on direct estimates of capital stock to infer profits. This methodology was apparently used in the belief that the departures of their data from a long-run equilibrium were more problematic than the deficiency of the capital stock data and the resulting estimates of profits. Given the implausible results of their benchmarking, and the unreliability of capital stock data, it was decided to assume that the 1977 benchmark data represented a long-run equilibrium. Some of the results of "benchmarking" are discussed in section II.2, above.

Calibration of the production and demand parameters for the Canadian manufacturing industries follows the procedure from Mansur and Whalley (15), in most respects, except for the calibration of the following items, which will be discussed in some detail:

(i) the fixed factor requirements $\bar{k}_i$ and $\bar{\ell}_i$

(ii) the perceived elasticity of demand η_i

(iii) the share elasticity of demand α

Given an estimate of the scale elasticity of production (or cost), it is possible to infer the share of fixed costs (F) in total cost. The scale elasticity of cost, S_i, can be written:

$$S_i = \frac{dC_i}{dq_i}\frac{q_i}{C_i} \qquad (11)$$

C_i is the total cost of production of a firm in industry i, producing output q_i. In the case that marginal cost is constant at $\overline{MC}$, the scale elasticity of cost is equal to the share of variable in fixed cost.

$$S_i = \frac{\overline{MC} \cdot q_i}{C_i} = \frac{\text{Total Variable Cost}}{\text{Total Cost}} \tag{12}$$

The total amount of fixed costs can now be determined, given the total cost of production. Given the number of firms, n, the per-firm fixed cost F can then be determined:

$$F = (1-S_i) \cdot (\frac{\text{Industry Total Cost}}{n}) \tag{13}$$

As in H-C, it was assumed that all fixed costs were made up of primary factor costs[16]. It was further assumed that fixed factors were used in the same proportions as variable factors. This allowed the fixed factor requirements to be determined, using the rule that one unit of a primary factor is the amount that costs producers $1 in the benchmark equilibrium data.

For a known F, and a known ratio of capital to labour used, γ_i, the per firm requirements can be calculated:

$$\bar{\ell}_i = \frac{F}{W+R\gamma_i} \tag{14}$$

$$\bar{k}_i = \frac{\gamma_i F}{W+R\gamma_i} \tag{15}$$

Calibration of the remainder of the utility and production parameters is completed in the normal fashion. In the case of an industry with MC pricing, however, the perceived elasticity of demand and the share elasticity of demand (α) must be determined. Again, imposition of the zero-profit (long-run equilibrium) condition allows all of these to be determined.

Once the utility and production parameters have been determined, it is possible to calculate ε, the elasticity of market demand. In long-run equilibrium, it must be true that the excess of total revenue over total variable cost for each firm must equal the fixed costs per firm. Algebraically:

$$m_i \cdot \overline{MC} \cdot q_i = F_i \tag{16}$$

, but recalling the optimal rule for choice of the mark-up rate m_i, (16) can be usefully rewritten as:

$$\eta_i = 1 + \frac{\overline{MC} \cdot q_i}{F_i} \tag{17}$$

In words, the perceived elasticity of demand must be known, once we know the share of fixed in total cost. The central case estimate of the scale elasticity of cost in the M1 industry is .86. This value is based on estimates from Fuss and Gupta (10). This scale elasticity of cost corresponds to a 14% share of fixed to total cost, and corresponds to a perceived elasticity of demand of 6.1. In the benchmark equilibrium, quantities are measured based on producer prices of $1. As a result, equation (10) can be rewritten and rearranged to get:

$$\alpha = \frac{n}{n-1} [\eta_i - \varepsilon [\frac{Q_o}{n_o}]] \frac{n}{n-1} \qquad (18)$$

This completes the calibration of the model.

As a result of the policy change, the perceived elasticity of demand may change, as a result of entry and exit (changes in n), changes in the market elasticity of demand (ε), or changes in the prices and quantities. It is assumed that α does <u>not</u> change as a result of policy changes.[17]

II.5 THE SOLUTION OF NGE MODELS WITH FIXED COSTS

Harris and Cox incorporated fixed costs per firm into their one-country model of Canada. They do not discuss the method of model solution used in detail. This section will discuss the solution of the revised model to be used. The novelty is in the evaluation of the excess demands.

NGE models of world trade solve for "counterfactual" equilibria using either a simplicial subdivision algorithm[18] or a modified Newton method.[19] Once the model has been calibrated using techniques explained in Mansur and Whalley (19), the evaluated excess demands are used to find an approximate equilibrium price vector. The solution speed of the algorithms is affected by the number of excess demands to be evaluated.

II.5.1 Models With Perfect Competition

In the case of an economy with price-taking firms and consumers, there may be several ways of representing the equilibrium conditions describing a long-run equilibrium. Given that the solution speed is affected by the number of excess demands to be evaluated, it is convenient to express the equilibrium conditions in terms of as few excess demands as possible.

A long-run equilibrium will satisfy three sets of equilibrium conditions:

(i) The supply of each commodity must equal its demand.[20]

(ii) The supply of each primary factor must equal its demand.

(iii) Firms in each industry must earn zero profits.

If an excess demand was calculated corresponding to each of these conditions, many excess demands would need to be evaluated at each step of the solution process. If there are G distinct goods, F distinct factors, and I distinct industries, this would require the evaluation of (G+F+I) excess demands at each step. The 8-bloc model has 48 distinct goods (6 in each of 8 blocs), 16 distinct factors (2 in each of the blocs), and 48 distinct industries. These 112 excess demands would be written:

$$
\begin{array}{llllr}
Z_1 & = & D_1(\phi) & - \; S_1(\phi) & (1.1) \\
\vdots & & \vdots & \vdots & \vdots \\
Z_G & = & D_G(\phi) & - \; S_G(\phi) & (1.G) \\
Z_{G+1} & = & K_d^1(\phi) & - \; K_o^1 & (1.G+1) \\
Z_{G+2} & = & K_d^2(\phi) & - \; L_o^1 & (1.G+2) \\
\vdots & & \vdots & \vdots & \vdots \\
Z_{G+F-1} & = & K_d^8(\phi) & - \; K_o^8 & (1.G+2F-1) \\
Z_{G+F} & = & L_d^8(\phi) & - \; L_o^8 & (1.G+F) \\
Z_{G+F+1} & = & (P_1 & - \; AC_I(\phi))n_1 & (1.G+F+1) \\
\vdots & & \vdots & \vdots & \vdots \\
Z_{G+F+I} & = & (P_I & - \; AC_I(\phi))n_I & (1.G+F+I)
\end{array}
$$

ϕ is the complete vector describing a possible equilibrium.

$$\phi = (P_1, \ldots P_G, R_1, W_1, \ldots R_8, W_8, n_1, \ldots n_I) \qquad (2)$$

These elements are the commodity prices P_1 to P_G, the factor prices (W,R) for labour and capital in each of the blocs, and the number of firms in each of the competitive industries. $D_i(\phi)$ and $S_i(\phi)$ represent the demand and supply functions for good i. $L_d^j(\phi)$ and $K_d^j(\phi)$ are the demands for the factors in region j. L_o^j and K_o^j are the inelastically supplied endowments of labour and capital in region j. $AC_i(\phi)$ is the cost minimizing average cost of product i.[21]

II.5.1.1 The Special Case of Constant Costs

In the event that all production exhibits constant returns to scale, the three sets of equilibrium conditions (1.1-1.G+F+I) can be represented by F excess demands, corresponding to the distinct factors. In this case, a smaller simplex with F elements can be used, and solution speed is greatly improved. The excess demands used can be written:

$$Z_1 = K_d^{\Delta 1}(R_1, W_1, \ldots R_8, W_8) - K_o' \qquad (3.1)$$

$$Z_2 = L_d^{\Delta 1}(R_1, W_1, \ldots R_8, W_8) - L_o' \qquad (3.2)$$

$$\vdots$$

$$Z_F = L_d^{\Delta 8}(R_1, W_1, \ldots R_8, W_8) - L_o^8 \qquad (3.F)$$

"Constrained" factor demands, $K_d^{\Delta i}$ and $L_d^{\Delta i}$, respectively, are calculated, given the factor prices prevalent in each bloc. These are the factor demands corresponding to the zero profit commodity prices consistent with the given factor prices. The methodology used to calculate the "constrained" excess demands is outlined in Figure 6.

---

1. Cost-minimizing factor costs per unit and unit factor requirements are calculated given the factor prices.

2. Zero profit (cost covering) prices for all commodities can be determined given the factor costs per unit and knowledge of the input/output structure of the model. (See section II.5.2.1.)

3. Total income can be calculated as the sum of the factor prices times the resource endowments.

4. Consumers maximize utility given total income calculated in step 3 and the cost-covering prices calculated in step 2. This yields the final demand for all commodities.

5. Total (intermediate plus final) demands for output can be calculated given the final demands and the input/output structure.

6. Constrained factor demands can be calculated by multiplying the total demands for output by the cost-minimizing unit factor requirements, and adding the resulting factor requirements by product.

7. The excess demand for a factor equals the constrained demand less available factor supplies.

FIGURE 6: Steps to Evaluate Constrained Excess Demands for Factors (Constant Costs)

The excess demands for factors evaluated this way satisfy Walras' Law and are homogeneous of degree zero in the vector of factor prices.[22] This assures consistency with the implied theoretical model, and assures that "fixed point" methods will find an equilibrium.

II.5.2 Models With Fixed Costs and Price-Setting Firms

In the event that fixed costs per firm are present, imposing the zero profit condition does not imply unique cost-covering prices, so that step 2 of Figure 6 is no longer possible. Since profits may exist in some of the (non-competitive) industries where there are price-setting firms, total income, as calculated in step 3 is no longer correct. This section discusses the solution of models with decreasing average cost and price-setting behaviour by firms. The simplifying assumption of constant marginal cost is maintained throughout.

In the revised model used to evaluate Canada-U.S. trade issues, the two manufacturing sectors (M1 and M2) are assumed to have fixed costs per firm and thus decreasing average cost. To simplify the exposition, decreasing average costs and the associated price-setting behaviour will be present in only one industry in the discussion which follows.

II.5.2.1 Long-Run Solution

The long-run equilibrium conditions of the model with one imperfectly competitive industry are still described by the equilibrium conditions (1.1) to (1.G+F+I). In other words, commodity market equilibrium, factor market equilibrium, and zero profits must be present in the long-run equilibrium. The model could be solved, once the profit maximizing behaviour is specified, using (F+G+I) excess demands corresponding to conditions (1.1) to (1.F+G+I), but this would be very cumbersome.

The method of solution used follows the steps of Figure 6, but overcomes the problem associated with step 2 by keeping track of the number of firms in the non-competitive industry. In this way, it becomes possible to generate the profit-maximizing (rather than zero-profit) prices of non-competitive commodities in step 2. In step 2 of the standard method/illustrated in Figure 6, cost-covering prices are calculated using the zero profit condition:

$$P_i = MFC_i + \sum_{j=1}^{G} P_j a_{ij} \qquad (4)$$

where a_{ij} are the intermediate requirements for commodity i. Denoting the unit marginal factor cost (MFC) vector as v, form the matrix equation

$$P = v + AP \qquad (5)$$

where A is the matrix of intermediate requirements. Rewriting this equation it is possible to solve for the zero profit prices given knowledge of the variable factor cost per unit.

$$\hat{P} = [I-A]^{-1}v \qquad (6)$$

In the presence of fixed costs and E-S pricing in one sector "j", firms set their price equal to the duty paid price of comparable U.S. imports "k".

$$P_j = (1 + t_k)P_k \tag{7}$$

In this case, cost-covering prices are calculated for all of the competitive industries, and the "E-S" price is calculated for commodity j, based on the input prices. The vector of cost-covering/profit-maximizing prices then becomes:

$$P = [I-A^{\Delta}]^{-1}v \tag{8}$$

where A^{Δ} is the intermediate requirements matrix A, with the row corresponding to the non-competitive commodity "j" replaced with the following row vector:

$$[0,\ 0,\ 0,\ \underset{\substack{\uparrow \\ \text{entry } k}}{(1+t_k)},\ 0,\ \ldots,\ 0]$$

Note that in this case it is unnecessary to know the number of firms to calculate the "profit-maximizing" price charged by the price-setting firms.

In the presence of fixed costs and MC pricing in sector j, firms choose the profit-maximizing markup of marginal cost, m_j, to satisfy:

$$m_j = \frac{1}{\eta_j - 1}. \tag{9}$$

As noted above, the perceived elasticity of demand, η_j, will depend on the number of firms in the industry n_j, and this optimal markup can be calculated, given n_j and the elasticity of market shares α_j and the price elasticity of market demand, ϵ_j.

The vector of cost-covering/profit-maximizing prices can be generated in this case as:

$$P = [I^{\Lambda}-A]^{-1}v \qquad (10)$$

where I^{Λ} is the identity matrix with the diagonal element corresponding to the commodity subject to monopolistic pricing, "j", set to $\frac{1}{1+m_j}$.

Having calculated the cost-covering/profit-maximizing prices, final demands are evaluated in step 4, following the calculation of total income in step 3. Except in equilibrium, profits in the non-competitive industry need not be zero, leading to a miscalculation of total income at step 3. To take account of this, an additional "transfer" term, T_j, is added to the price simplex corresponding to each non-competitive industry, j.

When total incomes are calculated, the total income of the Canadian consumer is increased by the excess of this transfer T_j over the total spent on fixed factors in industry j. Algebraically, the augmentation to consumer incomes can be written:

$$\hat{Y} = T_j - n_j(W\bar{\ell}_j + R\bar{k}_j) \qquad (11)$$

Final demands are calculated, given the new total income, and the prices calculated in step 2. Total demands are determined as before in step 5. The total demands for factors are calculated as before, except that the fixed factors required by the non-competitive industries are added in.

Two added excess demands are required for each non-competitive industry, corresponding to the transfer term T_j and the number of firms element n_j.

Solving for a long-run equilibrium with fixed costs per firm and price-setting firms amounts to finding equilibrium values for (i) the input prices for each bloc, (ii) the number of firms in each non-competitive industry and (iii) the associated size of transfer for each industry.

The complete set of excess demands which must be zeroed for equilibrium correspond to the factor market excess conditions (3.1) to (3.F) above for the blocs <u>other</u> than Canada, plus the following excess demands for Canada.

Excess Demand	"Price"
$Z_K = K_c + K_v + n_j\bar{k}_j - K^o$	(R)
$Z_L = L_c + L_v + n_j\bar{\ell}_j - L^o$	(W)
$Z_{T_j} = n_j(W\bar{\ell}_j - R\bar{k}_j) - T_j$	(T_j)
$Z_{n_j} = \dfrac{TR_v - WL_v - RK_v}{n_j} - [W\bar{\ell}_j + R\bar{k}_j]$	(n_j)

K_c, L_c are variable factors demands in the CRS industries and K_v, L_v are variable factor demands in the non-competitive industries. $\bar{k}_j$, ℓ_j are per firm fixed factor requirements and K^o, L^o are the factor endowments. TR_v is the total revenue of the non-competitive sector j.

The first two excess demands are merely the Canadian excess demands for factors, which must include demand for fixed factor requirements. The excess demand for T_j must be zero to assure that the budget constraint is in fact satisfied by the new equilibrium "price" vector. The excess demand for the number of firms is no more than the profit per firm in the non-competitive industry. In long-run equilibrium, with free entry and exit this must also be zero.

The system of excess demands represented by (3.1) to (3.F) plus the conditions (R), (W), (T_j) and (R_j) are homogeneous of degree zero in all of the input prices and T_j, and it is easily verified that Walras' Law holds.[23] The steps used to evaluate excess demands in this case are summarized in Figure 7.

II.5.2.2 Special Case - Pricing Behaviour Not Dependent on the Number of Firms

In the case that the profit maximizing price does not depend on the number of firms in the industry, it is possible to solve without adding any extra dimensions to the simplex. This will be the case if all firms pursue E-S collusive pricing.

1. Cost-minimizing variable factor costs per unit and unit variable factor requirements are calculated given the factor prices.

2. Cost-covering prices for the competitive (CRS) industries and profit-maximizing prices for the non-competitive industries can be determined given the variable factor costs per unit, knowledge of the input/output structure of the model, the profit maximizing rule, and the number of firms.

3. Total income can be calculated as the sum of the factor incomes plus the transfers from the non-competitive industries, less the expenditures on fixed factors in the fixed-cost sectors.

4. The final demands for all commodities can be calculated given total income and the cost-covering/profit-maximizing prices.

5. Total demands for commodities can be calculated given the final demands and the input/output structure.

6. Total demands for factors can be calculated by calculating the demands for "variable" factors and adding the demands for fixed factors which depend on the number of firms but not output.

7. Excess demands for factors equal the factor demands less available factor supplies.

8. The demand for T_j is equal to the total amount spent on fixed factors in sector j less the transfer T_j.

9. The demand for "entry to" sector j is merely equal to the profit per firm in sector j.

FIGURE 7: Steps to Evaluate Excess Demand Vector - Long-Run Equilibrium With Fixed Costs and Price-Setting Firms

In this case, the steps in Figure 6 can be followed, with the exception that profit maximizing prices are calculated at step 2, and demands for fixed factors are added at step 6. The demand for fixed factors (and the zero profit number of firms) is determined by spending the industry's variable profit on fixed factors in optimal proportions. In this case it is unnecessary to extraneously keep track of the number of firms or profits.

II.5.3 Short-Run

In the short-run, the number of firms in the non-competitive sector is fixed, but it is assumed that perfectly competitive firms can expand output in the short-run at constant cost.

Short-run profits or losses may exist in equilibrium in the non-competitive industries, and a transfer term is necessary to reflect this, but an extra term to represent the number of firms is obviously unnecessary. The demands for factors are calculated in the same way as before and the demand for "T_j" is written as:

$$Z_T = TR - WL_v - RK_v - T_j \qquad (12)$$

II.5.4 Summary

The 8-bloc model was adapted to accommodate two non-competitive sectors, with a small deterioration in solution speed due to added dimensions. The method used is appealing because it does not resort to a full dimension simplex. In cases where the non-competitive firms' profit maximizing price does not depend on the number of firms in the industry, no added dimensions are necessary to solve the 8-bloc model.

In the cases where the added dimensions are necessary, a drawback to the solution method used is that even the full dimension method may be more efficient if many industries set profit-maximizing prices.

II.6 CANADA-U.S. TRADE LIBERALIZATION

This section will discuss the impact of several liberalization experiments, estimated using the revised model presented above. This section focuses on bilateral tariff abolition. This focus was chosen for several reasons. First, while more ambitious policy changes such as complete free trade have greater potential gains, practical problems with eliminating non-tariff barriers on agricultural commodities in particular are substantial. Secondly, the non-tariff barriers implemented in the model are presented as tariff equivalents. The procedure for choosing the levels of such barriers, and the modelling of their incidence in the model is somewhat inadequate,[24] and resulting estimates of the effects of their elimination may be poor.

Although the proposal considered is modest, it has some probability of implementation, and is of interest for this reason. Unilateral abolition of tariffs on U.S. imports is also considered in section II.6.2.

The effects reported here contrast with the results of most previous work in the area of bilateral tariff reductions by Canada and the U.S., because the central case estimates suggest that Canada could lose from either bilateral abolition of tariffs (BTA) or unilateral abolition of tariffs on U.S. imports (UTA). The contrast of these results with those of Harris and Cox (6,12,13) is investigated in section II.7.

II.6.1 Canada-U.S. Tariff Abolition

Table 5 contains the estimated long-run effects of tariff abolition by Canada and the U.S. The first column shows the effect of a unilateral tariff cut by Canada on U.S. imports. The second row shows the effects of a unilateral cut by the U.S. on Canadian imports. Finally, the third row shows the effects of BTA.

A striking feature is the Canadian welfare loss, which contrasts with the large gains of Harris and Cox. This is partially attributable to the modest experiment conducted. Although the protection data present in the Harris-Cox model is very similar to the data used here, Harris and Cox analyse the effects of the reduction of all protection on all of Canada's trade with all countries.

Gains of over $1 billion annually exist to be shared between Canada and the U.S. as a result of liberalization, but without compensations, Canada could well suffer a welfare loss. The terms of trade go against Canada as a result of

TABLE 5: Tariff Removal Experiments on U.S.-Canada Bilateral Trade (Long-Run Central Case)

	Canada Abolishes Tariffs on U.S. Imports		U.S. Abolishes Tariffs on Canadian Imports		Bilateral Tariff Abolition	
Welfare[1]	$B	% of GNP	$B	% of GNP	$B	% of GNP
U.S.	1.5	.1	-.3	.0	1.2	.1
Canada	-.7	-.3	.5	.3	-.1	-.1
Terms of Trade	%Δ		%Δ		%Δ	
U.S.	+.8		-.2		+.6	
Canada	-3.0		+.4		-2.6	
Production %Δ	U.S.	Canada	U.S.	Canada	U.S.	Canada
Agr. & Food	.0	1.0	.0	.2	.0	1.2
Min.	-.2	1.7	.1	-.5	-.2	1.3
En.	.0	1.8	.1	-.2	.1	1.6
M1	.1	.3	.0	.3	.1	.6
M2	.0	2.8	.0	.9	.1	3.7
S & NT	.0	-.2	.0	.1	.0	-.1
I-O	M1	M2	M1	M2	M1	M2
# Firms	-.4%	-7.0%	.0%	-3.5%	-.4%	-10.5%
Length of Production Runs	+.7%	+9.8%	+.3%	+4.4%	+1.0%	+14.2%
Total Fixed Factor Savings[2]	$.5		$.1		$.7	

[1] Welfare effects reported as Hicksian equivalent variations (EVs) in billions of 1977 $U.S.

[2] Fixed factor savings are reported as the reduction in expenditures on fixed factors in the imperfectly competitive sectors. Values are in billions of 1977 $U.S.

BTA. This is counterintuitive from the point of view of traditional trade theory. Canada is often thought of as a small open economy, with little ability to affect the terms of trade, while the U.S. is a much larger trading partner. According to traditional theory, Canadian tariffs would be expected to cause domestic consumers to purchase less imports, but such tariffs would not have the effect of reducing the net-of-tariff price paid for the imports. This would not be true in the U.S. Tariffs imposed by the larger partner would be expected to decrease the price received by (Canadian) producers, yielding terms-of-trade gains. BTA would, thus, be expected to allow Canada to recapture some of these gains from the U.S. treasury.

This analysis is inappropriate in the current case for many reasons. First, trade in the model is not in terms of commodities which are perfect substitutes. As a result of this the hypothesized relation between elasticities of import demand and country size does not hold.[25] Secondly, Canadian tariff rates are initially about twice as high as those in the U.S. The relative height of tariffs is an important determinant of who may gain or lose from bilateral liberalization.[26] Finally, the 'terms-of-trade' effects reported in Table 5 have a second interpretation, related to the E-S hypothesis. One of the hypothesized outcomes of trade liberalization is improved efficiency of domestic producers, implying lower costs of production, and thus prices for Canadian-made manufactures. Part of the terms-of-trade losses reported are Canadian productive efficiency gains, attributable to larger production runs in both manufacturing sectors.[27]

While BTA is expected to cause small welfare losses to Canada, this qualitative result is somewhat sensitive to the elasticity specification of the model. Systematic sensitivity analysis of the welfare effects of BTA are presented in essay III of this thesis.

The rationalization effects generated are primarily the result of Canadian tariff cuts although additional rationalization occurs in the M2 sector as a result of U.S. cuts. These additional rationalization effects occur as an indirect result of the cut. Producer prices for M2 are virtually unchanged by the tariff cut, but the value of Canadian factors is increased. This results in a narrowing of the difference between price and marginal cost, in turn requiring longer production runs to eliminate economic losses.

Although Canadian tariffs are much higher on M1 than M2, the rationalization effects are much smaller due to the assumed monopolistically competitive structure. As discussed in section II.4.2.2, rationalization of a monopolistically competitive industry, through longer production runs, need not result from tariff liberalization. In order for rationalization to result from liberalization, the perceived elasticity of demand must rise, thereby reducing markups. In the case of the M1 industry, the market elasticity rises slightly as a result of either Canadian or U.S. tariff elimination. This results in small rationalization effects due to slightly reduced markups.[28] Larger rationalization effects result from BTA or UTA in the M2 industry, due to the unambiguous comparative statics of E-S pricing.

II.6.2 Unilateral Tariff Abolition by Canada

The welfare effects of UTA also reflect terms-of-trade losses. These must be interpreted differently than terms-of-trade effects from traditional models. The welfare loss to Canada of approximately $700 million is approximately equal to a 'traditional' terms-of-trade loss of $1.2 billion less fixed factor savings of $500 million. As in most NGE models of this type, countries which unilaterally cut tariffs experience traditional terms-of-trade losses.

The rationalization that occurs in Canadian manufacturing is illustrated by the effects on production and factor use presented in Table 6.

TABLE 6: Effects on Canada of Unilateral Tariff Abolition by Canada (% Changes)

	Output	Capital	Labour
Agr. & Food	+1.0	.9	1.0
Min.	+1.7	1.7	1.8
En.	+1.8	1.8	1.8
M1	.3	-.0	.0
M2	2.8	-1.5	-1.4
NT	-.2	-.3	-.1

A 2.8% increase in the output of M2 occurs as a result of UTA, even though total factor use falls. Total factor use falls by about 1.5%, but this represents an increase in variable factor use, which is less than the reduction in fixed factors used. Since there are 7% less firms in the industry as a result of UTA, there is a reduction by 7% in the use of capital and labour as fixed factors.

TABLE 7: Employment Effects of UTA on Canadian M2 Sector

	Value[1]	% Change
Change in Variable Labour	+.25	+3.3
Change in Fixed Labour	-.45	-7.0
Total Change	-.20	-1.5

[1] Values are in billions of 1977 US$.

II.6.3 Summary: Canada-U.S. Trade Liberalization

Using a model similar in structure to that used by Harris and Cox, both unilateral and bilateral tariff abolition by Canada on trade with the U.S. are found to cause welfare losses for Canada. These results contrast dramatically with the large welfare gains estimated by Harris and Cox as a result of their unilateral and multilateral free trade experiments. While the policy experiments analysed are different, the dramatic difference in results suggests that important differences in the models used remain. These differences are analysed in detail in the following section.

II.7 "MULTILATERAL" FREE TRADE RESULTS AND COMPARISONS TO HARRIS-COX

The previous section reported on the welfare and factor reallocation effects from two Canada-U.S. trade policy changes. UTA involves unilateral abolition by Canada of all tariffs on U.S. imports. BTA involves bilateral tariff abolition by Canada and the U.S. The welfare losses reported, and the small factor reallocations contrast dramatically with the results of Harris and Cox (see Table 8). Harris and Cox analyse policy experiments, referred to as MFT and UFT. MFT involves the elimination of all tariffs and other trade barriers[29] on all of Canada's imports, accompanied by the elimination of all protection on Canada's

TABLE 8: Comparison of Central Case Results

	Harris and Cox		Revised Whalley Model	
Experiment[1]	UFT	MFT	UTA	BTA
Welfare Effect[2]	4.1%	8.6%	-.3%	-.1%
Labour Reallocation[3]	5.1%	8.5%	.2%	.3%

1 Experiments are explained in the text.

2 Hicksian EV as a % of GNP.

3 % of the labour force that leaves employment in one industry and is re-employed in another.

exports to all other countries. Because of the two-country structure of the model, the MFT ("multilateral" free trade) is actually a comprehensive set of bilateral free trade proposals between Canada and the rest of the world. In this section, the revised Whalley model is used to estimate the effects of MFT as analysed by Harris and Cox. Dramatic differences between the results remain. These are discussed in sections II.7.1 and II.7.2.

II.7.1 "Multilateral" Free Trade

The revised Whalley model was used to evaluate the effects of MFT, "multilateral" free trade. In the context of the 8-bloc global model, this involved eliminating all protection on Canada's exports to all countries and all Canadian tariffs on imports from all countries. Trade restrictions on all other trade was left unchanged. The central case results of the MFT experiment are shown in Table 9.

TABLE 9: "Multilateral" Free Trade
(Elimination of all protection on all Canadian trade with all trading partners)

	Harris-Cox Central Case	Revised Whalley (Central Case)
Canadian Welfare[1]	+8.6%	+2.5%
Change in Average Length of Production Runs in Manufacturing	+67.%	+12.5%
Labour[2] Reallocation	8.5%	1.1%

[1] Hicksian EV reported as a % of GNP.

[2] % of labour force that leaves employment in one industry to become employed in another.

The revised Whalley model used to evaluate the results in Table 9 has similar protection data to that used in Harris and Cox. The primary sector protection used is identical, coming from the same source.[30] The protection on manufactures is crucially important to the size of rationalization gains. Protection is compared in Table 10. For comparison, the Harris-Cox protection data was aggregated to the 6-commodity aggregation here, while "world" rates were calculated from the protection data used here. As can be seen, the structure and level of total protection are quite similar.

TABLE 10: Comparisons of Tariff Rates

	Harris-Cox (Tariffs + NTBs)	Revised Whalley (Tariffs)	Revised Whalley (Tariffs + NTBs)
Canadian Tariffs			
M1	12.1%	12.4%	19.9%
M2	6.6%	5.0%	6.2%
"Foreign" Tariffs			
M1	17.3%	12.9%	15.4%
M2	4.4%	5.7%	5.7%

II.7.2 Unilateral Free Trade

The revised Whalley model was also used to evaluate the effects of unilateral abolition by Canada of all Canadian protection on imports from all other countries (UFT). This is the unilateral free trade experiment analysed by Harris and Cox. Once again, the results of the Whalley model are dramatically different. These results are briefly summarized in Table 11.

The observation of shorter production runs in Canadian manufacturing goes counter to the simple comparative statics of E-S pricing discussed in earlier sections. In this case, the result of UFT is to reduce the cost of production, at constant output per firm, of Canadian M2 by more than the selling price falls as a result of UFT. Protection equal

TABLE 11: Unilateral Free Trade

	Harris and Cox (Central Case)	Revised Whalley Model (Central Case)
Canadian Welfare[1]	+4.1%	-2.6%
Change in Average Length of Production Runs in Manufacturing	+41.%	-8.%
Labour Reallocation[2]	3.9%	1.5%

[1] Hicksian EV as a % of GNP.

[2] % of labour force that leaves employment in one industry and is re-employed in another.

to 5.5% is removed from M2, but producers' input prices fall by 8%. Reduced prices for producers' inputs result from the removal of Canadian protection, and the resulting decrease in Canadian factor prices. As a result of UFT, production in the manufacturing and service sectors fall, while production in the lightly protected energy and mining sectors rises.

II.7.3 Summary - Multilateral and Unilateral Free Trade

The MFT and UFT results calculated using the revised Whalley model contrast with those of Harris and Cox. Two major differences emerge. The welfare gains to Canada from MFT are much smaller using the revised Whalley model.

Welfare in Canada falls as a result of UFT using the revised Whalley model, whereas it rises in Harris and Cox. The factor reallocations and rationalization effects estimated with the revised Whalley model are also smaller. This is somewhat puzzling given the similarities of the models used. The source of the difference in welfare results, in particular, is examined in detail in section II.7.4.

II.7.4 Reconciliation of Harris and Cox and Revised Whalley Results

Tables 9 and 11 report dramatically different estimated results of the same policy experiments, using the Harris and Cox model and the revised Whalley model. As mentioned before, the levels of protection used in the two models are very similar, as are the basic trade and value-added data. This section first identifies possible sources of the discrepancy in welfare results, and where possible evaluates the contribution of each source to that discrepancy. Particular attention is paid to understanding the difference in the welfare results of MFT.

II.7.4.1 Significant Model Differences

Although the revised Whalley model and that of Harris and Cox are similar in many respects, structural and empirical differences remain, which contribute to the large discrepancy in results.

Some of the potentially important differences between the models are the following.

(i) Pricing behaviour in non-competitive industries.

(ii) Trade elasticities

(iii) Capital mobility assumption

(iv) Calibration procedure.

Other differences between the models do exist, but their contribution to the results obtained is less clear. For example, the level of aggregation differs between the two models. Harris and Cox have 29 industries, as opposed to 6 in the revised Whalley model. It is unclear how this difference in structure affects results. Similarly, some of the functional forms used in Harris and Cox are of the Cobb-Douglass variety, which implies an elasticity of substitution of 1. All functional forms in the revised Whalley model are of the nested CES variety, but since most of the elasticities of substitution are reasonably close to 1, it is unlikely that this is an important contributor to the difference in results.

In subsequent subsections, each of these items is discussed, and where possible, estimates of the impact of the items are provided. The importance of the capital mobility assumptions and trade elasticities are estimated, but a large residual remains, some of which may be attributable to the calibration procedure used by Harris and Cox.

It is argued that, although the precise implementation of pricing behaviour is different, the central cases analysed are comparable.

II.7.4.2 Pricing Behaviour

In the Harris and Cox model, each industry is made up of identical firms, some of which use MC pricing, and others of which use E-S pricing. In the central case results 50% of the firms in each industry are assumed to adopt each of the pricing policies. In fact, all firms change the same price, which is the simple mean of the MC and E-S prices.

In the revised Whalley model, all of the firms in the ~~non-~~mechanical manufacturing sector (M1) are assumed to follow MC pricing, while all firms in the equipment and vehicles sector (M2) are assumed to follow collusive (E-S) pricing. While the M1 sector is much larger than the M2 sector in terms of value added, the importance of trade to the M2 industry is much greater than that of the M1 industry. It is felt that the central case formulations used are comparable with respect to the pricing behaviour used.

Harris and Cox show that their model's results are very sensitive to the pricing behaviour, and present results corresponding to 80% E-S pricing. Comparing these results to the results of the current model with 100% E-S pricing does not serve to eliminate the discrepancy in results. These results are compared in Table 12.

TABLE 12: "Multilateral" Free Trade

	Harris and Cox Extreme Case 80% E-S Pricing	Harris and Cox (Approximation)* 100% E-S Pricing	Revised Whalley Extreme Case 100% E-S Pricing
Canadian Welfare[1]	+16.3%	+21.4%*	+8.5%
% Change in Average Length of Production Runs in Manufacturing	>100%*	>120%*	+43.%

1 Hicksian EV as a % of GNP

* Rough estimates based on available data.

II.7.4.3 Trade Elasticities

It is well known that the results of NGE models are very sensitive to the elasticity configuration used to calibrate the model. Harris and Cox use elasticity estimates which reflect 'elasticity optimism', being somewhat higher than the central case estimates used in the revised Whalley model. In order to facilitate comparison, MFT was evaluated in the Whalley model using higher trade elasticities comparable to those used by Harris and Cox.[31] This leads to a small change in the welfare effects due to the offsetting impacts of changes in the import and export elasticities. Changing the trade elasticities slightly reduces the difference between the results, as seen in Table 13.

TABLE 13: "Multilateral" Free Trade

	Harris and Cox (Central Case)	Revised Whalley Model (High Elasticities)
Canadian Welfare[1]	8.6%	3.2%
% Change in Average Length of Production Runs in Manufacturing	+67%	+18%

[1] Hicksian EV as a % of GNP.

These results will be used as the basis for comparison of the two models. They are based on:

(i) very similar protection data

(ii) very similar elasticity values

(iii) comparable pricing behaviour

(iv) the same trade policy experiment.

The Harris-Cox welfare results are almost three times as large as those from the revised Whalley model. Applying the welfare gain of 3.2% of GNP to Harris and Cox's 1976 base data, the absolute difference in the estimated welfare effects is in the order of $8.5 billion.[32]

II.7.4.4 Capital Mobility

As mentioned before, Harris and Cox assume that capital is freely mobile, or equivalently, that Canada faces an infinitely elastic supply curve of capital at the world interest rate. The revised Whalley model has no international capital mobility. A rough estimate of the added income resulting from capital mobility is available, particularly given the Cobb-Douglas structure of production assumed by Harris and Cox. Suppose that the aggregate demand for capital in Canada shifts to the right as a result of MFT. This is depicted in Figure 8.

The original (pre-MFT) demand for capital, D_K^O, intersects the supply of capital at point A. In the case of the revised Whalley model, the supply of capital is S_K^W. In the case of the Harris-Cox model, the supply of capital is S_K^H. If the two models were otherwise identical, the Whalley model would generate a new rental rate of R', with the same capital employed, while the Harris-Cox model would generate the new level of employment of capital of K' at the original rental rate R'.

Comparing the two post-MFT equilibria, notice that production in Canada in the case of the infinitely elastic supply curve will have risen by the area $\bar{K}_C$-K'-B-C. Note further, however, that foreign capitalists will have increased their incomes by the area $\bar{K}_C$-K'-A-C, leaving income

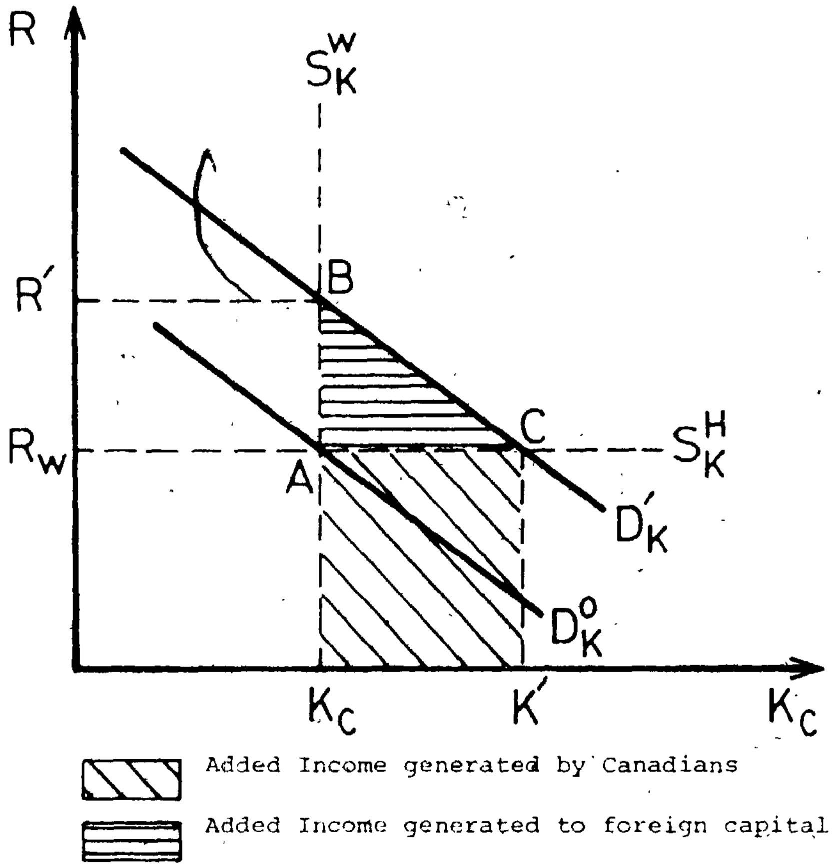

FIGURE 8: Effects of MFT in Canadian Capital Market

of the area A-B-C to be collected by Canadian firms and workers.

It is possible to roughly approximate the size of the area A-B-C, if we assume that an aggregate production function exists, which is also of the Cobb-Douglas form. In this case, the elasticity of marginal product of capital is equal to the share of labour in total value added (here approximately .75). Since the demand for capital curve is merely the value of the marginal product curve, knowledge of the elasticity of marginal product allows us to estimate the area of the triangle. Harris and Cox estimate the increase in capital services employed as a result of MFT to be $12.3 billion (20% of the original flow of services from capital). The vertical distance A-B is then approximately 15% of the world rental rate. The area A-B-C is then $.92 billion, or less than 1% of GNP.

II.7.4.5 Calibration Procedure

Both models are calibrated using extraneously specified values of several elasticities. The scale elasticity of cost is an important value, since it determines the amount of "fixed" factors assumed to exist in the pre-policy data.

The revised Whalley model is calibrated using an estimated scale elasticity of cost equal to .86. This means that 14% of original total cost in the Canadian manufacturing industries represents expenditure on fixed factors. This represents the upper limit on the "pure" rationalization savings available from extending production runs. In the case of the Whalley benchmark data, this upper limit is quite high, representing almost 15% of GNP.

Harris and Cox use an indirect calibration procedure, whereby a long-run benchmark equilibrium data set is inferred from the base data. In the base data, Harris and Cox use estimates of the scale elasticity of cost whose simple average is .97.[33] On the basis of these estimates, and the assumption of constant marginal cost, total expenditures on fixed factors in the base equilibrium data are approximately $5 billion or less than 3% of GNP.

From this 'base' data, Harris and Cox solve for a 'benchmark' long-run-equilibrium data set. In this data, there are 55% more firms in the benchmark data than in the base data. Markups, and, as a consequence, the share of fixed cost in total cost are much higher. Benchmark equilibrium markups are 18%, six times as high as the base long-run markups. This corresponds to an average scale elasticity of cost of .85, slightly lower than the benchmark equilibrium data of the revised Whalley model.[34] Fixed factors account for 15% of GNP in the benchmark data, as opposed to only 3% of GNP in the base data. The procedure by which the benchmark data is obtained from the base data is not explained in detail.[35]

If all of the fixed factors present in the benchmark data, but not in the base data were to be added to the welfare gains from liberalization, this would more than account for the unresolved difference in welfare effects. It is unclear how these additional fixed factors might come to be added to the welfare gains of liberalization. One third of the additional fixed factors introduced into the benchmark equilibrium by indirect calibration would exactly make up the difference in welfare results which remain after account has been taken of the impact of different trade elasticities and different capital mobility assumptions.

II.7.4.6 Summary - Reconciliation of MFT Results

This section has attempted to reconcile the MFT results from the Harris and Cox model, and the revised Whalley model. Two features contributing to the difference in welfare results are analysed and their impact evaluated. Differences in the trade elasticities used and the capital mobility assumptions used, account for approximately one quarter of the 6.1% difference in the central case welfare results. A third potential contributor to the difference in welfare results, the indirect calibration procedure used by Harris and Cox, is identified, but its quantitative contribution to the larger welfare gains in Harris and Cox is not estimated. Further details of the calibration procedure would aid this endeavour.

II.8 CONCLUSIONS AND POLICY IMPLICATIONS

This essay has presented the estimated effects of trade liberalization by Canada on a unilateral, bilateral and multilateral basis. It is found that both bilateral and unilateral tariff abolition by Canada are likely to cause welfare losses to Canada. These findings contrast dramatically with the results of Harris and Cox (6,12,13), who find that substantial welfare gains result from trade liberalization on either a unilateral or multilateral basis. The contrast between the unilateral results presented here, and those of Harris and Cox is somewhat surprising given the similarity of the models.

In an attempt to better understand the cause of the difference between the models, the revised Whalley model is used to evaluate the effect of multilateral free trade. In this case, both models suggest that large welfare gains to Canada can result from MFT, but the size of gains estimated by Harris and Cox are larger by 6.1% of GNP. Attempts to reconcile this difference in section II.7 are only partly successful, with trade elasticities and capital mobility assumptions identified as being responsible for approximately one quarter of this difference. A third potential source of the discrepancy, the indirect calibration procedure, is identified, but its contribution is not evaluated.

The policy implications of these results, particularly the result of bilateral tariff abolition (BTA), can easily be misunderstood. While it is true that Canada is expected to suffer small losses as a result of BTA, it is still true that BTA generates joint welfare gains for Canada and the U.S. In other words, the U.S. welfare gain is much larger (more than ten times larger) than the Canadian welfare loss. Two approaches to liberalization can assure mutual gains in such a case. If the U.S. were to agree to complete elimination of tariffs, while Canada reduced tariffs by less than 100%, mutual gains could be assured. Alternatively, the U.S. could easily compensate Canada for its expected welfare losses.

While it is usual to compare the effects of bilateral liberalization to the status-quo, such a perspective may be naive. Since the conclusion of the Tokyo Round of the G.A.T.T., the protectionist lobby in the U.S. has progressively become more vocal. Some would argue that in the absence of momentum for trade liberalization, inertia can develop on the side of protectionism. If such is the case, the small welfare losses expected to result from bilateral abolition may still be preferable to the effects of protectionism by the U.S.

The gains available to Canada from more broadly based liberalization are illustrated by the effects of MFT. These welfare gains represent significant incentives to pursue trade liberalization, particularly in the multilateral forum.

The message of the results reported here is, however, cautionary. While bilateral liberalization experiments such as BTA are found to generate welfare gains to the U.S.

and Canada jointly, it does not follow that any such bilateral arrangement will assure welfare gains to the U.S. and Canada separately.

ENDNOTES FOR II

1. By additional firms, I mean firms which are present in the benchmark but not the base data.

2. See in particular Wonnacott and Wonnacott (28, 29). English (8) raises similar points, but Eastman and Stykolt (7) are clearer in their statement of the relation between industrial rationalization and tariffs.

3. See Williams (27), Table 3.3.

4. This effect is present in Boadway and Treddenick (2).

5. The model is similar to that of Evans (9). Williams does not emphasize tax abolition although Chapter 2 clearly makes this point. See page 53.

6. The labour reallocation effects calculated by Williams are discussed in detail below.

7. Although they suggest the protection data is for 1971, it is based on original documents corresponding to 1976.

8. The U.S. firms are assumed to have achieved the MES level of output, so that changes in Canadian trade policy do not affect U.S. marginal costs or pricing.

9. Harris and Cox assume that firms in the short-run do not change the mark-up applied to marginal cost.

10. See Chamberlin (4).

11. Canadian firms are assumed to be unable (or unwilling) to price discriminate between Canadian and foreign consumers.

12. This partial equilibrium analysis ignores (among other things) the reduction in marginal cost likely to result from reduced tariffs on U.S. imports.

13. Hazledine (16) finds evidence that economies of scale do not exist in Canada's manufacturing industries. He finds that average costs per firm are constant but that average costs in an industry may decline as a result of tariff cuts as less efficient producers are forced from the market.

14. The elasticities calculated reflect substitution by consumers in final demand, and the implied increases in intermediate use, but they do not reflect changes in total demand caused by substitution in intermediate use. The elasticity of total market demand would presumably include the effects of such substitution. The notion of such a market price elasticity of demand is inconsistent with the zero-profit condition used to infer producer's prices in the model. Harris and Cox experience the same problem and deal with it in a similar way (12, p. 88).

15. The central case trade elasticities used correspond to a recent survey by Harrison (15). Elasticities of capital-for-labour substitution were estimated by the author for some related work. The elasticities used, and their standard errors are reported in Appendix A.

16. This assumption dramatically simplifies solution of the model. It is unclear that it will bias the result compared to the more plausible assumption that fixed costs are made up of produced inputs as well as primary factors.

17. In all cases, the desired inequality between α and ε holds.

18. Examples are the algorithm of Van der Laan and Talman (25), and the Scarf algorithm (22).

19. See Harrison and Kimbell (14).

20. The case where a price is zero, and the corresponding excess supply is positive is ignored for simplicity. Equally, the addition of a revenue term to deal with taxes and tariffs present in the model is ignored.

21. In some cases the level of output per firm may affect average cost.

22. These conditions distinguish models such as that of Shoven and Whalley (24) from earlier models such as Evans (9).

23. The number of firms term n_j is also rescaled to allow the entire vector of elements on the simplex to be rescaled without changing the real magnitude of the excess demands.

24. This is a feature common to Harris and Cox (6,12,13).

25. The estimated elasticities of import demand for the U.S. and Canada are very similar. The central case elasticities used for the U.S. and Canadian import price elasticities are 1.41 and 1.19 respectively.

26. See Markusen (20).

27. The size of the terms-of-trade losses is amplified when E-S pricing is present in both Canadian manufacturing industries.

28. Markups fall from 16.67% to 16.64%.

29. NTB's are modelled as tariff equivalents.

30. Protection data for both models was assembled from data supplied by the office of the Special Trade Representative in Washington.

31. Harris and Cox use Canadian export demand and import price elasticities which average 1.7. The Whalley model was solved with elasticities of substitution corresponding to the relevant means plus 1.4 standard errors. This leads to an import price elasticity of demand for Canada of 1.7 and an elasticity of demand for Canadian exports of 1.5. The elasticity of U.S. demand for imports was 1.9.

32. An additional run was completed, setting the U.S. and Canadian import elasticities, and the common export elasticity to 2.5. This further reduced, but did not eliminate, the discrepancy in results. The resulting welfare effect was still more than 3% lower than the Harris and Cox result.

33. See Harris and Cox (6), Appendix Table B3. Base long-run markups can be determined by subtracting the scale elasticity from 1.

34. See Harris and Cox (6, p. 106).

35. See Harris and Cox (6, pp. 174-175).

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APPENDIX A

TRADE ELASTICITIES USED

ELASTICITY	VALUE	STANDARD ERROR
SIG(EC)	1.109	.350
SIG(US)	1.413	.341
SIG(JAPAN)	1.024	.322
SIG(CANADA)	1.194	.363
SIG(OD)	.962	.482
SIG(OPEC)	.897	.383
SIG(NIC)	1.365	.789
SIG(LDC)	1.472	.718
SIGI	1.082	.326

III.1 INTRODUCTION

This essay will present "conditional" and "unconditional" systematic sensitivity results for the adjustment and welfare effects of some multilateral and bilateral trade liberalization experiments. These are evaluated in the context of John Whalley's 7-bloc model of world trade[1] and a revised version of Whalley's 8-bloc model respectively. The essay will concentrate on sensitivity to elasticity specification. Related issues of empirical specification (data and aggregation) and structural specification are briefly considered in section (i).[2]

The work reported here differs from previous work in that unconditional systematic sensitivity results are reported. Further, the calculation of the unconditional results permits the evaluation of a resource-saving approximation technique suggested by Pagan and Shannon (14). This technique has not previously been applied to a real data NGE model. It is possible to recommend a time-saving and accurate method for the calculation and presentation of systematic sensitivity results. An important focus of the systematic sensitivity results will be the intuition behind the results. It will be shown that the sensitivity results verify earlier work in the context of more abstract models.

III.2 SPECIFICATION OF NUMERICAL GENERAL EQUILIBRIUM MODELS

The results of numerical general equilibrium (NGE) models depend on many "empirical" and "structural" features of their specification. The elasticities, functional forms, aggregation scheme as well as the data and "benchmarking" procedures are elements of an NGE model's empirical specification. The market equilibrium conditions implied by the model are elements of the structural specification.

III.2.1 Structural Features of NGE Models

Four major elements make up the structure of an NGE model:

1. Basic Methodology
2. Model Closure
3. Factor Mobility Assumptions
4. Market Structure

Three basic methodologies have been used in NGE modelling, the Johansen approach, the Scarf approach and the linear programming approach.[3] The analysis of a 5% excise tax will be used to contrast the three methodologies.

The Johansen model would use estimates of the elasticities of supply and demand to calculate approximate changes in prices (and thus outputs) that would lead to the satisfaction of the equilibrium conditions assumed to hold. In the simplest case, the following equation system would need to be solved:

$$\%\Delta P - \%\Delta P^{C} = .5\% \qquad (1)$$

$$\%\Delta Q^{S} = \%\Delta Q^{D} \qquad (2)$$

where P equals the producer's price and P^{C} denotes the price consumers pay. Q^{S} and Q^{D} represent the quantities supplied and demanded respectively, and %Δ means proportionate change. Typically, of course, many more equilibrium conditions would be present and the demand functions will depend on both the own price and the prices of related goods. In any event, however, the solution derived will be a linear approximation to the new (post-tax) equilibrium. The advantages of this methodology are that it is easily learned and very easy to implement. The data requirements are also less stringent than with the Scarf methodology. The ORANI model[4] uses the Johansen methodology.

The 7-bloc model uses the Scarf methodology in which explicit production and utility functions (or their equivalents) are specified in such a way as to have demand and supply elasticities similar to available empirical estimates. Models are benchmarked to an original micro-consistent data set and a new equilibrium corresponding to the post-tax situation is calculated. The major advantage of this modelling approach is its transparency. Consumers have explicit budget constraints (involving gross of tax prices), while firms maximize profit subject to technological constraints at net of tax prices. In this example, the revenues from the tax are either returned to consumers or spent by a "government" consumer. The drawback of the approach is that data assembly is cumbersome and the resulting models are more difficult to solve.

The linear programming technique has been used less frequently in recent years. Linear programming models assume fixed coefficient production and thus do not allow for price-induced changes in shares in production or consumption. As noted in Essay II, these model results are driven by a peculiar price mechanism. The models are not dramatically easier to solve than the Scarf type models.

NGE models also differ in the way they are closed. Briefly, one country models use simple closing rules that represent "small country" assumptions. For example, Harris and Cox (7) suggest that Canada faces a fixed rental rate on capital, rather than explicitly modelling the world capital market. Global models explicitly close all of the markets. In this case (as in the 7-bloc model), explicit markets for all traded commodities and assets exist.

Models also vary in their factor mobility assumptions.

Factors may be industry-specific, country-specific, or freely mobile between countries and industries.

Finally, markets may be perfectly competitive and free of any price rigidities or they may allow some prices to be rigid. A recent innovation to NGE models is that of Harris and Cox (7) which specifies a non-competitive market structure.

III.2.2 Empirical Specification

The elements of empirical specification are more easily addressed, and attract less heated disagreement.

The process of "benchmarking" the model is a process of assuring that the model has as much in common with the true economy as possible. In particular, one would want a "no-policy-change" equilibrium to reproduce some base equilibrium data. There are two closely related ways in which this is done. Benchmarking is often referred to as calibration.

Direct benchmarking requires that a micro-consistent data set be assembled (one where all of the budget constraints hold and all of the supply equals demand conditions hold). Once this data set has been assembled, extraneous values of the elasticities are used to infer the share parameters of production and utility functions (having imposed the functional form). The 7-bloc model uses direct benchmarking, as does the 8-bloc model.

Indirect benchmarking involves assembling a microconsistent base data set which does not satisfy all of the equilibrium conditions of the general equilibrium. In particular, some industries may be making excess profits while others are making losses. In this case, the parameters are determined as before, but the benchmark data set is then determined by imposing the (long-run) zero profit condition. The indirect method is used by Harris and Cox.[5]

Data and elasticities are an important element of the benchmarking procedures and can affect the results. Elasticities for the models are usually chosen by literature search, with "best guess" values being inferred to correspond to particular model aggregation. Where possible, available data may be used to estimate elasticities corresponding directly to the model's aggregation.[6]

Most models (with the notable exception of the linear programming models) implicitly use the Armington approach to treat commodities produced in different countries as imperfect substitutes.[7] Since the level of aggregation in models may vary from six commodities in the 7-bloc model to 108 commodities in the model of Baldwin et al. (2), an open question is whether the elasticities should be different depending on the level of aggregation.

III.3 SYSTEMATIC SENSITIVITY

Model results depend on all of the elements of specification noted above, and little progress has been made towards choosing a "best" model specification procedure. Even given the model structure, it has often appeared that model results were too sensitive to elasticity specification for the NGE approach to give any useful insight into the quantitative effects of trade policy changes. Until very recently, no models presented systematic analysis of the model results' sensitivity to elasticity specification. Harrison (8) was the first to present such results. In what follows, a detailed sensitivity analysis of the liberalization experiments conducted in Essays I and II will be presented. The sensitivity properties of the models used are found to be somewhat different to the structurally similar model of Harrison.

III.3.1 Brief Overview of Elasticity Sensitivity

Systematic sensitivity analysis uses knowledge about the imprecision of elasticity estimates to generate measures of the resulting imprecision of results.

III.3.1.1 Presentation of Sensitivity Results

Consider any calculated result (welfare effect for example) from a specified policy experiment (such as a tax or tariff cut). We could denote this result:

$$Y = G(X, \sigma) \qquad (3)$$

where X is the vector describing the policy parameters and σ is the complete vector of extraneously specified elasticity values. G represents the mapping of the policy changes into results generated by the model.

Researchers will be interested in one or more of the following measures of the results of interest:

(a) "Point Estimate";
(b) Mean Value;
(c) confidence intervals or probability of gain;
(d) extreme bounds.

The following ways of presenting sensitivity results are available:

(i) limited sensitivity
(ii) conditional systematic sensitivity
(iii) unconditional systematic sensitivity
(iv) linear interpolation.

Stern (3) presents point estimates of results of a 50% multilateral tariff reduction for nine alternative sets of best guess values of the import and export elasticities in his 18 country model. These results suggest very wide extreme bounds on the results of interest. In particular, the employment and net trade effects take on both signs.

Whalley (16) presents sensitivity results to elasticity values by presenting a table of results corresponding to (i) perturbation of all import elasticities in all regions to two common "extreme" values; (ii) perturbation of all export elasticities in all regions to two common extreme values; and finally, (iii) perturbation of all import income elasticities to common extreme values in the LDC and NIC blocs. In each instance, the other elasticities are left at their best guess values.

In the 7-bloc and 8-bloc models, calibration of the model in terms of trade elasticities is achieved by varying elasticities of substitution in the (CES) utility functions and the (CES) intermediate use functions. Specifically, the model is calibrated to a given export price elasticity by setting the elasticity of substitution between domestic goods and imported goods to that value. Similarly, the model is calibrated to a given import price elasticity by setting the elasticity of substitution between imports from different countries to that value.[8]

Whalley's sensitivity results show less sensitivity than those of Stern, but the (terms of trade and welfare) effects occasionally take on both signs.

The sensitivity results presented by Stern and Whalley are denoted limited sensitivity analysis and may be difficult to interpret. This type of sensitivity analysis does not use available knowledge about the accuracy of elasticity estimates.

Conditional systematic sensitivity analysis (CSSA) involves the evaluation of y for values of the vector ε generated by moving each elasticity away from its point estimate while holding all others at their point estimates. It is then possible to compare the point estimate result y to the mean result $\bar{y}$ calculated as follows:

$$\bar{y} = \frac{1}{\sum_{i=1}^{S} f(\varepsilon^i)} \left[\sum_{i=1}^{S} f(\varepsilon^i) G(X, \varepsilon^i) \right] \qquad (4)$$

$$\hat{y} = G(X, \hat{\varepsilon})$$

S, the number of solutions, will be equal to one plus the number of values (other than the mean) which each parameter takes times the number of elasticities to be varied. $\hat{\varepsilon}$ refers to the vector of point estimates of the elasticity vector derived from econometric estimates. The point estimate $\hat{\varepsilon}$ is sometimes calculated as the mean of a sample of estimated means from several econometric studies, while in other cases it will be estimated for the particular work in question.[9]

Unconditional systematic sensitivity analysis (USSA) involves solving the model for values of σ generated by independently varying each elasticity over a given range (in terms of that elasticity's standard error).

For example, if there were two elasticities (σ_1 and σ_2) to be varied and each elasticity was to take on one value above the point estimate and one value below, the values of σ to be considered in the CSSA and USSA respectively would be as follows:

TABLE 1: Elasticity Values Considered

CSSA			USSA		
	σ_1	σ_2		σ_1	σ_2
1	0	0	1	0	0
2	1	0	2	0	1
3	-1	0	3	0	-1
4	0	1	4	1	0
5	0	-1	5	1	1
			6	1	-1
			7	-1	0
			8	-1	1
			9	-1	-1

where 0 refers to the point estimate and 1 and -1 refer to the positive and negative values respectively. The unconditional systematic sensitivity results will require many solutions of the model. Calculation of an unconditional sensitivity with NV values for each of NP elasticities would require NV^{NP} solutions of the model.

Harrison (8) presents CSSA results for a 50% multilateral tariff cut by developed countries in his 12 country model. Of particular interest is his observation that the results of his model are similar to those of Whalley given the uncertainty about elasticities. The mean estimates generated this way are very close to the point estimates (see Table 5, page 20 of Harrison (8)). Harrison notes that USSA is more complete but was infeasible for his model.

In related work, Harrison (9) computes a USSA for a very simple hypothetical GE model. Here, the degree of sensitivity of results to the elasticity of (capital-for-labour) substitution is impossible to predict without full knowledge of the model. In many of his simulations, the results are very sensitive to this elasticity, with relative factor prices changing by as much as 100 times when this elasticity goes from .2 to 4.9.

Both the conditional and unconditional systematic sensitivity results allow for the calculation of means, extreme bounds and confidence intervals if we know the form of $f(\sigma)$. While the unconditional sensitivity analysis is preferable to the conditional, calculation of an unconditional sensitivity analysis to all of the elasticities may be infeasible. There are 14 elasticities considered for sensitivity analysis in the 7-bloc model. An unconditional analysis involving only 5 values per elasticity[10] would require in excess of 6 billion solutions of the model.[11]

Partially in recognition of this fact, a linear interpolation procedure suggested by Pagan and Shannon (in the context of linearized NGE models)[12] will be considered. This procedure involves inferring elasticity multipliers for the welfare effects from the conditional sensitivity analysis to allow the approximation of the results of an unconditional sensitivity. This approximation would be exactly correct if the Hessian matrix of G with respect to σ was diagonal. This would dramatically reduce the time necessary for calculation of an approximate unconditional sensitivity.[13]

III.3.2 Technical Problems

Before turning to the analysis of the 7-bloc model, it is worth noting that some of the desired ingredients of our analysis are not present. Most notably, we refer to a p.d.f. for σ in equations (3) and (4). We would ideally like a jointly estimated probability density function for the complete vector of elasticities, since it is likely that some of the elasticity values we use (such as the import price elasticities) are subject to interdependent errors in estimation.

The p.d.f. used for the trade elasticities and elasticities of capital-labour substitution are all univariate normal. This ignores the fact that at least some of these elasticities are subject to interdependent errors in estimation. The mean and standard deviation of a sample of estimates of each of the trade elasticities was used, and estimated point estimates and standard errors of the elasticities of substitution were used.

A careful analysis of the systematic sensitivity of all of the welfare, trade volume, employment and terms of trade effects computed by the 7-bloc model is well beyond the scope of this essay. The main focus of this essay will be the sensitivity of U.S. welfare (as measured by a Hicksian equivalent variation) and U.S. factor adjustments to three different experiments, and Canadian welfare and adjustments to the third experiment only.

(i) A 50% Multilateral Reduction in Developed Country Tariffs (7-bloc model);

(ii) A 50% Multilateral Reduction in <u>All</u> Tariffs (7-bloc model);

(iii) Formation of a Canada-U.S. Free Tariff area (8-bloc model).

This narrow focussing of the analysis is necessary for both practical and technical reasons. It is impractical to analyze the mountains of data generated by a systematic sensitivity of all of the model's results. It presents a practical problem since the volume of data to be stored becomes unmanageable.

Three classes of elasticities will be considered for sensitivity analysis in both models.

(i) Elasticities of substitution between import types - these import elasticities are the same for all commodities in a given bloc. This elasticity is referred to as SIG and they differ by bloc.

(ii) The common elasticity of substitution between imports and domestic production. This value is assumed to be the same for all blocs and all commodities and is referred to as SIGI.

(iii) The elasticity of substitution between capital and labour is referred to as SUB. SUB is the same in a given industry in all blocs. There are thus 6 SUBs.

As noted before, SIG is calibrated to the estimated import elasticity of demand, while SIGI is calibrated to the estimated price elasticity of demand for exports. As specified, all blocs are assumed to face the same export price elasticity.

In the 8-bloc model, an additional pair of elasticities will be varied. These are the shares of total cost attributable to fixed costs in the two non-competitive industries in Canada. In the case of monopolistically competitive pricing, there is a one-to-one correspondence between the share of fixed costs (λ) and the perceived elasticity of demand (η).[14] Specifically,

$$\lambda = \frac{1}{\eta}$$

This is true since the original data is assumed to be a long-run equilibrium.

The analysis of each of the trade experiments will begin with a discussion of the point estimates of the welfare and adjustment effects. Conditional sensitivity (CSSA) results will then be discussed. These CSSA results will be used to choose elasticities for inclusion in the unconditional systematic sensitivity analysis (USSA). Finally, the USSA results will be compared to Pagan-Shannon approximations.

In all cases, reference will be made to two sets of point estimates for the elasticities used in the 7-bloc model. The point estimates used by Whalley will be referred to as JWPE elasticities. The point estimates corresponding to a revised literature survey by Harrison (9) and new estimates of the elasticities of substitution will be referred to as HWPE elasticities.

III.4 THE WELFARE AND EMPLOYMENT EFFECTS OF A 50% TARIFF CUT BY THE DEVELOPED BLOCS

The point estimates of welfare corresponding to the JWPE and revised HWPE elasticities are presented in Table 2. The welfare effects change in response to the revised elasticities. In the case of both the EEC and the LDC bloc, the qualitative result is changed.

TABLE 2: Point Estimates of Welfare Effects of 50% Tariff Cut By the Developed Blocs[1]

	JWPE	HWPE
E.E.C.	0.66	-.21
U.S.	-1.07	-.99
Japan	.83	.84
O. Dev.	.63	1.06
O.P.E.C.	.18	.23
N.I.C.	.21	.50
L.D.C.	-.16	.26
World	1.30	1.69

[1] Welfare effects are reported as Hicksian EVs in billions of 1977 U.S. $.

These results correspond to the long-run assumptions described earlier. CSSA results were calculated in order to choose elasticities for inclusion in a limited USSA. The CSSA results shown in Table 3 reflect that many of the welfare results are quite sensitive to the elasticity specification of the model. In particular, the extreme values of welfare for the EEC, the OD bloc, OPEC and the LDC bloc all straddle the origin.

TABLE 3: CSSA Welfare Results
50% Tariff Cut by Developed Blocs-Welfare (Hicksian EV $US billion 1977)

	Point Estimate	Mean	Standard Error	Minimum Value	Maximum Value	Probability of Gain
E.E.C.	-.21	-.23	.43	-2.88	1.35	.09
U.S.	-.99	-1.00	.16	-1.96	-.44	.00
Japan	.84	.83	.10	.15	1.08	1.00
O. Dev.	1.06	1.10	.61	-.48	5.50	.98
O.P.E.C.	.23	.22	.05	-.22	.30	.99
N.I.C.	.50	.50	.08	.21	.78	1.00
L.D.C.	.26	.25	.09	-.16	.57	.98
World	1.69	1.67	.13	.99	1.97	1.00

Employment Reallocation Effects - U.S. Industries*

Sector	Point Estimate	Mean	Minimum Value	Maximum Value	Probability of Increase
Ag.&Food	.05	.05	.03	.07	1.00
Mining	-.22	-.22	-.62	-.05	.00
Energy	-17.56	-17.56	-17.75	-17.39	.00
M1	.06	.06	.02	.09	1.00
M2	-.18	-.18	-.20	-.14	.00
Non-traded	.09	.09	.08	.10	1.00
Total	.08	.08	.08	.09	

* Percentage change in employment.
Total is percentage of total employment required to move between industries.

M1 - Non-mechanical manufacturing
M2 - Equipment and vehicle manufacturing

The energy sector faces a dramatic change in employment, but this decline is small in absolute terms at under $1 billion. The energy sector has by far the smallest employment of any of the industries (see Table 4).

TABLE 4: Employment by Industry (U.S.) and Capital/Labour Ratio

	Employment*	K/L
Ag. & Food	55.5	.98
Mining	16.3	.83
Energy	4.1	.26
M1	189.1	.22
M2	133.0	.14
Non-traded	900.1	.20
Total	1298.0	.23

* $ Billion 1977

III.4.1 Selection of Elasticities for USSA

The relative "importance" of elasticities to the results of NGE modelling depends on both the type of results which are of primary interest and the policy experiment considered. Two suggested indicators of the sensitivity of (e.g.) U.S. welfare to different elasticities could be used. The difference between U.S. welfare when the elasticity is at +1.4 standard errors and when it is at -1.4 standard errors in the CSSA is used as the preferred index of elasticity sensitivity of results. The measure suggested by Pagan and Shannon is this difference divided by the movement in the elasticity of interest (here 2.8 standard errors). The two measures are shown in Table 5. The measure suggested by Pagan and Shannon is referred to as PS and the preferred measure is called DIST. DIST is used to rank the elasticities in terms of their effect on U.S. welfare, since it takes account of the imprecision of our estimates as well as the direct impact of a given unit change of the elasticities.

U.S. welfare is affected most by changes in its own import price elasticity and the import price elasticities of the U.S.'s major trading partners. The common export elasticity is also very important.

TABLE 5: Importance of Elasticities to U.S. Welfare

50% Tariff Cut by Developed Blocs

Elasticity	DIST	Rank	PS
SIG (E.E.C.)	.306	4	.312
SIG (U.S.)	1.000	2	1.047
SIG (Japan)	.182	5	.202
SIG (O.Dev.)	1.297	1	.961
SIG (O.P.E.C.)	.013	8	.012
SIG (N.I.C.)	.049	6	.022
SIG (L.D.C.)	.012	9	.006
SIGI	.316	3	.347
SUB (Ag. & Food)	.001	11	.009
SUB (Mining)	.001	11	.003
SUB (Energy)	N.A.		N.A.[15]
SUB (M1)	.001	11	.003
SUB (M2)	.002	10	.010
SUB (Non-traded)	.014	7	.010

M1 refers to non-mechanical manufacturing
M2 refers to equipment and vehicles manufacturing

The non-traded sector elasticity of capital-for-labour substitution is the most important of the SUBs but its absolute contribution is quite small compared to the trade elasticities. This may result from the special structure of the model which has a common value for SUB in all blocs in a given industry.

"Importance" numbers have also been calculated for the employment changes in the U.S. A similar pattern emerged in these results, with the U.S. and OD import elasticities having the largest impact on labour reallocations, with the elasticity of capital-labour substitution in the non-traded sector having a smaller effect than these trade elasticities, but a larger effect than any of the other capital-for-labour elasticities.

USSA was conducted for the 50% tariff cut by developed blocs. The elasticities varied were the import price elasticities for the EEC, the U.S., and the OD bloc. These results are presented in Table 6.

The welfare effects from several blocs straddle the origin in the USSA. The EEC, U.S., the OD bloc and the LDC bloc all fall into this category. In every case except the EEC, the bulk of the p.d.f. lies on one side of the origin. The EEC has a 38% probability of experiencing a welfare gain from a developed bloc tariff cut of 50%. The uncertainty in this statement comes from the uncertainty about our elasticity estimates.

TABLE 6: USSA Welfare Results
50% Tariff Cut by Developed Blocs
Welfare (Hicksian EV $US billion 1977)

	Point Estimate	Mean	Standard Error	Minimum Value	Maximum Value	Probability of Gain
E.E.C.	-.21	-.40	1.28	-3.86	2.58	.38
U.S.	-.99	-1.06	.50	-2.36	.32	.02
Japan	.84	.76	.28	.01	1.30	1.00
O. Dev.	1.06	1.43	1.82	-1.75	6.61	.78
O.P.E.C.	.23	.16	.15	-.31	.33	.89
N.I.C.	.50	.45	.14	.04	.82	1.00
L.D.C.	.26	.20	.20	-.35	.61	.85
World	1.69	1.55	.33	.59	2.23	1.00

Employment Reallocation Effects - U.S. Industries*

Sector	Point Estimate	Mean	Minimum Value	Maximum Value	Probability of Increase
Ag. & Food	.05	.05	.01	.06	1.00
Mining	-.22	-.25	-.77	.12	.07
Energy	-17.56	-17.56	-17.85	-17.24	.00
M1	.06	.06	.02	.12	1.00
M2	-.18	-.18	-.22	-.13	.00
Non-traded	.09	.09	.08	.10	1.00
Total	.08	.08	.08	.09	

* Percentage change in employment.

The employment reallocation effects are small and are relatively insensitive to the elasticity specification. This is likely due to the fact that the tariff rates reduced are originally small.

The fact that the USSA generates wider bounds for the U.S. is not surprising since all of the solutions from the CSSA which involved the important elasticities are included in the USSA. Note that the bounds for all blocs' welfare need not be wider in the USSA than the CSSA since the elasticities were chosen for inclusion in the USSA on the basis of their impact on U.S. welfare. The extreme bounds of U.S. welfare do correspond to extreme values of the elasticities.

Reviewing the range of solutions, three "rules of thumb" appear to emerge from the systematic sensitivity analysis relevant to the welfare effects. First, the more elastic the bloc's demand for imports, the larger their losses (or the smaller their gains). Secondly, the more elastic are your trading partner's demands for imports, the smaller the losses (or the larger the gains). Finally, the larger the (common) elasticity of demand for exports, the larger the gains to be shared from trade liberalization.[16] This is illustrated for the U.S. in Table 7.

III.4.2 Pagan/Shannon Interpolation

An approximation technique suggested by Pagan and Shannon was also used to approximate the USSA results reported in Table 6. The technique involves the calculation of

TABLE [illegible]. Outliers for U.S. Welfare From 50% Multilateral Tariff Cut by Developed Blocs

U.S. Welfare	U.S. Import Elasticity	OD Import Elasticity	Common Export Elasticity
-2.36	Highest	Lowest	Lowest
.32	Lowest	Highest	Highest

approximate first derivatives of G for a given policy using unconditional sensitivity results. That is, we would like an approximation of:

$$\frac{DG(X,\sigma)}{d\sigma_j} = G_j \tag{5}$$

The welfare corresponding to a given policy and a given value σ^1 for the vector of elasticities would be approximated by:

$$\hat{y} = y + (\sigma^1 - \sigma)(G_*) \tag{6}$$

where y is the point estimate of the result of interest and G_* is the vector of approximate first derivatives of $G(X,\sigma)$. The approximation $\hat{y}$ will not be very accurate if the interaction terms are large, that is if the terms:

$$\frac{d^2G(X,\sigma)}{d\sigma_i d\sigma_k} \tag{7}$$

are very large we would expect the approximations to be very poor. If G( ) is approximately linear, the approximation should be good.

To measure the goodness of fit of the approximation, R^2 was calculated as:

$$R^2 = \frac{\sum_{i=1}^{S} f(x^i)(y_i - \hat{y}_i)^2}{\sum_{i=1}^{S} f(x^i)(y_i - \bar{y})^2}$$

where $\hat{y}_i$ is the approximation corresponding to the solution of the model y_i. The R^2 value for each bloc's welfare is above 95%, suggesting that the approximation technique is very useful.

The Pagan/Shannon approximations are presented below.

TABLE 8: Comparison of USSA and PS Approximations - Welfare

Bloc	Mean		Standard Error		Prob. of Welfare Gain	
	USSA	PS	USSA	PS	USSA	PS
E.E.C.	-.40	-.42	1.28	1.28	.38	.38
U.S.	-1.06	-1.08	.50	.48	.02	.00
Japan	.76	.77	.28	.28	1.00	1.00
O. Dev.	1.43	1.47	1.82	1.82	.78	.80
O.P.E.C.	.16	.16	.15	.15	.89	.89
N.I.C.	.45	.46	.14	.14	[illegible]	1.00
L.D.C.	.20	.21	.20	.20	.85	.86
World	1.55	1.57	.33	.33	1.00	1.00

Although the employment reallocation numbers seem to be well approximated by the PS interpolation, the results in Table 9 are somewhat misleading. When the R^2 calculations for all of the employment reallocations are calculated, the values are not all high. For some of the results, the PS interpolation is a poor estimator of the actual values of the employment effects. Some of the R^2 values are negative. The service sector numbers for the EEC, U.S. and the NIC bloc are all quite low, as are the total reallocations for several blocs.

TABLE 9: Comparison of U.S. Labour Reallocation Effects - 50% Multilateral Tariff Cut by Developed Blocs ($US billion 1977)

Sector	Mean		Standard Error		Prob. of Increase	
	USSA	PS	USSA	PS	USSA	PS
Ag. & Food	.04	.04	.01	.01	1.00	1.00
Mining	-.04	-.04	.03	.03	.07	.07
Energy	-.72	-.72	.01	.01	.00	.00
M1	.13	.13	.04	.05	1.00	1.00
M2	-.23	-.23	.03	.03	.00	.00
Non-traded	.85	.88	.04	.06	1.00	1.00
Total	1.02	1.04	.04	.04	1.00	1.00

TABLE 10: R^2 Values for Employment Reallocations - 50% Multilateral Tariff Cut by Developed Blocs

	Sector						
	A&F	Min.	En.	M1	M2	NT	Total
E.E.C.	.77	.98	.95	.94	.54	.00	.32
U.S.	.77	.99	.99	.96	.91	-.61	.40
Japan	.99	.99	.99	.84	.40	.95	.37
O. Dev.	1.00	.99	1.00	1.00	1.00	1.00	.99
O.P.E.C.	.96	.99	.94	.28	.82	.69	.67
N.I.C.	.79	.99	.94	.94	.93	-.17	.67
L.D.C.	.92	.97	.99	.97	.96	.89	.87

III.4.3 Conclusions: 50% Developed Bloc Tariff Cut

Systematic sensitivity analysis of a 50% multilateral tariff reduction by the developed blocs suggests that while some of the qualitative welfare effects are quite sensitive to elasticity specification, an important result does not appear to be in this class. In particular, the observation that the U.S. would lose from such a tariff cut is reinforced by the results.

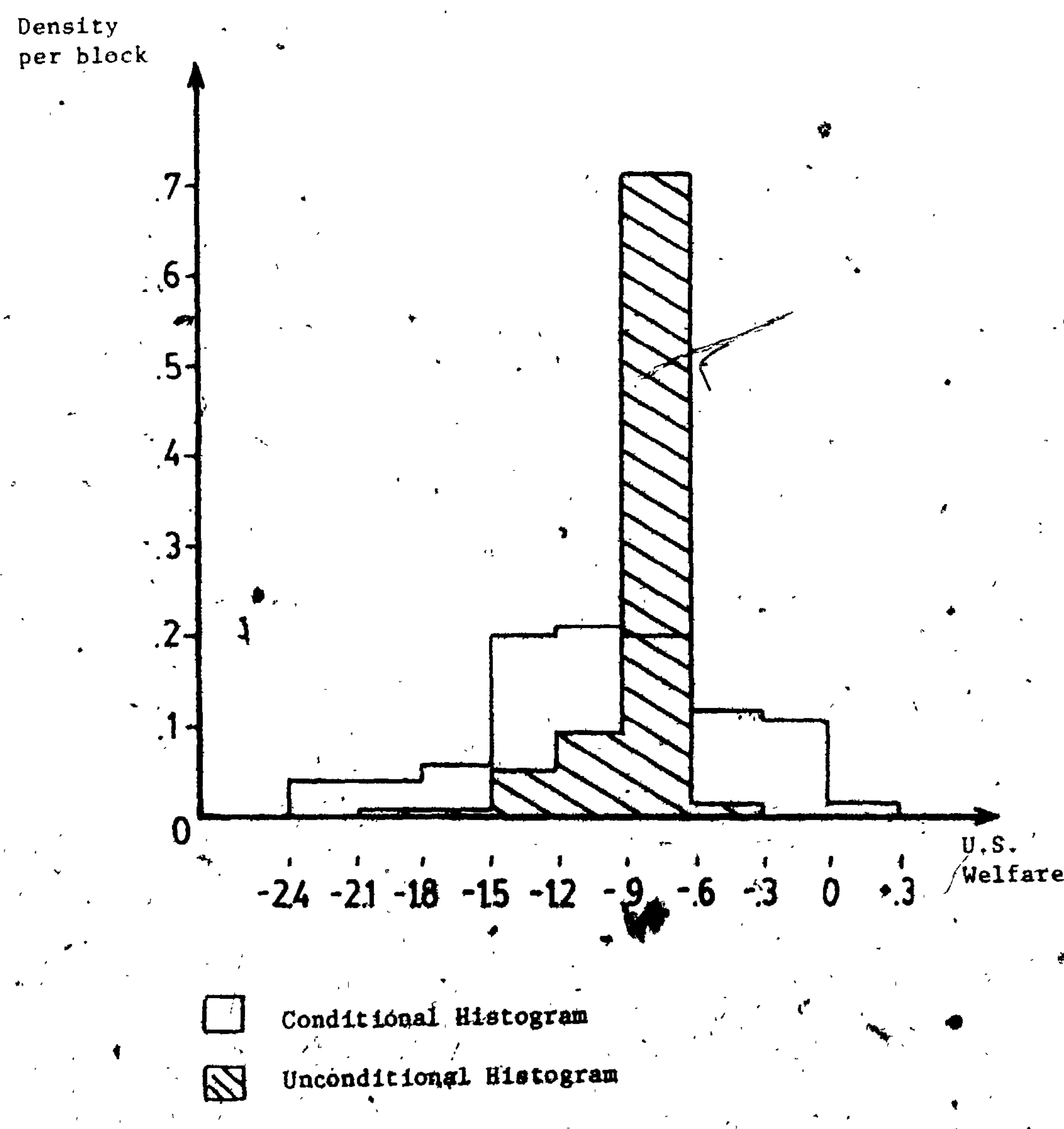
The employment effects of such a liberalization, as mentioned before, are small and are not as sensitive to elasticity specification as the welfare results.

Of interest for the purpose of cost savings, the PS approximations appear to be reliable approximations of the welfare effects from an USSA. Although the PS approximations of the employment effects are less adequate, they do give reasonable estimates of the probability of industry employment increase and the mean employment effect in this case.

It was also found that the USSA conducted on a subset of results gives a more diffuse p.d.f. on welfare in particular. In other words, USSA procedures on relatively few elasticities may be a worthwhile supplement to CSSA procedures on all elasticities of interest. This is illustrated in Figure 1, where histograms for the CSSA on 14 elasticities

FIGURE 1: Comparison of Conditional and Unconditional Histograms and U.S. Welfare[1]

50% Developed Bloc Cut



[1]Welfare reported as Hicksian EV in billions of 1977 $U.S.

and the USSA are compared.

III.5 THE WELFARE AND EMPLOYMENT EFFECTS OF A 50% MULTILATERAL TARIFF CUT BY ALL BLOCS

As noted before, the estimated welfare effects for a 50% multilateral tariff cut by all blocs show the LDC and NIC blocs losing, while the developed world gains. This may be due to the higher level of tariffs originally in place in the developing blocs. If these are in fact closer to optimal tariffs (given the original tariffs in other blocs), than those of the developed world, Markusen's (12) analysis would suggest that they would be expected to lose for this reason. It is interesting that the gains and losses to specific blocs are quite large compared to the total (worldwide) welfare gain.

TABLE 11: Welfare Effects of a 50% Tariff Cut by All Blocs (Point-Estimates)

Bloc	JWPE	HWPE
E.E.C.	10.96	10.27
U.S.	2.53	3.39
Japan	5.81	6.11
O.Dev.	.62	2.36
O.P.E.C.	3.01	3.02
N.I.C.	-6.69	-8.29
L.D.C.	-4.55	-5.90
World	11.68	10.94

Using the revised elasticity estimates does not change the qualitative story dramatically. The OD bloc gains much more and the developing world loses even more.

Turning to the conditional results in Table 12, the magnitude of welfare gains varies dramatically in response to elasticities but the qualitative story of who gains or who loses is robust. Although the extreme bounds of OD welfare straddle the origin, the bulk of the density is above zero (99%).

TABLE 12: CSSA of 50% Tariff Cut by All Blocs (Welfare)

Bloc	Point Estimate	Mean	Minimum Value	Maximum Value	Probability of Welfare Gain
E.E.C.	10.27	10.26	7.09	14.89	1.00
U.S.	3.39	3.36	2.34	4.95	1.00
Japan	6.11	6.09	5.05	6.80	1.00
O.Dev.	2.36	2.42	-1.33	7.73	.99
O.P.E.C.	3.00	2.98	2.14	4.05	1.00
N.I.C.	-8.29	-8.30	-10.60	-5.44	.00
L.D.C.	-5.90	-5.93	-8.41	-3.89	.00
World	10.94	10.87	8.27	13.03	1.00

The pattern of importance of the capital-labour elasticities of substitution is as before (Table 13). The elasticity of substitution in the (large) non-traded sector is the most important to U.S. welfare. The relative importance of the trade elasticities is quite different than in the previous tariff-cutting experiment. Here, the common export elasticity falls very low on the list of importance (as determined by the ranking of DIST). This might be due to the fact that no relative tariffs have changed in this experiment while at least some change in the other experiment. The import elasticity for the NIC bloc is also of much greater importance to U.S. welfare.

TABLE 13: Importance of Elasticities to U.S. Welfare Effect (50% Tariff Cut by All Blocs) (From Conditional Runs)

Elasticity	DIST	Rank (DIST)	PS
SIG(E.E.C.)	.663	4	1.351
SIG(U.S.)	2.122	1	4.441
SIG(Japan)	.385	6	.855
SIG(O.Dev.)	1.187	2	1.760
SIG(O.P.E.C.)	.415	5	.773
SIG(N.I.C.)	1.076	3	.974
SIG(L.D.C.)	.375	7	.373
SIGI	.074	8	.162
SUB(Ag. & Food)	.001	13*	.017
SUB(Mining)	.001	13*	.007
SUB(Energy)	.024	10	.168
SUB(M1)	.003	11	.020
SUB(M2)	.002	12	.019
SUB(Non-traded)	.033	9	.049

* Ties

In this case the contrast between PS and DIST as measures of importance is quite clear. Although the EEC import elasticity has the third largest effect on U.S. welfare for a given absolute change, the NIC elasticity has the third largest effect for a given change in terms of the elasticity's standard error. Changes in the NIC import elasticity have a large effect mainly because it is changed by a much larger amount in absolute terms. The NIC import elasticity is varied from a low value of .29 to a maximum of 2.48, because of its large standard error. This compares to a range of .62 to 1.60 for the EEC import elasticity.

On the basis of the CSSA results, an USSA was conducted, involving the U.S., OD and NIC import elasticities. Some of the welfare results exhibit larger standard errors (e.g. Japan, OPEC, NIC) under the conditional sensitivity analysis, highlighting the fact that the welfare change of different blocs depends on different elasticities. The same is true of the extreme bounds generated for (eg.) OPEC which are wider in the conditional sensitivity. Recall that the unconditional sensitivity will represent an analysis of a chosen subset of elasticities. In this case, they are chosen very poorly as far as their effect on OPEC welfare.

For this policy, two of the three rules of thumb mentioned above are verified again. As the own import price elasticity is increased, the smaller are the U.S. gains. As the import price elasticity of the OD bloc is increased, the larger are the U.S. gains. The results for changes in the common export elasticity were mixed.

USSA results for the employment reallocation effects were also calculated. In this case, the "qualitative" results on employment changes were not sensitive to the elasticity specification used, although some of the results are sensitive to the elasticities used.

TABLE 14: USSA on Employment Changes in the U.S. From 50% Multilateral Tariff Reduction by All Blocs*

Sector	Point Estimate	Mean	Minimum Value	Maximum Value	Probability of Employment Increase
Ag. & Food		.27	.16	.38	1.00
Mining		.97	.14	1.54	1.00
Energy		-17.83	-18.32	-17.22	.00
M1		.19	.04	.34	1.00
M2		-.73	-.91	-.56	.00
Non-traded		.11	.11	.12	1.00
Total		.13	.11	.15	

*Percentage change in employment. Total is the percent of total employment required to move between industries.

A PS approximation of these results was also computed from the CSSA results. For the welfare results, the PS approximation was virtually identical to the USSA. The R^2 calculations for welfare were high (above 99% for all blocs but the LDC bloc at 97%). The PS estimates were good approximations (R^2 above 85%) of all of the employment reallocation numbers, except those for the service sectors. The summary statistics for the PS approximation (mean, standard deviation and probabilities of gain) of the employment reallocations were virtually identical.

III.5.1 Conclusions: 50% Tariff Cut by All Blocs

In the analysis of a 50% worldwide tariff cut, it appears that the quantitative estimates of the size of gain accruing to each bloc are quite sensitive to the elasticities used. Referring to Table 12, the EEC could gain anywhere from $7 billion to $15 billion from liberalization. At the same time, the qualitative results are largely unchanged, that is that the developed blocs gain from tariff abolition and the LDC and NIC blocs lose. Only in the case of the Other Developed bloc is there any uncertainty about whether they will gain or lose.

The size of reallocation effects is also quite sensitive to the elasticity specification, but the pattern of employment changes is not dependent on reasonable perturbation of the elasticities.

Once again, the PS approximation technique seems to be an excellent approximation for the welfare results discussed here, and an adequate approximation for the employment reallocation effects if the primary interest is in the summary statistics.

III.6 THE WELFARE AND EMPLOYMENT EFFECTS OF BILATERAL LIBERALIZATION BETWEEN CANADA AND THE U.S.

This section presents CSSA results and PS approximations for the short- and long-run results considered in Essay II. Attention was focussed on the Canada and U.S. import elasticities, the export price elasticity and the shares of fixed in total cost in the Canadian manufacturing industries since the other elasticities had virtually no impact on the Canadian or U.S. welfare and adjustment effects.

III.6.1 Long-Run

The pattern of elasticity importance for the long-run bilateral liberalization are presented in Table 15. The perceived elasticities are used to calibrate the model to a given share of fixed to total cost and to a corresponding perceived elasticity of demand in the firms with monopolistically competitive pricing.

TABLE 15: Importance of Elasticities (DIST)
Long-Run Bilateral Tariff Abolition

Elasticity	U.S. Welfare	Canadian Welfare
U.S. Import	.71	.32
Canadian Import	.10	.31
Common Export	.46	1.[illegible]
Perceived in M1	.01	.10
Perceived in M2	.00	.02

The perceived elasticities were varied over a range corresponding to shares of fixed in total cost from 12% to 18%.

These results show much less sensitivity than those in Cox and Harris (4), but this is partially due to the wide range over which Harris and Cox vary their elasticities.[17] The results in Table 15 are the result of moving elasticities 1.4 standard errors away from their point estimates in a CSSA run.

On the basis of these results, USSA and PS approximation results were computed. The Canadian and U.S. import elasticities and the common export elasticity were varied in the unconditional analyses. As in previous experiments, the bounds on Canadian and U.S. welfare generated by the CSSA were narrower than the bounds generated by the USSA. The P-S welfare approximations for this experiment were extremely accurate, even at the extreme points. The summary welfare statistics for the USSA and PS approximations were virtually identical and are therefore not reported separately. As before, the point estimates and means are extremely close.

TABLE 16: USSA of Long-Run Welfare Effects of Bilateral Tariff Abolition*

	Point Estimate	Mean	Minimum Value	Maximum Value	Probability of Gain
U.S. Welfare	1.24	1.23	.60	1.87	1.00
Canadian Welfare	-.13	-.13	-1.15	.91	.39

* Figures in billions of 1976 $US.

While the U.S. seems certain to gain from bilateral tariff abolition, the results for Canada are less clear cut. The size of terms-of-trade effects are very sensitive to the elasticity specification of the model. Since the Canadian welfare effects are dominated by a terms-of-trade effect, the welfare results are indeed sensitive to "reasonable" variations in the trade elasticities. Harris and Cox (4) use "high" trade elasticities which yield smaller terms-of-trade effects against Canada. In the event that the three trade elasticities used were set to the high values[18], Canada gains $.6 billion, with the U.S. gaining $1.2 billion.

Table 18 presents an USSA of the labour reallocation effects of bilateral tariff abolition. These reallocations are somewhat larger than those previously found for the multilateral tariff reduction exercises. The proportionate

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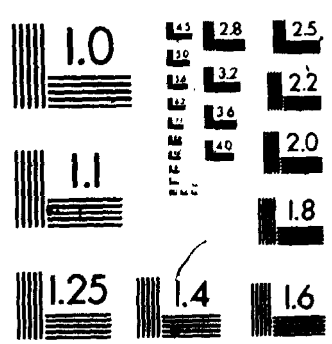

TABLE 17: Long-Run Labour Reallocation Effects of Bilateral Tariff Abolition (5x3 USSA)

U.S. Employment Changes (%Δ)

Sector	Mean	Minimum Value	Maximum Value	Probability of Increase
Ag. & Food	.0	-.0	.0	.72
Mining	-.2	-.3	-.0	.00
Energy	.1	-.1	.2	.91
M1	.1	.0	.1	1.00
M2	.1	-.0	.1	.99
Non-traded	-.0	-.0	-.0	.00
Total	.0	.0	.0	

Canadian Employment Changes (%Δ)

Sector	Mean	Minimum Value	Maximum Value	Probability of Increase
Ag. & Food	1.2	.8	1.4	1.00
Mining	1.2	.3	1.8	1.00
Energy	1.5	.9	2.0	1.00
M1	.2	-.1	.6	.94
M2	-2.5	-4.2	-.8	.00
Non-traded	-.1	-.2	.1	.08
Total	.21	.16	.28	

labour adjustment numbers are much larger in Canada than the U.S. though the absolute changes in employment are similar.[19] At most, one in 360 workers would have to move between sectors in Canada according to this calculation.[20]

Returning to welfare, the pattern of effects noted earlier appears in the bilateral abolition results. The U.S. experiences a smaller gain when either its own import elasticity is large or Canada's import elasticity is small. Canada experiences a smaller loss under the same conditions. Canada's loss is decreased and the U.S. gain is increased the higher is the common elasticity of demand for exports. Some results from the USSA are presented below to highlight this. (See Table 18.)

It is also noteworthy that the gains available to be shared between Canada and the U.S. are not always positive and vary dramatically from a loss of $.1 billion to a gain of over $2.3 billion. The mean gain to share is $1.1 billion and the probability of a joint welfare gain is 99%.[21]

III.6.2 Short-Run

The short-run effects were analyzed using the same procedure as the long-run results in Table 19.

TABLE 18: Long-Run Welfare Effects of Bilateral Tariff Abolition - Pattern of Elasticity Sensitivity

Case		Elasticity	Configuration	Welfare ($ billions)	
(i)	Smallest U.S. Gain	U.S. Import	Most Elastic	U.S.	.6
		Cdn. Import	Least Elastic	Canada	-.5
		Common Export	Least Elastic		
(ii)	Largest U.S. Gain	U.S. Import	Least Elastic	U.S.	1.9
		Cdn. Import	Most Elastic	Canada	.3
		Common Export	Most Elastic		
(iii)	Largest Canadian Loss	U.S. Import	Least Elastic	U.S.	1.4
		Cdn. Import	Most Elastic	Canada	-1.2
		Common Export	Least Elastic		
(iv)	Largest Canadian Gain	U.S. Import	Most Elastic	U.S.	1.0
		Cdn. Import	Least Elastic	Canada	.9
		Common Export	Most Elastic		

TABLE 19: Importance of Elasticities (DIST) Short-Run Bilateral Tariff Abolition

Elasticity	U.S. Welfare	Canadian Welfare
U.S. Import	.70	.20
Canadian Import	.13	.28
Common Export	.41	1.03
Perceived in M1	.01	.05
Perceived in M2	.01	.10

The CSSA shows that the trade elasticities to have the most impact on welfare results and on labour reallocations. The "trade" elasticities were varied in the USSA and PS approximations. As in the long-run experiment, the PS approximation generated summary statistics for welfare that were virtually identical to the USSA results and R-squared was .9999 for Canadian and U.S. welfare.

TABLE 20: USSA of Short-Run Welfare Effects of Bilateral Tariff Abolition*

	Mean	Minimum Value	Maximum Value	Probability of Welfare Gain
U.S.	1.2	.4	1.8	1.00
Canada	-.7	-1.5	.1	.00
U.S. + Canada	.5	-.7	1.5	.83

* Hicksian EVs in $ billion U.S. (1976).

If one makes a temporary unemployment calculation of the type reported in Essay II, and deducts this from the short-run joint welfare gain, the mean of the resulting "net of adjustment cost" welfare is $.3 billion. The probability that even the short-run gains are positive is 72%.

The pattern of elasticity sensitivity of the welfare results is reinforced by the short-run results. The extreme values reported in Table 20 correspond to the elasticity configurations described in Table 18.

The short-run labour reallocations show a similar pattern to the long-run reallocations, although the M2 sector employment rises in the short-run. This is due to the absence of fixed cost savings in the short run.

TABLE 21: USSA of Short-Run Labour Reallocation Effects of Bilateral Tariff Abolition*

	Mean	Minimum Value	Maximum Value	Probability of Employment Increase
Agri. & Food	.82	.57	.96	1.00
Mining	.79	-.40	1.54	.95
Energy	1.17	.29	1.76	1.00
M1	.16	-.06	.40	.97
M2	2.06	1.12	3.04	1.00
S & Non-traded	-.52	-.63	-.44	.00
Total	.29	.25	.37	

* Percentage change in industry employment. Total is percentage of labour force moving between industries.

As in the previous experiments, the PS approximations yielded virtually identical summary statistics on welfare and factor reallocations. The approximations of the reallocation numbers by industry and the welfare effects are good (R-squared greater than .95). The approximations of the percentage of the labour force moving between sectors were occasionally very poor.

III.6.3 Conclusions: Bilateral Tariff Abolition

Systematic sensitivity of the major results of Canada-U.S. bilateral tariff abolition suggests the following conclusions:

(i) The sum of the U.S. and Canadian long-term effects from BTA is positive.

(ii) The sum of the short-term U.S. and Canadian welfare effects may be sufficiently large to generate short-run gains to be shared.

(iii) For reasonable re-specification of the model, the U.S. experiences a welfare gain in either the short-run or the long-run.

(iv) Canada could well experience a small welfare loss from bilateral tariff abolition in the absence of compensation.

(v) The labour reallocation effects caused by bilateral tariff abolition are larger than the labour reallocation effects seen in the multilateral tariff cuts analyzed earlier, but are still smaller than the effects of ongoing technological progress.

(vi) The unemployment effects and associated "adjustment costs" of bilateral tariff abolition are very small.

III.7 THE PRESENTATION OF SYSTEMATIC SENSITIVITY RESULTS

The aim of systematic sensitivity results is to provide a convenient summary of the fragility of NGE model results, particularly as the result of imprecision in the elasticity estimated used. The method of "limited robustness" as used by Whalley (15) and Cox and Harris (4) does not give an easily interpreted impression of the fragility of the results, and often ignores available estimates of the precision of elasticity estimates.

The recommended procedure for the completion and presentation of systematic sensitivity results is summarized in Table 22.

TABLE 22: Recommended Systematic Sensitivity Procedure

1. Conduct CSSA on all elasticities to be considered. Four values other than the mean are recommended. (+1.4, +.7, -.7, -1.4 standard errors)

2. On the basis of DIST measure of importance select the most important elasticities for inclusion in the USSA. The number of parameters to be considered will depend on resource constraints.

3. Conduct USSA on the most important parameters, using the same values for the elasticities recommended in 1.

4. If there are subsidiary results which have a different pattern of importance from the main results, PS approximation of these results should also be calculated.

PS approximations may be substituted for USSA when costs are prohibitive. Recall that the evidence here (for multilateral and bilateral tariff reductions) was that the PS approximations of welfare were very good and the estimates of factor reallocations were fair.

Having completed this procedure, reporting the mean, extreme values and probability of gain from the USSA results will usually give a compact and easily interpreted summary of the elasticity sensitivity of results.

While limited robustness results such as Cox and Harris (4, p. 136) may be hard to interpret, it may still be useful to present results corresponding to particular cases of extreme interest. For example, the "high" elasticity case may be presented to reflect the concerns of those who feel that all trade elasticity estimates are too low. In this essay, "limited robustness" results of the extreme values were presented.

III.8 SUMMARY AND CONCLUSIONS

There is some skepticism about the results of NGE analysis centred on the uncertainty which exists about the elasticity values which are so important to model results. This essay has performed systematic sensitivity analysis of three different trade policy experiments. The results suggest that some of the results are qualitatively robust to reasonable perturbations of the elasticities, while others are not. It is not a priori clear which results will be robust and as such systematic sensitivity analysis does seem to be warranted.

As expected, the CSSA results give an unduly optimistic indication of the sensitivity of the results to the elasticities. CSSA results also point out that different results are sensitive to different elasticities. USSA results can give better indications of the sensitivity of results, but are more costly to perform.

The Pagan-Shannon interpolation technique provides an accurate approximation of the USSA welfare results for all three policy experiments. The PS interpolations of the employment effects give very good estimates of the mean, the standard error, and the probability of employment increase, but the PS interpolations are not always good estimates of the individual USSA solutions. In most cases, however, PS interpolations make the (preferred) USSA results accessible.

Of some interest is the additional finding of the relation between the size of welfare gains or losses from tariff reductions and the trade elasticities of the model used. A larger own import elasticity was associated with larger losses or smaller gains. A higher import elasticity in one's trading partner lead to smaller losses or larger gains from liberalization. The higher the common elasticity of demand for exports, the larger the gains to be shared from trade liberalization. These results were consistently found in all three experiments conducted.

ENDNOTES

1. See Whalley (15).

2. For present purposes, the model structure implied by the 7-bloc model will be treated as a maintained hypothesis.

3. See Johansen (10), Scarf (13) and Evans (6) respectively for example.

4. See Dixon, Parmenter, Sutton and Vincent (5).

5. Other benchmarking procedures do exist. One important technique which has not received widespread application attempts to use additional information from the data to infer better estimates of the share parameters. Unfortunately, this technique requires more than one year's data to be implemented. See Mansur and Whalley (11).

6. Mansur and Whalley (11) also recommend a method of subsystem estimation of NGE model parameters.

7. See Armington (1).

8. Mansur and Whalley (11) point out that this is a good approximation as long as the import shares are relatively small.

9. For the current study, the estimates of the trade elasticities come from a revised literature survey by Harrison (9) while the estimates of the elasticities of capital-labour substitution were estimated for the current work.

10. These five values are (i) the mean, (ii) the mean plus .7 standard errors, (iii) the mean minus .7 standard errors, (iv) the mean plus 1.4 standard errors and (v) the mean minus 1.4 standard errors. These five values are used in all of what follows.

11. In the case of the 7-bloc model, this would require approximately 10,000 years of CPU time on a DEC-20 mainframe computer.

12. Pagan and Shannon note that the results are easily generalized to Scarf-type models.

13. A solution of the 7-bloc model takes approximately one minute of CPU time while calculation of Pagan and Shannon's approximation for a solution takes about one-tenth second. Even with this saving a full Pagan-Shannon interpolation with five values of 14 parameters would require more than 38 years of CPU time on a DEC-20 mainframe computer.

14. See Section II.4.

15. The model could not be solved for the smallest value of SUB(3) (.15). Changes in SUB(3) within the limits where it did solve lead to changes in welfare comparable to those for SUB(1), SUB(2), and SUB(4).

16. Recall that the common export elasticity is in fact the elasticity of substitution between domestic goods and the composite of imports.

17. Harris and Cox vary the share of fixed in total cost over a range of 10 to 42%.

18. Canadian import, U.S. import and common export elasticity set to +1.4 standard errors.

19. In the U.S., labour services valued at $.25 billion move intersectorally while in Canada $.23 billion in labour services are redeployed.

20. This again contrasts with Harris and Cox who estimate that 7% of the labour force would move between sectors.

21. In cases where joint losses occur, the developed world trading partners of Canada and the U.S. experience welfare gains of more than $1 billion.

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CONCLUSION

In Essays I and II, short-run modelling from earlier work was extended. The finding that short-run welfare gains to multilateral liberalization could be even smaller when the short-run formulations were extended accords well with intuition.

Of some general interest was the observation that extending the rigid wage formulation could have substantial effects on the results, but those impacts were largely confined to the blocs where the rigid wage was binding. Extending the specific factors formulation had little impact on results. Treating capital as homogeneous would therefore seem to be a useful approximation for the purpose of trade policy evaluation.

Analysis of the short- and long-run effects of bilateral tariff abolition by Canada with the U.S. lead to the conclusion that joint gains exist in the long-run and likely in the short-run as well. This is true even when taking account of the temporary unemployment costs associated with the reallocation of labour. The estimates reported here do suggest, however, that Canada could lose from bilateral tariff abolition due to adverse terms-of-trade effects associated with the higher Canadian tariffs (particularly on manufactures). An avenue for future research is to investigate liberalization proposals that would lead to welfare gains for both Canada and the U.S. without compensation.

Using the revised Whalley model described in sections II.4 and II.5 of the thesis to analyze multilateral trade liberalization yields the conclusion that the structurally similar model of Harris and Cox yields substantially different results. This reinforces the impression given when comparing the two models' results of different policy experiments. The benchmarking procedure adopted by Harris and Cox is identified as a potential source of the differences in results.

The evaluation of three different trade liberalization experiments using two similar numerical general equilibrium (NGE) models yields the conclusion that even product and factor neutral technological progress is likely to generate higher adjustment and unemployment effects than any of the trade liberalization experiments considered here. This conclusion is always true for developed countries. This is in line with earlier findings in the context of econometric or accounting studies.

Extensive CSSA and USSA results on three trade policy experiments yield the following results with regard to systematic sensitivity analysis of NGE model results:

(i) USSA procedures on selected elasticities yield more diffuse distributions of the results than CSSA procedures on all of the elasticities.

(ii) PS approximations of USSA results are, in many cases, accurate, resource saving substitutes for USSA.

Finally, the result of all three essays suggest a simple relationship between the elasticity configuration of the model and the size of welfare gains from multilateral or bilateral liberalization. This is quickly summarized in Table 1.

TABLE 1: Relation Between Welfare Effect and Elasticity Configuration

Own Import Price Elasticity	−
Major Trading Partner's Import Price Elasticity	+
Elasticity of Demand for Exports*	+

+ (-) denotes that higher absolute values of the elasticity imply larger (smaller) gains or smaller (larger) losses.

* Elasticity of substitution between imports and domestic products.

These results appear to be in line with Markusen's (1) propositions in the context of a much simpler model of bilateral trade.

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