SIMULATIONS ON A COMPUTATIONAL GENERAL EQUILIBRIUM TRADE MODEL INCORPORATING SCALE ECONOMIES AND PRODUCT DIFFERENTIATION, WITH VARYING FACTOR ENDOWMENTS

by

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ABSTRACT

The purpose of this thesis is to evaluate the welfare implications of introducing imperfect competition into the conventional model of international trade, under varying factor endowments, with and without intervention on the part of the trading partners. The approach used is the construction of a two-country, two-product, two-input computational general equilibrium model incorporating output-generated scale economies at the firm level, and product differentiation in one of the product markets. The model constructed is based on assumptions in the recent theoretical literature on the "new" trade theory, which chooses to represent imperfect markets through Chamberlin's monopolistically competitive market structure.

The model can be considered a generalized form of the familiar Heckscher-Ohlin (H-O) model, which is representative of conventional trade theory. It therefore provides the opportunity, by varying the value of certain key parameters in the model, to directly compare welfare levels under varying degrees of scale economies and product differentiation. This type of model has been referred to in the literature as a Neo-Chamberlinian-Heckscher-Ohlin (C-H-O) generalized trade model.

The model is solved using the Gauss Non-Linear Simultaneous Equations application (NLSYS) on the following three versions of the generalized C-H-O model: one which utilizes an exact specification of demand elasticity for the differentiated product, one which utilizes an approximation of elasticity commonly utilized in the literature, and one which utilizes the more restricted Heckscher-Ohlin version of the model. Simulations are carried out on each version of the model, for varying values of key model parameters and alternative combinations of factor endowments, and resulting welfare levels are compared.

In addition, an import tariff and a consumption subsidy on the differentiated product are introduced as exogenous policy variables in the generalized model. Simulations are carried out for a variety of policy scenarios, involving use of one or both policy instruments by one or both countries, under alternative factor endowments. Welfare levels with and without policy intervention are compared. The purpose is to investigate whether welfare gains are possible with policy intervention, and which instrument or combination of instruments give the greatest potential welfare gain.

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Chapter 1
INTRODUCTION

Traditional trade theory has focused almost exclusively on two explanations for trade: differences in technologies (the Ricardian model) and differences in factor endowments (the "modern" theory, as described by the Heckscher-Ohlin (H-O) model). In both cases, trade theory has relied on the simplifying assumptions of constant returns to scale and perfect competition. While the existence and importance of scale economies has been recognized, until recently, they had received little formal analysis, and little effort had been made to incorporate scale economies in any comprehensive manner into a more generalized theory of trade.[1]

This reluctance on the part of trade theorists to deal with scale economies has been due to the difficulties in incorporating scale economies into a general equilibrium model, and in deriving general conclusions or principles for a trade theory which would allow for scale economies. In particular:

- The existence of scale economies internal to the firm is not consistent with perfect competition. Since there is no generally accepted theory of imperfect competition, the theorist is faced with the problem of choosing among the numerous modelling alternatives.[2] The results obtained with respect to trade patterns and the welfare effects of trade will depend on the specific modelling assumptions made.

- The existence of scale economies introduces the likelihood of non-convexities in the production set, giving rise to the possibility of multiple and unstable equilibria.[3]

- When scale economies exist there is a divergence between private and social costs. We are no longer dealing with market equilibria which are social optima, and, as a result, the possibility arises that a country might lose as a result of trade.

However, in recent years the "modern" theory has come under increasing criticism due to its inadequacy in explaining empirical evidence that:

- The largest and fastest growing component of world trade has been intra-industry trade in manufactures between the industrialized countries.[4]

- Much of the expansion of trade in the postwar period has taken place without significant income distribution or resource reallocation effects.[5]

A renewed interest in and appreciation of the importance of scale economies, coupled with modelling developments in industrial organization theory, have resulted in greater attention being focused on alternatives to, or generalizations of, the traditional H-O model. This focus on an imperfectly competitive framework has been referred to as the "new" trade theory, or the "industrial organization approach to trade theory".

There have been two main strands in the literature on this new "I-O" approach. One focuses on arguments for an interventionist trade policy in imperfectly competitive markets (See Brander and Spencer (1984(a) & (b)) and Venables (1985)), and on models of oligopolistic competition and strategic trade policy intervention. In many respects this can be viewed as an extention of the literature on domestic distortions (See Bhagwati, Ramaswami & Scrinivasan (1969), Bhagwati (1971), and Ghosh (1979)).

The other focus in the literature has been to attempt to develop a framework for a more generalized trade theory. A number of models have been developed which incorporate monopolistic competition and product differentiation in an attempt to explain the apparent discrepancies between traditional trade theory and the empirical evidence. (See

Krugman (1979, 1980, 1981), Dixit and Norman (1980), Lancaster (1980), Helpman (1981), Feenstra and Judd (1982), Venables (1982), Horn (1983), Lawrence and Spiller (1983)).[6]

While these models might be considered to be more of an abstraction from the real world than the oligopolistic models, they provide a useful extension or generalization of the conventional perfect competition homogeneous product trade model for a number of reasons. They incorporate imperfect competition in a manner which draws a distinction between intra-industry trade (based on product differentiation and scale economies) and inter-industry trade (based on comparative advantage) and which is developed as a generalization of existing trade theory, rather than as an alternative theory. At the same time they avoid the difficult problem of dealing with strategic firm behaviour, and they largely avoid the problems associated with non-convexities of the production set.[7] Also, although dealing with a market equilibrium which is not a social optimum, they provide a market equilibrium which is constrained pareto optimal: it is the imperfectly competitive market structure which most closely approximates perfect competition.

The introduction of economies of scale and product differentiation provides additional potential sources of gain from trade to those resulting from exploitation of comparative advantage. These may derive from:

- fuller exploitation of economies of scale;
- reduction of monopolistic market distortion;[8] and
- increased variety of products consumed.[9]

Whether welfare gains might exist and the extent of these gains compared to the traditional perfect competition homogeneous product model will depend on the model's particular specification of production technology and preferences. Attempts have been made in the theoretical literature to indicate whether or not welfare gains from trade exist in these models. However results have been tied either to very simple one-product one-input models (eg. Krugman (1979)) or dependent on very strong symmetry assumptions. See Helpman and Krugman (1985).

The objective in this thesis is to construct a computational general equilibrium model which utilizes the assumptions in the theoretical literature, but is general enough to allow for comparison of welfare levels in the generalized model incorporating monopolistic competition with results obtained under the traditional trade model, with varying relative factor endowments and country size.

Since the mid-1970s, spurred by the work of Scarf, Shoven, Whalley and others[10] in developing computational methods for solving non-linear general equilibrium models, a wide variety of applied general equilibrium (AGE) trade models have been developed, covering a range of applications. Some are multicountry models designed to analyze global trade policy issues. Others are single country models. They are all specific in that they are calibrated to a particular equilibrium data set, chosen for the specific economy(s) represented by the model.[11] These models play a useful role in their attempt to bridge the gap between theory and its policy application. They provide a useful tool for quantitative analysis within a given theoretical framework, enabling theorists to get beyond qualitative results and policymakers to analyze the impact of proposed trade policies.

The computational model developed for this thesis differs from most such models in that it is a very simple general two-country two-product two-input model, which allows for ease in comparison of welfare results with the conventional theoretical trade model. Furthermore, it is not tied to a need to estimate and utilize parameter values for a specific country or group of countries, but enables us to investigate welfare effects for a wide range of parameter values of the model (including relative and world endowments), and therefore provides more general results.

This thesis will also investigate the possibility of achieving welfare gains by policy intervention. The possibility that a country can improve its level of national welfare from that attained under free trade by the imposition of tariffs has been discussed at length in the tariff literature, for the conventional perfect competition, homogeneous product case. The possibility for the improvement of national welfare results from the fact that, while free trade equilibrium represents a global pareto optimum, it does not necessarily represent the optimal position from the national perspective.[12] Analysis has shown that if a country is large enough to influence its terms of trade it can gain by the imposition of an "optimal" tariff which exploits its monopoly power in the market, provided that other countries do not retaliate. In ad valorem form the optimal tariff has been shown to be equal to the inverse of the elasticity of foreign export supply, in the two good homogeneous product case.[13] In the traditional model the "optimal" tariff for the small country is zero.

The introduction of imperfect competition and differentiated products complicates the calculation of an "optimal" tariff, which will depend on both domestic and international monopoly power, and on demand effects resulting not only from relative price changes, but also from changes in the number of varieties produced and consumed. There is unfortunately no neat "general" optimal tariff formula for these models. Further, it has been shown (See Lancaster (1984) and Gros (1987)) that when there is monopolistic competition even a small economy can gain by imposing a tariff which reflects the degree of monopoly power of the domestic industry.[14]

However, this monopoly power is partially due to domestic market distortion, i.e., non-optimal allocation of production. The argument is made in the literature on domestic distortions that, in the case of domestic distortions, a tariff is a second best policy instrument. A combined tax and production subsidy provides the optimal policy instrument; a tariff should be used only when the distortion is international not domestic. (See Bhagwati (1971).) In the monopolistic competition model there are two sources of monopoly power which a country is able to exploit: the country's monopoly power in the international market and the monopoly power of individual firms. It follows therefore that the use of more than one policy instrument might be desirable, and provide the maximum potential gain. This thesis will therefore consider the impact of two policy instruments:

- an ad valorem tariff on imported varieties of the differentiated product, and
- a consumption subsidy on domestically produced varieties of the differentiated product (which has the same effect as a production subsidy).

A variety of policy scenarios will be considered, including ones in which one or both countries make use of either or both policy instruments. The purpose is to investigate whether welfare gains are possible with policy intervention, and which policy instrument or combination of instruments provides the greatest potential gain.

The computational model is developed in the Chapter 2. A description of the types of simulations carried out on the model and the results of these simulations are presented in Chapter 3.

Chapter 2
DEVELOPMENT OF THE MODEL

The model is a two-industry (i = X, Y, where X is a differentiated product and Y is a homogeneous product), two-input (K, L), two-country (j = 1,2) static general equilibrium model. It is assumed that preferences and production technologies can be represented by homothetic, continuous twice differentiable functions. Further, it is assumed that the objective of each country is to maximize its own (national) welfare. The level of national welfare is measured by a community utility function.[15]

Input markets are assumed to be perfectly competitive; inputs are nationally mobile between industries, but immobile internationally. Producers are assumed to take prices as given, and choose output levels which maximize expected profits; product markets exhibit free entry and exit (i.e., markets are contestable). There are no transaction costs; factor input costs are the only variable cost of production (eg. no transportation costs). The model has only two sets of agents, or sectors - consumers and producers. While a government sector exists in the policy realm, its operation is assumed to be costless.

The following symmetry assumptions are made:

- identical preferences in both countries, and
- all firms have access to the same production technologies, regardless of country of location.

Therefore the two countries are identical, except for relative and absolute factor endowments.

The model is represented by a system of equations which, given factor endowments and specified functional forms describing preferences and production technologies, include equations specifying:

- production equilibrium for each industry i, in each country j;
- equilibrium in factor input markets (K, L) in each country j; and
- international equilibrium in the products market, i.e., excess demand functions for each product X^j and Y.

However, this system of equations is not independent as, by Walras' Law, if all markets clear but one, the last market must automatically clear, when the national income accounting identities for each country hold. Therefore the system does not have a unique solution. But it can be solved for relative solution values of the unknowns (i.e., relative prices of factor inputs and product outputs, and output and consumption levels of each product, in each country), by dropping one of the equilibrium conditions, and normalizing the equations in terms of one of the unknowns. Common practice in the literature on these types of models is to use the homogeneous product Y as numeraire, and normalize (i.e., set $p_Y = 1$) to obtain a relative solution set.

Equations are added to evaluate and compare the national welfare level in each country (using the indirect utility function V^j, j = 1,2).

Section I describes the specification of consumer preferences and derives demand functions. Section II develops the supply side of the model (equilibrium conditions for producers and factor market clearing conditions). Section III sets out the international market clearing conditions for equilibrium in the goods markets (excess demand functions), and for balance of payments equilibrium. In Section IV the model is modified to include exogenously imposed ad valorem tariffs and subsidies on the differentiated product X.

Section V derives the indirect utility functions for each country j.

I. Equilibrium in Consumption

This model is a representative consumer model; it assumes that all consumers are represented by the same utility function, and further that preferences in the two countries are identical. Therefore the welfare of each country is represented by the welfare of a single (collective) consumer, and the individual's utility function represents the society's social welfare function.

Preferences are represented by a two-level utility function of the form:

$$W^j = W^j[D_Y^j,\ u^j(.)] \qquad j = 1,2 \tag{1.0}$$

where D_Y^j is the quantity of the homogeneous product Y consumed in country j, and $u^j(.)$ is the sub-utility derived from the consumption of the differentiated product X in country j. It is assumed that the upper tier utility function $W^j[.]$ is an increasing, homothetic function. The sub-utility function $u^j(.)$ depends on the quantity of each variety k of product X consumed.

It is assumed that all varieties of the differentiated product contribute equally to the welfare of the consumer (i.e., enter symmetrically into the utility function), and that consumers obtain utility from variety in consumption (i.e., that the utility obtained from product X increases with both the amount consumed and the number of varieties consumed).[16] This specification of preferences has been chosen over the "ideal" product approach because it is a mathematically simpler approach (utilizing the convexity characteristics of a conventional utility function), and lends itself directly to the representative consumer approach.

With this approach, the sub-utility function is assumed to take the following CES form:

$$1.1 \qquad u_x^j(\cdot) = \left(\sum_{k=1}^{N} (D_{xk}^j)^{\beta}\right)^{\frac{1}{\beta}} \qquad 0<\beta<1; \quad N = \sum_{j=1}^{2} n^j$$

where n^j = number of varieties of product X produced in country j, and

D_{xk}^j = quantity of variety k of product X consumed in country j.

The model follows the common practice in the theoretical literature of representing upper tier preferences as Cobb-Douglas, with the utility function of a representative consumer in country j being specified as follows:[17]

$$1.2 \qquad W^j = \left(\sum_{k=1}^{N} (D_{xk}{}^j)^{\beta}\right)^{\frac{\alpha}{\beta}} (D_y^j)^{1-\alpha} \qquad 0<\alpha,\beta<1$$

The elasticity of substitution between varieties of product X ($\sigma_x = 1/(1 - \beta)$) must be greater than one (i.e., $\beta < 1$) for products to be less than perfect substitutes. As $\beta \rightarrow 1$, $\sigma_x \rightarrow \infty$ and product varieties become perfect substitutes (i.e., we have a homogeneous product). When $\beta = 1$, and the social welfare function simplifies to:

$$1.2a \qquad W^j = (\Sigma D_{xk}^j)^{\alpha}(D_y^j)^{1-\alpha} = (D_x^j)^{\alpha}(D_y^j)^{1-\alpha} \qquad j = 1,2$$

This preference specification is consistent with preference assumptions of the H-O trade model.

Maximization of the utility function W^j, subject to the national income (I^j) constraint:

$$1.3 \qquad \sum_{k=1}^{N} p_{xk}^j D_{xk}^j + p_y^j D_y^j = I^j \qquad j = 1, 2$$

yields Marshallian demand functions for the product Y and for each variety k of product X in country j.

Due to the weak separability of preferences and linear homogeneity of the sub-utility function the maximization problem can be solved in two stages. In the first stage the sub-utility function $u^j(.)$ is maximized for a given expenditure level E_x^j on the differentiated product:

$$1.4 \qquad \underset{(D_{x1}^j \ldots D_{xN}^j)}{Max}\; u^j(\cdot) = \left(\sum_{k=1}^{N} (D_{xk}^j)^{\beta} \right)^{\frac{1}{\beta}} \qquad s.t. \quad \sum_{k=1}^{N} p_{xk}^j D_{xk}^j = E_x^j$$

This provides optimal values D_{xi}^j, for any variety i, conditional on the expenditure level E_x^j in country j:

$$1.5 \qquad D_{xi}^j = \frac{(p_{xi}^j)^{\frac{1}{\beta - 1}}}{\sum_{k=1}^{N} (p_{xk}^j)^{\frac{\beta}{\beta - 1}}} \cdot E_x^j$$

Substituting these optimal values D_{xi}^j in the second stage maximization problem, the optimal expenditure share for product X, E_x^j, is chosen to maximize overall welfare in country j:

$$1.6 \quad \underset{(X^j,\, Y^j)}{Max}\, W^j\,[\cdot] = (X^j)^{\alpha}(Y^j)^{1-\alpha} \quad s.t. \quad P_x^j X^j + p_y^j Y^j = I^j$$

Solution of this maximization problem gives demand equations:

$$1.7 \qquad X^j = \alpha I^j / P_x^j \qquad \text{with } E_x^j = \alpha I^j$$

Substituting into equation 1.5 for E_x^j gives country j demand equations:

$$1.8 \quad D_{xi}^j = \frac{(p_{xi}^j)^{\frac{1}{\beta - 1}}}{\sum_{k=1}^{N} (p_{xk}^j)^{\frac{\beta}{\beta - 1}}} \cdot \alpha I^j \quad \text{for variety } i \text{ of product } X$$

$$D_y^j = \frac{(1 - \alpha)}{p_y^j} \cdot I^j \qquad \text{for product } Y$$

Given the symmetry assumptions made with respect to varieties of product X, all varieties have the same equilibrium price ($p_{xk}^j = p_x^j$). Taking product Y as numeraire and normalizing prices (i.e., setting $p_y^j = 1$), we obtain the following simplified demand functions for country j, with $p^j = p_x^j/p_y^j$:

$$1.9 \quad D_{xi}^j = \frac{(p^i)^{\frac{1}{\beta - 1}}}{n^1 (p^1)^{\frac{\beta}{\beta - 1}} + n^2 (p^2)^{\frac{\beta}{\beta - 1}}} \cdot \alpha I^j$$

$$D_y^j = (1 - \alpha)\; I^j \qquad i,\, j = 1,2$$

where i = 1 for varieties of X produced in country 1, and
= 2 for varieties produced in country 2.

In the more restricted H-O version of the model where $\beta = 1$ these demand functions simplify further to:

1.9a $D_x^j = \alpha I^j/p \qquad D_y^j = (1 - \alpha)\, I^j \qquad j = 1,2$

II. **Equilibrium in Production**

It is assumed that there are two industries: one which produces a homogeneous product Y (eg. food) with technology exhibiting constant returns to scale; and one which produces a differentiated product X (eg. manufactures) with technology exhibiting output generated scale economies at the firm level. Each is produced using two inputs, labour (L) and capital (K). Production technologies are assumed to be homothetic. Therefore cost functions of individual firms are of the form:

2.0 $C_z[r, w, z] = c_z[r, w]\, g[z]$

where z is individual firm output of X or Y, and w, r are factor input prices of L and K, respectively. Production technology is specified as CES,[18] and is specific to each industry, but common to firms within an industry, regardless of the country of its location.

A. Producer Equilibrium

It is assumed that producers choose output levels which maximize their profits, taking the prices of other firms as given. It is also assumed that there is free entry in each industry, and that firms will enter or leave as profits are positive or negative. Consequently, equilibrium is characterized by the following conditions:

1. Individual firms produce at the output level which maximizes profits, that is, where marginal revenue equals marginal cost.

2. Industry equilibrium is obtained when there are zero profits for each firm.

For industry Y, constant returns to scale are assumed ($g[z] = y$), and the cost function is given by:

$$2.1 \quad C_y^j = (a_y (r^j)^\rho + (1-a_y)(w^j)^\rho)^{\frac{1}{\rho}} y^j \quad 0 \neq \rho < 1,\ 0 < a_y < 1,\ j=1,2$$

where r^j = capital input price in country j
w^j = labour input price in country j
y^j = firm output of product Y in country j.[19]

From Condition 1, firm equilibrium for industry Y is given by:

$$2.2 \qquad P^j - \partial C_y^j[r^j, w^j, y^j]/\partial y^j \leq 0 \qquad j = 1,2$$

As long as marginal revenue (p^j) exceeds marginal cost output will increase. Since industry Y is perfectly competitive we have $MC_y = AC_y$ and $MR_y = p_y = 1$. Therefore satisfaction of Condition 1 also satisfies Condition 2. Combining Conditions 1 and 2 and substituting in the specified functional form for the cost function gives the following industry Y equilibrium condition:

$$2.3 \qquad 1 - (a_y(r^j)^\rho + (1 - a_y)(w^j)^\rho)^{1/\rho} \leq 0; \qquad j = 1,2.$$

This can be further simplified to:

2.3a $1 - (a_y(r^j)^\rho + (1 - a_y)(w^j)^\rho) \leq 0; \quad j = 1,2.$

If at the equilibrium factor and product prices you have marginal revenue less than marginal cost, then country j will not produce product Y (i.e., $y^j = 0$). For the purpose of solving the equation system it is necessary that all conditions be formulated as equalities. In order to reflect firm behaviour and still change the inequality to an equality, the equilibrium condition is rewritten (from Kuhn-Tucker conditions) as follows:

2.3b $Y^j - Y^j (a_y(r^j)^\rho + (1 - a_y)(w^j)^\rho) = 0; \quad y^j \geq 0; \quad j = 1, 2.$

Since there is only one equilibrium condition, only industry output (Y^j) can be determined; individual firm output and number of firms are indeterminant.

With respect to the differentiated product industry X, it is assumed that there are an infinite number of possible varieties k, each of which could be produced using identical technology and with identical cost functions. Due to finite factor endowments and economies of scale, only a finite number of varieties, N, will be produced, with n^j being produced in country j. Each firm will maximize its revenue by producing a unique variety; therefore n^j also represents the number of firms in industry X in country j.

The cost function for industry X uses a simple specification of output generated scale economies, specifically, g[z] = x + h (where h could be interpreted as representing a fixed cost of production). The degree of economies of scale $\theta[r, w, x]$ is a declining function of firm output:

$$\theta[r, w, x] = g[x]/g'[x]x = 1 + h/x.$$

The cost function for any variety k of product X is given by:

$$2.4 \quad C_{xk} = (a_x(r^j)^\rho + (1 - a_x)(w^j)^\rho)^{\frac{1}{\rho}}(x^j + h)$$

with $j = 1 \ \forall \ i = 1,\ldots,n^1$ and $j = 2 \ \forall \ i = n^1 + 1,\ldots,n^1 + n^2$ when the varieties produced by country 1 are numbered $1,\ldots,n^1$ and those produced by country 2 are listed $n^1 + 1,\ldots,n^1 + n^2$.

Each producer will maximize his profit by taking as given the prices of other varieties produced and produce a unique variety of product X, at an output level which satisfies Condition 1:

$$2.5 \qquad p_k^j(1 - 1/e_k) - \partial C_{xk}[r^j, w^j, x_k^j]/\partial x_k^j \leq 0 \qquad j = 1, 2$$

where p_k^j = the normalized price of variety k

e_k^j = elasticity of demand for variety k.

Given the symmetry assumptions of this model with respect to preferences and cost functions, and the assumption of homotheticity in production, it follows that all varieties in a country j will be produced in equal quantity (i.e., $x_k^j = x^j$; $j = 1,2$) at the equilibrium price p^j. Accordingly, substituting in the specific functional form of the cost function gives the following equation for firm equilibrium:

$$p^j(1- 1/e^j) - (a_x(r^j)^\rho + (1 - a_x)(w^j)^\rho)^{1/\rho} \leq 0; \quad j = 1, 2$$

which simplifies to:

$$2.6 \qquad [p^j(1 - 1/e^j)]^\rho - a_x(r^j)^\rho - (1 - a_x)(w^j)^\rho \leq 0; \quad j = 1, 2$$

where e^j = elasticity of demand for varieties of x produced in country j.

Utilizing Kuhn-Tucker conditions, as for industry Y, gives:

2.6a $X^j[p^j(1 - 1/e^j)]^\rho - X^j(a_x(r^j)^\rho + (1 - a_x)(w^j)^\rho) = 0;\ X^j \geq 0$

The elasticity of demand for variety k is derived as follows:

$$e_k = \left[\frac{p_k}{D_{xk}} \cdot \frac{\partial D_{xk}}{\partial p_{xk}}\right] \qquad where\ D_{xk} = D^1_{xk} + D^2_{xk}$$

$$= -\left[\frac{\frac{p_k}{D_{xk}}(-\sigma_x\alpha(I^1+I^2)p_k^{-\sigma_x-1}\Sigma p_i^{1-\sigma_x} - (1-\sigma_x)p_k^{-\sigma_x}p_k^{-\sigma_x}\alpha(I^1+I^2)}{(\Sigma(p_i)^{1-\sigma_x})^2}\right]$$

$$= \sigma_x + (1 - \sigma_x)\frac{(p_k)^{1-\sigma_x}}{\Sigma(p_i)^{1-\sigma_x}} \qquad where\ \sigma_x = \frac{1}{1-\beta}$$

With $x_k^j = x^j$, and $p_k^j = p^j$, this simplifies to:

$$2.7 \qquad e^j = \frac{1}{1-\beta} - \frac{\beta}{1-\beta}\left(\frac{(p^j)^{\frac{\beta}{\beta-1}}}{n^1(p^1)^{\frac{\beta}{\beta-1}} + n^2(p^2)^{\frac{\beta}{\beta-1}}}\right) \qquad j = 1,2$$

As N becomes large (i.e., as $n^1 + n^2 \rightarrow \infty$) e^j approaches a constant value determined by the parameter β of the sub-utility function $u^j(.)$ (i.e., $e^j = e \rightarrow 1/(1 - \beta)$). The normal practice in the literature has been to assume that N is very large so that the elasticity of demand can be assumed to be constant. This gives the following simplified equation for firm equilibrium:

2.6b $X^j(p^j\beta)^\rho - X^j(a_x(r^j)^\rho + (1 - a_x)(w^j)^\rho) = 0;\ j = 1, 2$

Industry equilibrium requires that each firm have zero profits (Condition 2). This is given by:

$$2.8 \qquad p^j x^j - C_x^j[r^j,\ w^j,\ x^j] = 0 \qquad j = 1,2.$$

It can be shown that this implies that in equilibrium the degree of monopoly power in industry X ($R^j[.]$) must equal the degree of scale economies ($\theta^j[.]$) in each country, i.e.:

$$(1 - 1/e^j)^{-1} = 1 + h/x^j \quad \text{which gives}$$

$$2.9 \qquad x^j = h\ (\ e^j - 1\ ) \qquad j = 1,2.$$

as the equation determining country j equilibrium firm output. When it is assumed that $e^j = e = 1/(1 - \beta)$, this becomes:

$$2.9a \qquad x^j = x = h\ \beta\ /\ (1 - \beta) \qquad j = 1,2.$$

This gives a unique value for optimal firm size which is the same for both countries and completely determined by the parameter β of the sub-utility function and the scale parameter h, and unaffected by prices.

Equations 2.3b, 2.6a, 2.7 and 2.9 (or in the case where e is assumed to be constant, 2.3b, 2.6b, and 2.9a) provide 8 (5) equations which determine equilibrium output for industry Y, and demand elasticities, firm output and number of firms (varieties) in industry X in each country, given relative product and factor input prices. (Note that total industry X output $X^j = n^j x^j$.) In the more restricted H-O version of the model, $R[.] = \theta[.] = 1$ in industry X, and equations 2.3b and 2.6b (with $\beta = 1$) define producer equilibrium.

B. Factor Market Equilibrium

In deriving the factor market clearing equilibrium conditions we assume full employment of factor inputs and let:

L	=	total world endowment of labour
K	=	" " " " capital
sl^1	=	country 1 share of labour
sl^2	=	" 2 " " " = $1 - sl^1$
sk^1	=	" 1 " " capital
sk^2	=	" 2 " " " = $1 - sk^1$
and		$0 < sl^1, sk^1 < 1$.

The demand for factor input i (i = L, K) in industry Z in each country j is given by the first partial derivative of the cost function with respect to the factor input price:

i.e.
$$L_z^j = \partial\, C_z^j\, [r^j, w^j, z^j] \,/\, \partial\, w^j \qquad z = x, y;$$
$$K_z^j = \partial\, C_z^j\, [r^j, w^j, z^j] \,/\, \partial\, r^j \qquad j = 1, 2$$

Since production technology (and cost functions) are homothetic (i.e., $C_z[r, w, z] = c_z[r, w]\, g[z]$), it is possible to derive factor input coefficients for each industry (a_{iz}^j) by taking partial derivatives of the function $c_z[r, w]$ with respect to input prices. This gives the following eight input coefficients for labour and capital in industry Z:

2.10 $$a_{lz}^j = (w^j)^{\rho-1}(1 - a_z)(a_z(r^j)^\rho + (1 - a_z)(w^j)^\rho)^{(1/\rho)-1}$$

2.11 $$a_{kz}^j = (r^j)^{\rho-1}a_z(a_z(r^j)^\rho + (1 - a_z)(w^j)^\rho)^{(1/\rho)-1}$$
$$z = x, y; \; j = 1, 2$$

Aggregate demand for capital and labour in each country j is then given by: $a_{iy}^j\, Y^j + a_{ix}^j\, (x + h)\, n^j$; $i = K^j, L^j$.

Using the input coefficients as derived above, the factor market clearing conditions are given by the following four equations:

2.12 $\quad a_{ly}^{j}\, Y^{j} + a_{lx}^{j}\,(x + h)\, n^{j} = L\, sl^{j}$

2.13 $\quad a_{ky}^{j}\, Y^{j} + a_{kx}^{j}\,(x + h)\, n^{j} = K\, sk^{j} \qquad j = 1,2.$

For the H-O version of the model, the cost function of industry X is of the form: $C_{x}^{j}[r^{j}, w^{j}, x^{j}] = c_{x}^{j}[r^{j}, w^{j}]\, x^{j}$. In this case the factor market clearing conditions are given by:

2.12a $\quad a_{ly}^{j}\, Y^{j} + a_{lx}^{j}\, X^{j} = L\, sl^{j}$

2.13a $\quad a_{ky}^{j}\, Y^{j} + a_{lx}^{j}\, X^{j} = K\, sk^{j} \qquad j = 1,2.$

where $X^{j} = x^{j}n^{j}$ = industry output, and firm output and number of firms is indeterminant.

III. **International Product Market Equilibrium**

International product market equilibrium is characterized by equality of world demand and supply for every product, and balance of payments equilibrium for each country. The system of product market clearing equations can be written in terms of net (or excess) expenditure and excess demand functions, which in equilibrium meet the following conditions:

- there must be zero world excess demand for each good ($ED_{z} = ED_{z}^{1} + ED_{z}^{2} = 0$; $z = X^{i}, Y$), where ED_{x}^{1} and EDx_{x}^{2} is excess demand for product Z in country 1 and 2, respectively,[20] and

- there must be balance of payments equilibrium (total expenditures on all products consumed must equal national income, or equivalently, the value of exports must equal the value of imports).

Given the demand specification of this model (in which demand for each product is represented as a share of income, with the sum of these shares being unity), it can be shown that when the national income identity holds (i.e., when $I^j = Y^j + p^j n^j x^j$) the balance of payments condition is automatically met.[21]

By Walras' Law if all but one of the product market equilibrium conditions hold the last necessarily holds. For the purposes of this analysis I have chosen to drop the equation relating to equilibrium in the market for the homogeneous product Y, the numeraire good. Therefore all that is required for international product market equilibrium is that excess demand for each variety of product X produced is zero:

3.0 $ED_{xi} = x^i - Dx_i^1 - Dx_i^2 = 0,$

for every variety of product X produced in country i.

Substituting in the demand functions for varieties of product X produced in country i, derived in Section I (Equations 1.9), gives the following two equations specifying international product market equilibrium:

3.1
$$ED_{xi} = x^i - \frac{\alpha\,(p^i)^{\frac{1}{\beta-1}}\left(\sum_{j=1}^{2} I^j\right)}{n^1\,(p^1)^{\frac{\beta}{\beta-1}} + n^2\,(p^2)^{\frac{\beta}{\beta-1}}} = 0$$
$$= x^i - \alpha\,(p^i)^{\frac{1}{\beta-1}}.\frac{(x(p^1n^1 + p^2n^2) + y^1 + y^2)}{n^1(p^1)^{\frac{\beta}{\beta-1}} + n^2(p^2)^{\frac{\beta}{\beta-1}}} = 0$$

i = 1,2

For the H-O version of the model this simplifies to one excess demand condition for product X:

$$3.2 \qquad ED_x = X^1 + X^2 - \alpha\,(I^1 + I^2)/p = 0.$$

IV. **Tariff-ridden Equilibrium**

As indicated in Chapter 1, a country may attempt to improve its national welfare level from that attained in the free trade equilibrium through commercial/trade policy intervention. While there are a number of policy instruments available to governments we will restrict ourselves here to consideration of two policy instruments: ad valorem tariffs on imported varieties of product X, and subsidies on the domestically produced varieties of product X, expressed as a percentage of the producer price.

It is assumed that the tariff is collected by the government, and redistributed directly to consumers. The subsidy is expressed as a percentage of the producer price. It is modelled as a subsidy on consumption, regardless of in which country the consumption occurs; therefore it is equivalent to a producer subsidy. It is assumed that the subsidy is paid by government directly to consumers, and is financed through a compensating domestic income tax.

With the introduction of consumption subsidies the price paid by consumers in both countries for any variety of product X produced by country i becomes $p^i(1 + t_i^{\,i})$, $t_i^{\,i} \leq 0$. In the case of imported varieties of product X, the domestic price price is the tariff inclusive price $p^i(1 + t_i^{\,i})(1 + t_i^{\,j})$, $t_i^{\,j} \geq 0$. However the price received by producers in country i continues to be p^i. The introduction of tariffs and/or subsidies therefore influences producer and factor market equilibrium only indirectly through their effect on demand and the elasticity of demand.

Substituting in the subsidy/tariff inclusive prices for p^i in Equation 1.9 gives the following revised demand functions for individual varieties of product X:

$$4.0 \quad D_{xi}^{j} = \frac{[p^i(1+t_i^i)(1+t_i^j)]^{\frac{1}{\beta-1}}}{n^i[p^i(1+t_i^i)(1+t_i^j)]^{\frac{\beta}{\beta-1}} + n^j[p^j(1+t_j^j)]^{\frac{\beta}{\beta-1}}} \cdot \alpha I^j$$

$$4.1 \quad D_{xi}^{i} = \frac{[p^i(1+t_i^i)]^{\frac{1}{\beta-1}}}{n^i[p^i(1+t_i^i)]^{\frac{\beta}{\beta-1}} + n^j[p^j(1+t_j^j)(1+t_j^i)]^{\frac{\beta}{\beta-1}}} \cdot \alpha I^i$$

When ad valorem tariffs/subsidies in the differentiated product X are introduced into the model the elasticity of demand for any variety of product X produced in country i (Equation 2.6) becomes:

4.2

$$e^i = \frac{1}{1-\beta} - \frac{\beta}{x^i(1-\beta)}\left[\frac{D_{xi}^i[p^i(1+t_i^i)]^{\frac{\beta}{\beta-1}}}{n^i[p^i(1+t_i^i)]^{\frac{\beta}{\beta-1}} + n^j[p^j(1+t_j^j)(1+t_j^i)]^{\frac{\beta}{\beta-1}}} + \frac{D_{xi}^j[p^i(1+t_i^i)(1+t_i^j)]^{\frac{\beta}{\beta-1}}}{n^i[p^i(1+t_i^i)(1+t_i^j)]^{\frac{\beta}{\beta-1}} + n^j[p^j(1+t_j^j)]^{\frac{\beta}{\beta-1}}}\right]$$

Note that when tariffs and subsidies are introduced, demand elasticities and domestic prices may differ in the two countries for the generalized form of the model using the exact specification of demand elasticity. When assuming N is large we can still use the approximation, $e = 1/(1-\beta)$. Setting $t_i^j = 0 \;\forall\; i,j$ gives the free trade form of the model which was derived in Sections I through III.

V. The Indirect Utility Function

Levels of national welfare in the two countries will be compared using the indirect utility function, V^j, which can be derived by substituting into the utility function U^j, the equilibrium demand specifications, D_{xi}^j, as set out in Equations 4.0 and 4.1:

4.3 $$V^j = (\Sigma(D_x^j)^{\beta})^{\alpha/\beta}\,(D_y^j)^{1-\alpha}$$

$$= [\; n^1\,(D_{x1}^j)^{\beta} + n^2\,(D_{x2}^j)^{\beta}\;]^{\alpha/\beta}\,(D_y^j)^{1-\alpha}$$

$$=\left(\frac{\alpha}{1-\alpha}\right)^{\alpha}(1-\alpha)\,I^j\left(n^i[p^i(1+t_i^i)(1+t_i^j)]^{\frac{\beta}{\beta-1}}+n^j[p^j(1+t_j^j)]^{\frac{\beta}{\beta-1}}\right)^{\frac{\alpha(1-\beta)}{\beta}}$$

where 4.4 $$I^j = p^j n^j x^j + Y^j + n^j p^j t_j^j (D_{xj}^i + D_{xj}^j) + n^i p^i t_i^j D_{xi}^j$$

Note that:

$n^j\, p^j\, t_j^j\, (D_{xj}^i + D_{xj}^j) \leq 0$

= subsidies paid to consumers by country j, and

$n^i\, p^i\, t_i^j\, D_{xi}^j \geq 0$ = tariff revenues of country j.

For the H-O version of the model the utility function simplifies to:

4.3a $$V^j = (\,D_x^j\,)^{\alpha}\,(\,D_y^j\,)^{1-\alpha} = (\alpha/p)^{\alpha}\,(1-\alpha)^{1-\alpha}\,I^j$$

where

4.4a $$I^j = p\,X^j + Y^j \qquad j = 1,2.$$

VI. Summary of the Model

The C-H-O version of the model consists of the following 30 equations for the exact specification of product X demand elasticity (27 equations when elasticity is approximated by a constant):

- 2 industry Y producer equilibrium conditions (Eqn. 2.3b)
- 2 industry X producer equilibrium conditions (Eqn. 2.6a for the exact specification of elasticity, or 2.6b, taking e to be constant)
- 2 equations specifying demand elasticity (Eqn 4.2) in the case of exact specification of elasticity
- 2 equations specifying equilibrium firm output of industry X (Eqn 2.9), or 1 equation (Eqn 2.9a), if e is a constant
- 8 equations specifying factor input coefficients (Eqns 2.10, 2.11)
- 4 factor market clearing equations (Eqns 2.12, 2.13)
- 4 demand equations for product X (Eqns 4.0 and 4.1)
- 2 equations specifying conditions for international product market equilibrium for product X (Eqn 3.0)
- 2 national income identities (Eqn 4.4)
- 2 equations specifying the indirect utility functions of each country (Eqn. 4.3).

The restricted H-O version of the model has 21 equations (with only one international product market equilibrium equation, and no equations specifying demand elasticities or individual firm output).

The model solves for relative factor prices in each country (r^j, w^j), factor input coefficients (a_{lx}^j, a_{kx}, a_{ly}^j, a_{ky}^j), output of product Y (Y^j), relative prices of varieties of product X (p^j), number of varieties of product X produced in each country (n^j), elasticity of demand for product X varieties produced in each country (e^j), country j demand for varieties of X produced in each country i (D_{xi}^j), income levels in each country (I^j), and the national welfare level in each country (V^j). The H-O version of the model solves only for total demand and total industry output of product X in each country, as product X is a homogeneous product, and the number of firms and firm output are not defined.

A summary of notation used in the model and model equations for the generalized form of the model is provided in Appendix I.

Chapter 3
SOLUTION OF THE MODEL/SIMULATION RESULTS

Once parameter values (production and preference coefficients) and factor endowments are specified the model developed in Chapter 2 can be solved. The program which has been used is the Gauss Nonlinear Simultaneous Equations (NLSYS) Application. This program is very powerful and can solve nonlinear systems of over 90 equations.

The program requires that initial or starting values for the variables be provided. A solution set for the model is obtained through an iterative procedure, using a quasi-Newton algorithm. More specifically NLSYS approximates the Jacobian (and its inverse) of the equation system, using a forward difference method. For each iteration a step length is chosen, using a line-search algorithm, to move closer to a minimum of the equation system $F(X)=0$ (i.e., where the model equations are written in their implicit form). The solution set obtained from NLSYS is an approximation, rather than an exact solution.

The solution set obtained is sensitive to the starting values chosen, and in particular to the values chosen for the price variables. More than one set of solution values exist, and the solution located by NLSYS is generally the solution closest to the starting values. Care, therefore, had to be taken in choosing starting values which give an economically viable equilibrium (i.e., with non-negative prices and outputs), which is stable in the neighborhood of the solution point. Note also that, because the solution set is an approximation, different starting values can result in different solution estimates for the same equilibrium point. The choice of starting values proved to be more of a problem when the equilibrium involved one or both of the countries specializing in the production of a single product, in which case the price variables could vary significantly.

Copies of the Gauss command files for each of the three versions of the model - the exact demand elasticity specification (the CHOEX version), the constant elasticity approximation (the CHOCE version), and the more restricted Heckscher-Ohlin specification (the H-O version) - are provided in Appendices II, III and IV, respectively, along with a sample solution set.

Simulations were carried out under varying relative factor endowments and country size (i.e., for varying values of SL1 and SK1) in order to:

- compare the free trade market equilibrium (in particular, welfare levels) in the generalized C-H-O model with the equilibrium in the more restricted H-O version of the model;
- investigate the impact on welfare levels, in the C-H-O form of the model, of introducing tariffs and subsidies on the differentiated product X; and
- determine how sensitive the above results were to the elasticity specification used (i.e., to whether the exact or constant elasticity approximation is used).

Given the symmetry assumptions of the model with respect to preferences and production technologies, it was only necessary to carry out simulations for one-half the possible range of endowment shares (i.e., from the perspective of country 1 for $0.05 \leq SL1 \leq 0.5$ and $0.05 \leq SK1 \leq 0.95$).

I. Simulations Comparing Market Equilibria

In order to investigate the effect of introducing monopolistic competition on the free trade market equilibrium, the following simulations were carried out, and equilibria were compared, for all three versions of the model, under varying factor endowments:

- values of h = 0.1, 1, 5, 25, 100, 1000 (to study the impact of varying the degree of scale economies in industry X);
- values of β = 0.5, 0.6, 0.7, 0.8, 0.9, and, in the H-O version for $\beta = 1$ (to study the impact of varying the strength of product differentiation in industry X); and
- values of ρ = 0.1, 0.2, 0.3 (to study the impact of varying the ease of substitutability between factor inputs).

The following parameter values were arbitrarily assumed, and not varied:

- $\alpha = 0.6$ (income share of product X, from the upper tier utility function);
- $a_y = 0.6$ and $a_x = 0.2$ (cost share coefficients). Note that under this specification product Y is relatively capital intensive and product X is relatively labour intensive.

The world endowment levels under which simulations were carried out were L = 2000 and K = 1000, although a limited number of simulations were carried out to determine the impact of varying world factor endowments - where alternatively labour or capital was the abundant factor, and where there was a significantly different absolute level of world endowments.

In carrying out these simulations, I was particularly interested to note the effects of the above parameters in determining total world welfare levels, the welfare share of each country and the pattern of specialization for each of the three versions of the model. I also wanted to determine how close an approximation was provided by the constant elasticity model specification.

A summary of free trade equilibrium welfare levels, under varying values of h, β, and ρ is provided in Table 3.1.

As was explained in Chapter 2, Section II A, on producer equilibrium, monopolistic competition implies that in equilibrium the degree on monopoly power in industry X must equal the degree of economies of scale. This gives the following relationship between firm output x and the scale parameter h: $x = h(e-1)$, where e is the elasticity of demand for any variety of product x. Therefore, as h changes, both firm output and demand elasticity adjust to maintain the equality. However, without a quantitative model, except in the case of any but the most simple models, one could do no more than deduce the direction of these adjustments.

Tables 3.2 A and B provides a summary of simulation results of varying the scale parameter h (for the case where $\rho = 0.2$, $L = 2000$, $K = 1000$). As one might expect, as h increases the elasticity of demand for individual varieties of product X decreases and the relative price of X increases. This results in a decline in total output in industry X. However, except for large values of h, the main adjustment comes through change in firm output ($x\downarrow$ as $h\downarrow$) and the number of varieties produced ($n\downarrow$ as $h\uparrow$), with total output and price changing only marginally. Small values of h give higher levels of welfare. This can be explained by two considerations: lower values of h mean lower fixed costs, and also result in a larger number of varieties available for consumption. This is due to the CES demand specification for product X. With the constant elasticity

Table 3.1

Total Welfare in Market Equilibrium,

under varying parametric values (K=1000, L=2000)

Model Specification[1.]	ρ=0.1	ρ=0.2	ρ=0.3
Case I: β=0.5			
h=1	60,384.9000	60,443.7920	60,515.9960
h=5	22,990.2920	23,012.7140	23,040.2060
h=25	8,752.1756	8,760.7150	8,771.1848
h=100	3,803.2318	3,806.9670	3,811.5466
Case II: β=0.6			
h=1	15,746.5896	15,755.9078	15,767.3278
h=5	8,271.7268	8,276.6220	8,282.6212
h=25	4,344.6056	4,347.1790	4,350.3326
h=100	2,490.1968	2,491.6912	2,493.5226
Case III: β=0.7			
h=1	6,249.8132	6,251.8002	6,254.2346
h=5	4,131.7002	4,133.0140[2.]	4,134.6234
h=25	2,730.9714	2,731.8416	2,732.9076
h=100	1,906.9792	1,907.6059	1,908.3735
Case IV: β=0.8			
h=1	3,240.5180	3,240.8828	3,241.3298
h=5	2,545.4486	2,545.3520	2,546.0864
h=25	1,998.9677	1,999.1948	1,999.4731
h=100	1,617.5494	1,617.7555	1,618.0079
Case V: β=0.9			
h=1	2,030.1558	2,030.0602	2,029.9432
h=5	1,823.5690	1,823.4833	1,823.3784
h=25	1,637.2229	1,637.1490	1,637.0585
h=100	1,483.0200	1,482.9861	1,482.9444
Case VI: β=1, h=0			
(H=O version of model)	1,527.8711	1,527.6040	1,527.2770

Notes: 1. These are results obtained using exact demand elasticity specification (CHOEX). The constant elasticity approximation gives slightly higher (less than 1%) welfare levels.

2. For base parameter values used in further model simulations (i.e., b = .7, ρ = .2, h = 5) constant elasticity specification provides an extremely close approximation of the model. The total welfare level varies by only .0007% (at 4133.0444).

Table 3.2 A

Effect on Total Welfare and Selected Variables

of Varying the Scale Parameter h

(for ρ=0.2, L=2,000, K=1,000)

Exact Elasticity Model Specification

Value of h	1000	100	25	5	1	0.1
Case I: β=.5						
Relative price of x	4.1455	1.9985	1.9158	1.8949	1.8908	1.8898
Demand elasticity of x	1.2952	1.8968	1.9732	1.9946	1.9489	1.9999
Firm output of x	295.2253	89.6789	24.329	4.9729	0.9989	0.09999
Number of firms	1.42	9.69	37.26	184.28	919.39	9189.43
Total output of x	418.8952	868.8899	906.3939	916.399	918.3818	918.8512
Total Welfare	776.2268	3,806.967	8,760.715	23,012.714	60,443.792	240,631.12
Case II: β=.6						
Relative price of x	3.4545	1.6654	1.5965	1.57911	1.5757	1.5749
Demand elasticity of x	1.3765	2.3113	2.45	2.4898	2.4980	2.4998
Firm output of x	376.5008	131.1348	36.2502	7.4492	1.4980	0.1500
Number of firms	1.34	7.95	30.00	147.62	735.71	7,351.74
Total output of x	502.6662	1,042.6659	1,087.6728	1,099.6725	1,102.1002	1,102.7617
Total Welfare	787.7925	2,491.6912	4,347.179	8,276.622	15,755.9078	39,577.06

Table 3.2 A (cont.)

Value of h	1000	100	25	5	1	0.1
Case III: β=.7						
Relative price of x	2.961	1.4275	1.3685	1.3535	1.3506	1.3499
Demand elasticity of x	1.4687	2.9578	3.2308	3.3123	3.329	3.3329
Firm output of x	468.6594	195.7798	55.7696	11.5615	2.3291	0.2332
Number of firms	1.25	6.21	22.75	110.97	552.04	5514.06
Total output of x	586.4335	1,216.4582	1,268.9480	1,282.9473	1,285.7466	1,285.8784
Total Welfare	815.4767	1,907.6059	2,731.8416	4,133.0140	6,251.8002	11,301.8120
Case IV: β=.8						
Relative price of x	2.5909	1.2491	1.1974	1.1843	1.1818	1.1812
Demand elasticity of x	1.574	4.1063	4.742	4.9462	4.9891	4.9989
Firm output of x	574.0437	310.626	93.5493	19.7309	3.989	0.3999
Number of firms	1.17	4.48	15.50	74.31	368.36	3676.37
Total output of x	670.2305	1,390.2377	1,450.2293	1,466.2308	1,469.3769	1,470.1812
Total Welfare	853.6099	1,617.7555	1,999.1948	2,545.3520	3,240.8828	4,577.8708
Case V: β=.9						
Relative price of x	2.303	1.1103	1.0644	1.0527	1.0504	1.0499
Demand elasticity of x	1.6957	6.7127	8.9092	9.7610	9.9513	9.9951
Firm output of x	695.721	571.2672	197.7311	43.805	8.9513	0.8995
Number of firms	1.08	2.74	8.25	37.66	184.68	1,838.69
Total output of x	754.0224	1,564.0153	1,631.4991	1,649.5079	1,653.1136	1,653.8981
Total Welfare	899.8883	1,482.9861	1,637.1490	1,823.4833	2,030.0602	2,366.8784

Table 3.2 B

Constant Elasticity Model Specification

Value of h	1000	100	25	5	1	0.1
Case I: β=.5						
Relative price of x	1.8898	1.8898	1.8898	1.8898	1.8898	1.8898
Firm output of x	1,000	100	25	5	1	0.1
Number of firms	0.9189	9.1889	36.76	183.78	918.893	9,188.93
Total Welfare	957.9697	3,813.7462	8,761.6878	23,012.8160	60,433.8020	240,631.12
Case II: β=.6						
Relative price of x	1.575	1.575	1.575	1.575	1.575	1.575
Firm output of x	1,500	150	37.5	7.5	1.5	0.15
Number of firms	0.7351	7.3511	29.40	147.02	735.11	7351.14
Total Welfare	944.1308	2,497.1436	4,347.7796	8,276.6678	15,755.9114	39,577.06
Case III: β=.7						
Relative price of x	1.3498	1.3498	1.3498	1.3498	1.3498	1.3498
Firm output of x	2,333.33	233.33	58.33	11.67	2.33	0.23
Number of firms	0.5513	5.5134	22.05	110.27	551.336	5,513.36
Total Welfare	1,058.2217	1,913.02	2,732.3412	4,133.0444	6,251.8020	11,301.812

Table 3.2 B (cont.)

Value of h	1000	100	25	5	1	0.1
Case IV: β=.8						
Relative price of x	1.1181	1.1181	1.1181	1.1181	1.1181	1.1181
Firm output of x	4,000	400	100	20	4	0.4
Number of firms	0.3677	3.6756	14.70	73.51	367.557	3675.57
Total Welfare	1,149.9092	1,624.2899	1,999.7354	2,545.7634	3,240.8844	4,577.8708
Case V: β=.9						
Relative price of x	1.0499	1.0499	1.0499	1.0499	1.0499	1.0499
Firm output of x	9,000	900	225	45	9	0.9
Number of firms	0.1838	1.8378	7.35	36.76	183.7790	1,837.7900
Total Welfare	1,280.8825	1,493.3994	1,637.9977	1,823.5232	2,030.0620	2,366.8786

Table 3.2 C

Heckscher-Ohlin Model Specification

β=1, h=0

Relative price	0.9449
Output of x	1,837.786
Total Welfare	1,527.6040

approximation price and total output of product X are unaffected by the value of h. All the adjustment comes through offsetting changes in firm size and the number of firms. The constant elasticity specification therefore provides a good approximation to the exact elasticity specification of the model for small values of h, i.e., $h \leq 25$, but not when the value of h is large.

While the scale parameter h affects welfare levels, the degree of substitutability between varieties of product X (as determined by parameter β of the sub-utility function defining consumer preferences for product X) has a more profound impact on welfare levels. The parameter β affects welfare both directly through its effect on the amount of utility derived from consumption of any variety of product X, and indirectly through its effect on the number of varieties produced and consumed. For lower values of β less utility is derived from given level of consumption of any variety of product X.

However, lower values of β imply a higher total utility from consumption of product X due to an increase in the number of varieties consumed. The lower the value of β, the less perfect substitutes the varieties are for each other (i.e., the stronger is the product differentiation), and the more inelastic is demand for each variety of X produced, the higher is the price, the lower is the amount of each variety produced and the more varieties are produced. Lower values of β therefore result in higher levels of welfare due to the increased number of varieties available for consumption. The welfare gain due to increased variety in consumption more than compensates for the welfare loss due to the higher price and lower total consumption of product X. Combinations of low values of h (modest scale economies) and low values of β (strong product differentiation) give the highest welfare levels.

Welfare gains over the conventional perfect competition model (i.e., the H-O version, where h = 0 and β = 1) are therefore assured by the introduction of monopolistic competition, and are attributable to product differentiation and increased variety in consumption. In the absence of product differentiation, imperfect competition (and scale economies) would lead to welfare levels lower than in the case of perfectly competitive markets - due to pricing above marginal cost and a lower than optimal total production level of product X. There are, in fact two opposing forces at work in the monopolistic competition model: welfare losses due to market distortion (misallocation) leading to sub-optimal production of product X (due to scale economies), and welfare gains due to increased variety in consumption (due to product differentiation). Except in the case of high values for h (e.g., h $\geq$ 100) and β ($\beta \geq 0.9$) the gains significantly outweigh the losses.

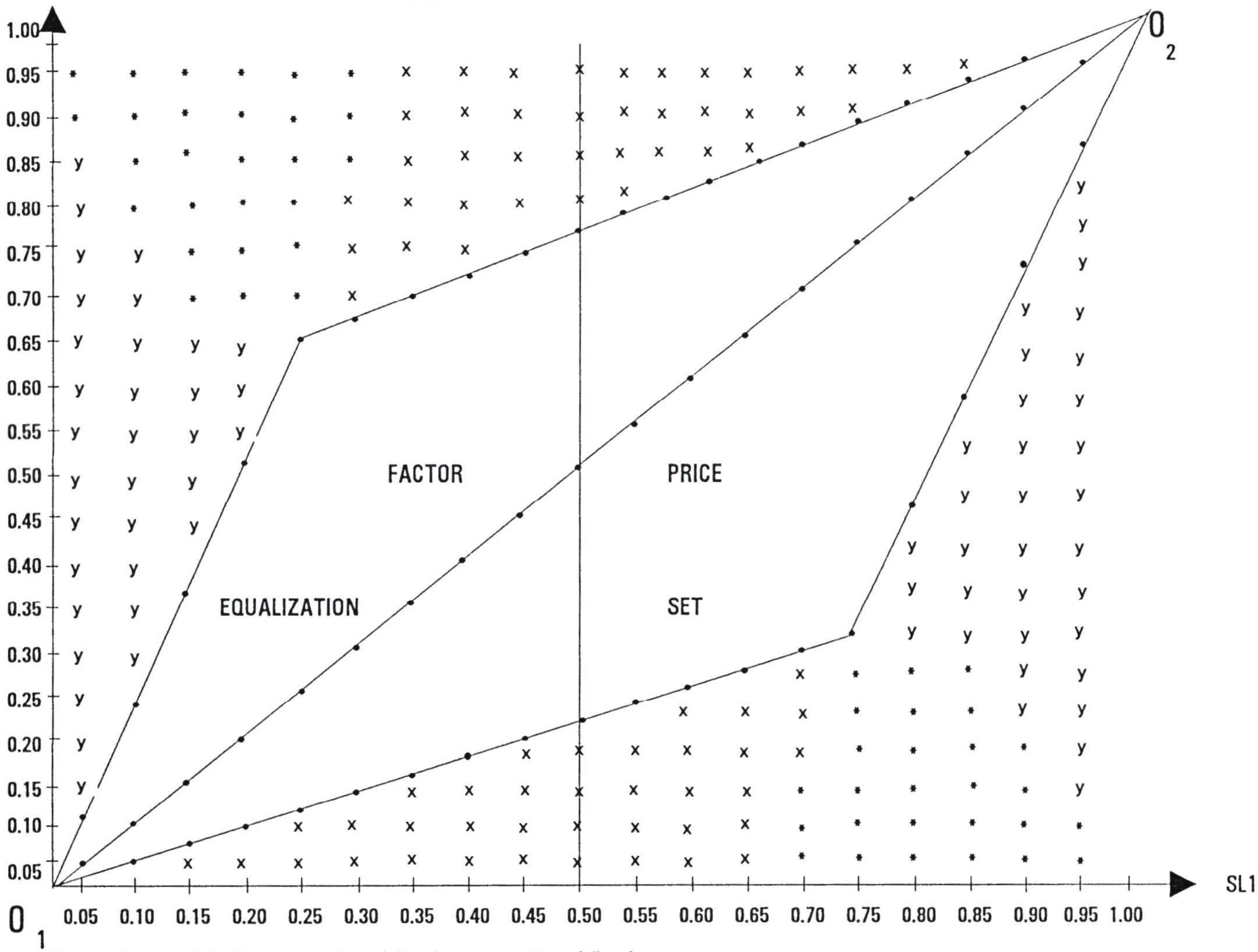
The above simulations for different values of the parameters h and β were carried out for a wide range of relative factor endowments (i.e., values of SL1 and SK1) in order to determine the effect of the model specification and parameter values used on country shares of total world welfare, and on the pattern of production specialization. With respect to production specialization, production patterns of the two countries and the boundaries of the factor price equalization set (i.e., the set of relative factor endowments which result in trading equilibria with both countries producing both products) are completely determined by input coefficients (the technology as given by parameters a_X and a_Y), ρ and world endowments of labour and capital. Whichever model specification (CHOEX, CHOCE or H-O) is used, the values of the scale parameter h or the parameter β, have no impact on production specialization (although there will be an impact on total output).

Figure 1 shows the factor price equalization set (FPE) for a_X = 0.2, a_Y = 0.6, ρ = 0.2, L = 2000, K = 1000. Also shown are factor endowment shares which result in one or both countries specializing in the production of only one product. The critical determinant as to the pattern of specialization is the K/L ratio in each country. If $K/L > 2.25$ then the country specializes in production of Y; if $L/K > 2.25$ then the country specializes in production of X.

With respect to total world welfare, in the H-O version of the model total welfare is maximized within the factor price equalization set (FPE) and is constant for all relative factor endowments combinations throughout the set. Total welfare decreases more the further removed endowment shares are from the FPE. This is not uniformly the case with the generalized form of the model, which has a small band on the perimeter of the FPE set over which welfare levels are higher than in the FPE set. This takes place over a range of endowment shares where the larger country is much larger and has a comparative advantage in the differentiated product X (e.g., SL1=0.05 and SK1=0.15; SL1=0.1 and SK1=0.3 to 0.35; SK1=0.15 and SK1=0.45 to 0.5). This reflects the fact that market equilibria are not pareto optima, i.e., not the social optimum.

Each country's share in total welfare is determined by total world endowments, their share in endowments, the input coefficients (value of a_X, a_Y, ρ), and the inter-product preference specification (value of α), but is unaffected by the value of parameters h or β. Therefore relative country shares are unaffected by which of the three model specifications is used.

FIGURE 1.
PATTERN OF PRODUCTION SPECIALIZATION



* - complete specialization: country 1 specializes in y, country 2 specializes in x
y - one country specializes in good y, x - one country specializes in good x

Table 3.3 presents country 1 welfare shares (SW1) for values of $\rho = 0.2$, L = 2000, K = 1000, and for values of β and h), for factor endowment combinations in the range $0.05 \leq SL1 \leq 0.5$. Country 2's welfare share is 1 - SW1. Country 1 welfare shares for factor endowment combinations in the range $0.5 < SL1 \leq 0.95$ is identical to Country 2 shares for those combinations.

Table 3.3

Relative Welfare Share of Country 1,

for varying factor endowments

(g=0.2, L = 2000, K = 1000)

Share of Capital (SK1)	Share of Labour (SL1)									
	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50
.05	**.05**[2]	.0817	.1131	.1430	.1719	.2005	.2292	.2583	.2883	.3193
.10	.0683	**.10**	.1317	.1635	.1927	.2278	.2597	.2916	.3240	.3571
.15	.8670	.1183	**.15**	.1817	.2135	.2452	.2774	.3108	.3443	.3783
.20	.1041	.1365	.1683	**.20**	.2317	.2635	.2952	.3269	.3587	.3932
.25	.1205	.1548	.1865	.2183	**.25**	.2817	.3135	.3452	.3769	.4086
.30	.1363	.1741	.2048	.2365	.2683	**.30**	.3317	.3635	.3952	.4269
.35	.1519	.1935	.2231	.2548	.2865	.3183	**.35**	.3817	.4135	.4452
.40	.1678	.2129	.2414	.2731	.3048	.3365	.3683	**.40**	.4317	.4635
.45	.1842	.2325	.2624	.2914	.3231	.3548	.3865	.4183	**.45**	.4817
.50	.2014	.2526	.2939	.3096	.3414	.3731	.4048	.4365	.4683	**.50**
.55	.2198	.2736	.3059	.3291	.3596	.3914	.4231	.4548	.4865	.5183
.60	.2397	.2958	.3288	.3522	.3779	.4096	.4414	.4731	.5048	.5365
.65	.2618	.3197	.3530	.3761	.3962	.4279	.4596	.4914	.5231	.5548
.70	.2867	.3458	.4*	.4*	.4*	.4435	.4779	.5096	.5414	.5731
.75	.3155	.3749	.4*	.4*	.4*	.4520	.4889	.5250	.5596	.5914
.80	.3797	.4*	.4*	.4*	.4*	.4625	.5001	.5365	.5720	.6068
.85	.3920	.4*	.4*	.4*	.4*	.4*	.5149	.5516	.5871	.6217
.90	.4*	.4*	.4*	.4*	.4*	.4*	.5366	.5736	.6089	.6429
.95	.4*	.4*	.4*	.4*	.4*	.4*	.5771	.6138	.6482	.6807

Notes:

1. Welfare share equals countries share of total world income (i.e., relative country size as measured by relative income).
2. Welfare share = relative share of world endowments = relative country size.

* Country 1 specializes in production of Y; Country 2 specializes in production of X. Country shares determined by relative income shares of consumption of products X and Y.

Table 3.4 illustrates the effect on total welfare of varying world factor endowments. As could be anticipated, increasing world factor endowments uniformly by some factor (in this case by a factor of 10) results in a proportional welfare increase in the conventional Heckscher-Ohlin (perfect competition) version of the model. In the generalized C-H-O model, with monopolistic competition, welfare increases more than proportionally, due to an increase in the number of varieties produced.

Table 3.4

Total Welfare in Market

Equilibrium, under varying world endowments

	Model Specification	
	H-O Version	CHOCE Version[1.]
Case I		
L=2,000, K=1,000	1,527.6040	4,133.0444
Case II		
L=20,000, K=10,000	15,276.0404	74,715.8820
Case III		
L=1,000, K=2,000	1,213.6655	2,896.4952
Case IV		
L=10,000, K=20,000	12,136.6548	52,361.9340

Note: 1. For parameter values $\beta = 0.7$, $\rho = 0.2$, $h = 5$

In both versions of the model higher welfare levels are attained when labour is the abundant factor, with the difference being accentuated when there is a differentiated product. This is due to parameter values chosen for the upper tier preference specification and for the factor cost coefficients. As a result the income share of product X is greater than that of product Y, and product X uses labour relatively more intensively in its production than does product Y.

relatively more intensively in its production than does product Y.

As can be seen from Table 3.1 (page 31), varying the elasticity (or ease) of factor input substitution has only a marginal effect on total world welfare. For the simulations undertaken, the change in total welfare varied from -0.0214% (in the H-O version of the model with $\beta=1$) to 0.0975% (when $\beta=0.5$) for decreases in the elasticity of factor input substitution, of approximately 10%. Thus the impact of changing the ease of factor input substitution depends on the strength of product differentiation, with a change in ρ having a greater impact for lower values of β.

As the value of ρ increases (and the elasticity of factor input substitutability decreases) the price of the abundant factor, and the relative price of the product which uses that factor more intensively, declines and output of that product increases. The price of the scarce factor and the relative price of the product which uses the scarce factor relatively more intensely increases and output declines. In the case of the H-O version of the model this results in a decrease in total welfare due to a decrease in income. However, in the case of the C-H-O version of the model, if the abundant factor is the one used more intensively by the differentiated product industry X, output increases due to increases of both firm output and number of firms. For low values of β the increased variety in consumption increases welfare more than enough to compensate for the lower income level. For values of β close to 1 the impact of changing the value of ρ on the number of varieties produced and on total welfare declines. By contract, if capital were the abundant factor then welfare would decrease for both the generalized C-H-O and restricted H-O versions of the model, as is shown in Table 3.5.

Table 3.5

Effect of Varying the Elasticity of Factor Input Substitution ($\delta_{KL} = \rho - 1$)

World Endowment	Total World Welfare: CHOCE version [1]	Total World Welfare: H-O version	Country 1 Welfare Share: SL1=.25 and SK1=.45 [2]	Country 1 Welfare Share: SL1=.5 and SK1=.25 [3]
Case I				
L = 2000, K = 1000				
ρ=0.1	4131.7308	1527.8711	0.3225	0.4094
ρ=0.2	4133.0444	1527.6040	0.3231	0.4086
ρ=0.3	4134.6538	1527.2770	0.3238	0.4077
Case II				
L=1000, K=2000				
ρ=.01	2985.3423	1236.5044	0.3168	0.4124
ρ=0.2	2896.4952	1213.6655	0.3107	0.4241
ρ=0.3	2799.2447	1185.7238	0.3036	0.4330

Notes:
1. For parameter values β = 0.7, h = 5
2. Country 1 is smaller and capital intensive
3. Country 1 is smaller and labour intensive

As can be seen from the above table, changing the value of ρ also has an impact on countries' relative welfare shares. For any given factor endowment allocation, the welfare share of the country which has relatively more of the abundant factor decreases as ρ increases (i.e., as factors become less easily substitutable), and the share of the country with relatively more of the scarce factor increases.

As mentioned above changing ρ also impacts on production specialization. As ρ increases the FPE set shrinks inwards toward the diagonal. However, for the range of values of ρ on which simulations were carried out this change was very slight, and too small to be noticeable at the level of detail of Figure 1.

II. Simulations with Tariffs/Subsidies on the Differentiated Product X

The impact on welfare when tariffs or subsidies are introduced on the differentiated product X was investigated for the constant elasticity specification of the generalized C-H-O model (choosing a specific set of parameter values for which the CHOCE version of the model provides a close approximation of the exact elasticity model specification). Simulations were carried out for the following possible cases:

(i) the two counties have the same relative factor endowments, and
   1) they differ greatly in size (SL1=SK1=0.1)
   2) they differ moderately in size (SL1=SK1=0.3)
   3) they are the same size (SL1=SK1=0.5; the countries are identical)

(ii) the smaller country has relatively more capital, and
   1) is approximately 1/4 the size of the larger country, as measured by their national income levels (SL1=0.15, SK1=0.25)
   2) is approximately half the size of the larger country (SL1=0.2, SK1=0.45)
   3) is approximately the same size as the larger country (SL1=0.4, SK1=0.65)

(iii) the smaller country has relatively more labour, and
   1) is approximately 1/4 the size of the larger country (SL1=0.2, SK1=0.15)
   2) is approximately half the size of the larger country SL1=0.4, SK1=0.2)
   3) is approximately the same size as the larger country (SL1=0.5, SK1=0.35)

In each case the following possible policy scenarios were considered:

a) An ad valorem tariff is levied on imported varieties of the differentiated product X by one country only, either the smaller or larger country;

b) Both countries introduce tariffs, either at the same rate or with one country's rate lower than the other;

c) One or both countries introduce a subsidy on consumption of their domestically produced varieties of product X; or

d) One or both countries introduce a combination of tariffs and subsidies.

I wished to discover the welfare gain (or loss) relative to the market equilibrium welfare levels without policy intervention. The results of simulations under each of the four policy scenarios are discussed below. These same simulations were carried out for the CHOEX version of the model for four of the above factor endowment combinations (SL1 = SK1 =0.5, 0.1; SL1=0.2, SK1=0.45; and SL1=0.4, SK1=0.2). The welfare results were identical (to four decimal places) to the results using the CHOCE version of the model.

A. Unilateral Imposition of Tariff on the Differentiated Product X

Simulations were carried out for tariff rates tij = 0.1, 0.2, 0.3, . . ., 1.0, with either the smaller or larger country levying the tariff. For all nine factor endowment combinations considered, both the larger and smaller country registered welfare gains over some range of tariff rates. The welfare gain was maximized at some tariff rate, or range of tariff rates, i.e., there is a positive, non-zero "optimal" tariff rate even for the smaller country.

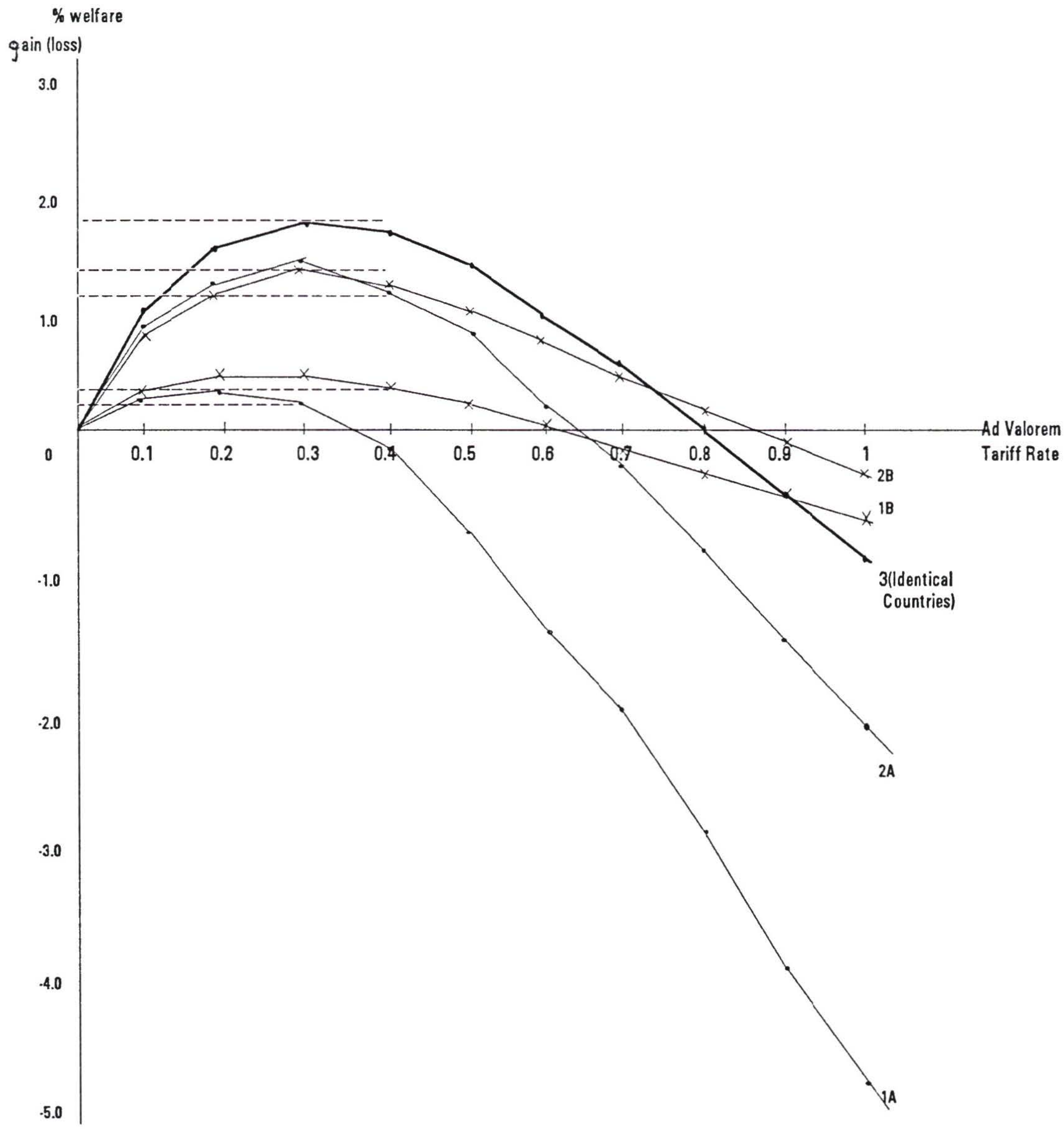
The pattern of welfare gains (or losses) under alternative tariff rates, for each factor endowment combination, are shown in Figures 2 (i), (ii), and (iii).

When countries differ only in size (Case(i)) it can be seen that the possible welfare gain is higher the more similar the two countries are in size, with the maximum welfare gain achieved if the two countries are identical. The range of tariffs over which a welfare gain occurs is greater for the larger country, and this range increases as the countries become more similar.

The "optimum" tariff rate is approximately 30% when the countries are identical. The optimal rate declines, but only slightly, as the countries become more different in size. The optimal tariff rate for the smaller country is the same as for the larger country, regardless of how different the two countries are in size. Note that in the traditional Heckscher-Ohlin model there would be no trade, and therefore the possibility of increasing welfare through a tariff would not exist, in the case where countries had the same relative factor endowments.

Higher welfare gains are possible for both counties when they have different relative factor endowments. When the smaller country has relatively more capital (Case (ii), i.e., the larger country has a comparative advantage in product X), the smaller country is able to obtain a greater welfare gain by introducing an optimal tariff than can the larger country. The maximum possible gain is greater, the more similar the two countries are in size (as in Case(i)). However, past some tariff rate, the larger country will register a greater gain (or less of a loss) in welfare relative to the market equilibrium than will the smaller country.

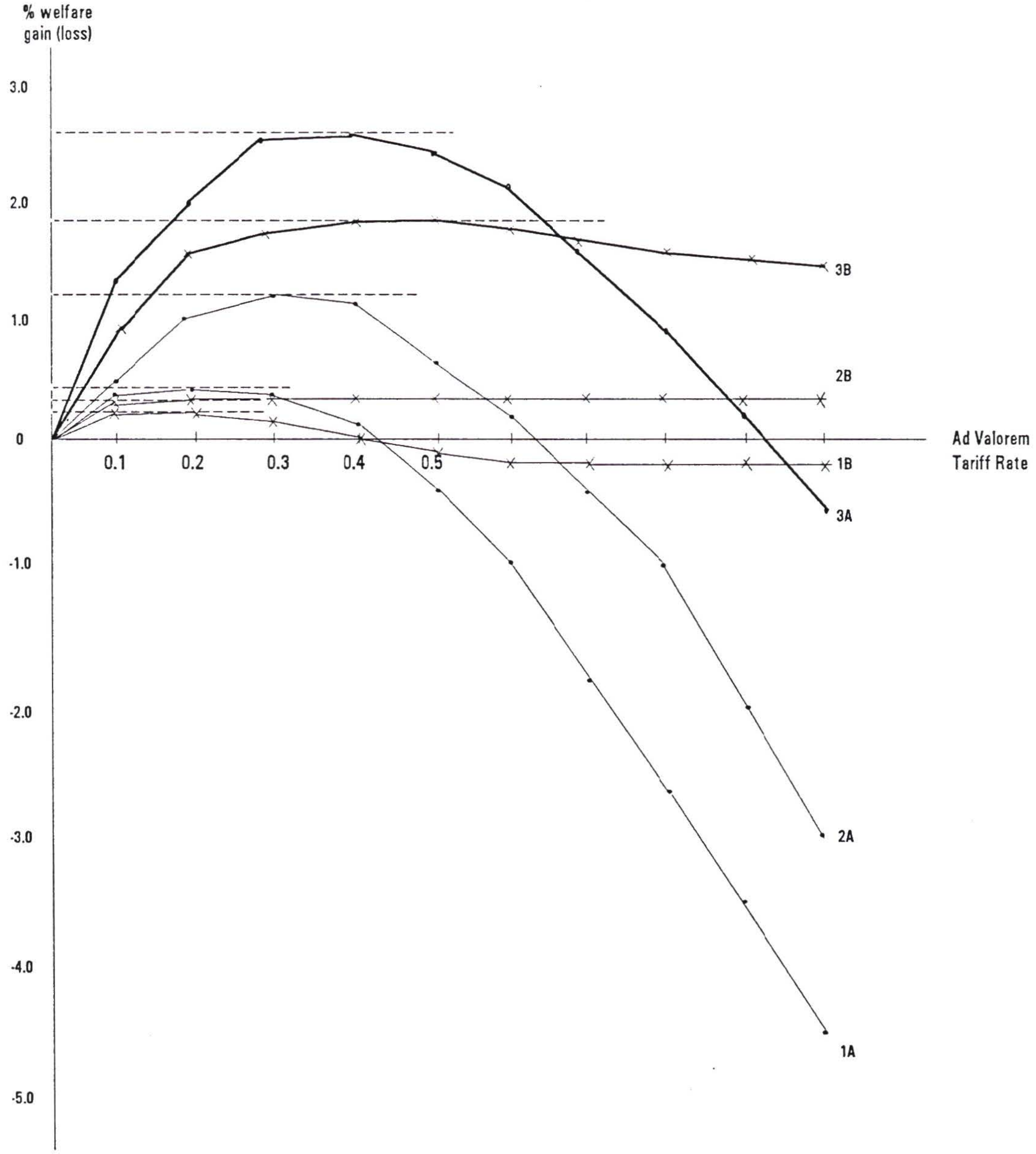
Figure 2(i)
Welfare Gain (Loss) with Unilateral Imposition
of Tariff on the Differentiated Product X
Case (i): Countries Differ Only in Size



Notes: 1. Countries differ greatly in size
2. Countries differ moderately in size
3. Countries are the same size
A. Smaller country levies tariff
B. Larger country levies tariff

Figure 2(ii)

Case (ii): Smaller Country Relatively Capital Abundant



Notes: 1. Countries differ greatly in size

2. Countries differ moderately in size

3. Countries are approximately the same size

A. Smaller country levies tariff

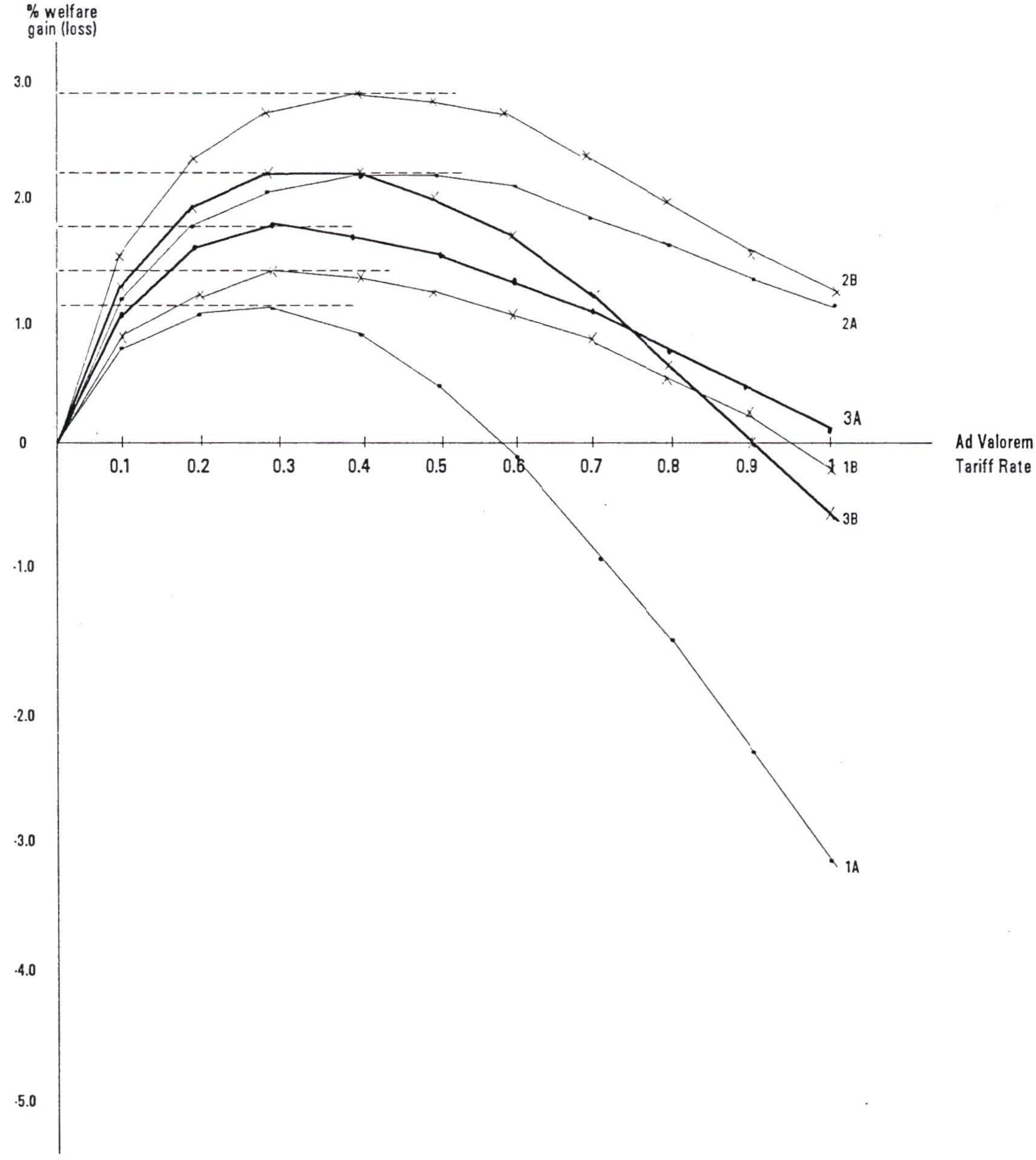
B. Larger country levies tariff

The "optimum" tariff rate for the smaller country is the same or only slightly lower than that of the larger country. It is higher the more similar in size are the two countries, and when the countries are approximately the same size, it is higher than the optimal rate when the two countries are identical.

Possible welfare gains for both countries are higher when the smaller country, as opposed to the larger country, has the comparative advantage in product X (Case (iii)). The greatest possibility for welfare gains for both countries occurs when the countries are moderately different in size. By comparing the results in Case (ii) and Case (iii), it is readily apparent that the country with the comparative advantage in product X has the higher optimal tariff, but the other country has the potential for the greatest welfare gain through the unilateral imposition of a tariff on product X.

Figure 2(iii)

Case (iii): Smaller Country Relatively Labour Abundant



Notes: 1. Countries differ greatly in size

2. Countries differ moderately in size

3. Countries are approximately the same size

A. Smaller country levies tariff

B. Larger country levies tariff

B. Both Countries Introduce Tariffs on Product X

Simulations were carried out for tariff rates of 0.1, 0.3, 0.7 and 1.5 for each of the factor endowment combinations described above, under the following assumptions:

- the larger country levies a tariff which is smaller than the tariff levied by the smaller country (more specifically, t12 = 0.5 t21);
- both countries levy tariffs of the same magnitude (t12 = t21); or
- the smaller country levies a smaller tariff than that of the larger country(t21 = 0.5 t12)

Table 3.6 shows total world welfare relative to the market equilibrium welfare level (RWW), the relative welfare level of country 1 (RW1) and the relative welfare of Country 2 (RW2). The market equilibrium welfare level with no policy intervention equals one.

Although relative welfare gains were possible over a wide range of tariff rates, regardless of country size, when there was no retaliation, this is not the case when both countries introduce tariffs. When the countries are identical only a minor gain is possible (0.18% gain) if a country levies a small tariff (10%), and the other country levies a much smaller tariff (5%). In all other situations a welfare loss results for both countries.

If the counties differ greatly in size (SL1=SK1=0.1) the larger country can achieve a modest increase in welfare (0.06% to 0.31%) even if the smaller country introduces tariffs of as much as twice as high - for tariff rates of up to 30%.

Table 3.6

Welfare Levels Relative to Market Equilibrium Levels When Both Countries Levy Tariffs

Alternative Relative Factor Endowments	a) t12 = 0.5 t21 (Country 2 tariff is 1/2 Country 1 tariff)				b) t12 = t21 (Both Counties have same tariff)				c) t21 = 0.5 t12 (Country 1 tariff is 1/2 Country 2 tariff)			
	t21=0.1	t21=0.3	t21=0.7	t21=.15	t21=0.1	t21=0.3	t21=0.7	t21=.15	t21=0.1	t21=0.3	t21=0.7	t21=.15
CASE (i)												
SL1=SK1=0.5												
RWW	0.9957	0.9832	0.9542	0.9111	0.9942	0.9764	0.9384	0.8903	------ N/C ------			
RW1	1.0018	0.9940	0.9613	0.9064	0.9942	0.9764	0.9384	0.8903				
RW2	0.9899	0.9725	0.9471	0.9158	0.9942	0.9764	0.9384	0.8903				
SL1=SK1=0.1												
RWW	0.9987	0.9949	0.9854	0.9678	0.9980	0.9920	0.9796	0.9617	0.9984	0.9936	0.9836	0.9719
RW1	0.9804	0.9438	0.8781	0.7721	0.9610	0.9071	0.8425	0.7530	0.9597	0.9080	0.8599	0.8175
RW2	1.0007	1.0006	0.9973	0.9895	1.0021	1.0014	0.9948	0.9848	1.0027	1.0031	0.9973	0.9891
CASE (ii)												
1) SL1=0.15, SK1=0.25												
RWW	0.9978	0.9921	0.9784	0.9501	0.9968	0.9891	0.9743	0.9455	0.9974	0.9912	0.9793	0.9684
RW1	0.9926	0.9762	0.9376	0.8468	0.9830	0.9594	0.9237	0.8390	0.9812	0.9579	0.9238	0.9118
RW2	0.9990	0.9958	0.9878	0.9739	0.9999	0.9959	0.9859	0.9699	1.0012	0.9988	0.9920	0.9814
2) SL1=0.2, SK1=0.45												
RWW	0.9972	0.9906	0.9724	0.9295	0.9961	0.9888	0.9702	0.9261	0.9969	0.9905	0.9847	0.9649
RW1	0.9988	0.9951	0.9739	0.8913	0.9922	0.9852	0.9672	0.8874	0.9888	0.9724	0.9682	0.9598
RW2	0.9966	0.9888	0.9718	0.9452	0.9978	0.9903	0.9714	0.9420	1.0002	0.9980	0.9914	0.9670
3) SL1=0.4, SK1=0.65												
RWW	0.9961	0.9843	0.9534	0.8979	0.9947	0.9798	0.9455	0.8902	0.9961	0.9864	0.9668	0.9324
RW1	1.0051	1.0069	0.9871	0.9234	0.9984	0.9943	0.9750	0.9173	0.9922	0.9835	0.9783	0.9639
RW2	0.9875	0.9626	0.9209	0.8732	0.9911	0.9658	0.9169	0.8641	0.9999	0.9893	0.9557	0.9019

Table 3.6 (cont.)												
Alternative Relative Factor Endowments	a) t12 = 0.5 t21 (Country 2 tariff is 1/2 Country 1 tariff)				b) t12 = t21 (Both Counties have same tariff)				c) t21 = 0.5 t12 (Country 1 tariff is 1/2 Country 2 tariff)			
	t21=0.1	t21=0.3	t21=0.7	t21=.15	t21=0.1	t21=0.3	t21=0.7	t21=.15	t21=0.1	t21=0.3	t21=0.7	t21=.15
CASE (iii)												
1) SL1=0.2, SK1=0.15												
RWW	0.9977	0.9907	0.9733	0.9440	0.9966	0.9858	0.9615	0.9293	0.9974	0.9892	0.9698	0.9424
RW1	0.9835	0.9485	0.8789	0.7778	0.9629	0.9059	0.8303	0.7485	0.9599	0.9041	0.8440	0.7908
RW2	1.0008	1.0001	0.9942	0.9809	1.0041	1.0035	0.9906	0.9695	1.0058	1.0081	0.9978	0.9761
2) SL1=0.4, SK1=0.2												
RWW	0.9965	0.9863	0.9635	0.9275	0.9949	0.9791	0.9436	0.8931	0.9963	0.9842	0.9533	0.9026
RW1	0.9919	0.9657	0.9044	0.8188	0.9742	0.9238	0.8457	0.7717	0.9698	0.9201	0.8530	0.7882
RW2	0.9987	0.9962	0.9922	0.9803	1.0050	1.0059	0.9911	0.8442	1.0092	1.0153	1.0020	0.9585
3) SL1=0.5, SK1=0.35												
RWW	0.9960	0.9846	0.9596	0.9210	0.9943	0.9772	0.9397	0.8887	0.9959	0.9863	0.9581	0.9115
RW1	0.9987	0.9850	0.9444	0.8834	0.9883	0.9594	0.9075	0.8533	0.9842	0.9499	0.9119	0.8774
RW2	0.9938	0.9842	0.9718	0.9511	0.9992	0.9915	0.9655	0.9171	1.0053	1.0155	0.9952	0.9389

When the larger country has the comparative advantage in product X (Case (ii)), the smaller country is only able to gain by introducing a tariff if the countries are very close in size, and if the smaller country's tariff level is significantly higher than that of the larger country. In any event a gain is only possible for relatively low tariff rates, and the gain is modest (0.51% to 0.69%). The possibility of gain for the larger country is even more limited: the two countries must be reasonably different in size, the tariff rates must be low (10% or less); and the smaller country's tariff must be significantly lower. Furthermore, the possible gain in welfare is very slight (0.02% to 0.12%).

When the smaller country has the comparative advantage in product X (Case(iii)), the larger country can gain by introducing a tariff, even if the smaller country introduces a comparable or smaller tariff, but only at tariff rates below 30%. If the countries are close in size then the larger country is only able to gain if the smaller country's tariff rate is significantly lower.

C. Consumption Subsidy on Product X

Simulations were carried out for subsidy rates tii = 0 , -0.1, -0.3, introduced by one or both of the countries, for each of the eight representative factor endowment combinations chosen. The results obtained for total world welfare relative to the market equilibrium without intervention (RWW), as well as the relative welfare level of Country 1 (RW1) and Country 2 (RW2), are presented in Table 3.7. There are many subsidy combinations which result in an increase in world welfare and a number which result in welfare gains for both countries, relative to welfare levels without intervention.

Table 3.7

Welfare Levels Relative to Market Equilibrium Levels When One or Both Countries Introduce Subsidies

Alternative Relative Factor Endowments	Subsidy by Smaller Country t11 = -0.1	Subsidy by Smaller Country t11 = -0.3	Subsidy by Larger Country t22 = -0.1	Subsidy by Larger Country t22 = -0.3	Both Countries Introduce Subsidies t11 = t22 = -0.1	t11 = t22 = -0.3	t11 = -0.1, t22 = -0.3	t11 = -0.3, t22 = -0.1
CASE (i)								
SL1 = SK1 = 0.5								
RWW	1.0021	0.9918	1.0021	0.9918	1.0074	1.0146	1.0033	1.0033
RW1	0.9997	0.9614	1.0050	1.0223	1.0074	1.0146	1.0316	0.9751
RW2	1.0050	1.0223	0.9997	0.9614	1.0074	1.0146	0.9751	1.0316
SL1 = SK1 = 0.1								
RWW	1.0003	0.9962	1.0061	1.0072	1.0074	1.0146	1.0110	1.0054
RW1	0.9956	0.9437	1.0110	1.0651	1.0074	1.0146	1.0639	0.9568
RW2	1.0008	1.0020	1.0056	1.0009	1.0074	1.0146	1.0051	1.0109
CASE (ii)								
1) SL1 = 0.15, SK1 = 0.25								
RWW	1.0007	0.9934	1.0049	0.9989	1.0074	1.0146	1.0078	1.0040
RW1	1.0013	0.9595	1.0302	1.1234	1.0337	1.1060	1.1361	0.9948
RW2	1.0005	1.0012	0.9991	0.9704	1.0013	0.9936	0.9784	1.0062
2) SL1 = 0.2, SK1 = 0.45								
RWW	1.0013	0.9918	1.0036	1.0072	1.0074	1.0146	1.0072	1.0032
RW1	1.0114	0.9922	1.0347	1.1620	1.0494	1.1609	1.1620	1.0361
RW2	0.9972	0.9916	0.9907	0.9436	0.9901	0.9544	0.9436	0.9896
3) SL1 = 0.4, SK1 = 0.65								
RWW	1.0027	0.9929	1.0020	1.0002	1.0074	1.0146	1.0066	1.0038
RW1	1.0134	1.0067	1.0157	1.0324	1.0323	1.1013	1.0673	1.0325
RW2	0.9923	0.9796	0.9887	0.9690	0.9833	0.9308	0.9479	0.9761

Table 3.7 (cont.)								
Alternative Relative Factor Endowments	Subsidy by Smaller Country		Subsidy by Larger Country		Both Countries Introduce Subsidies			
	t11 = -0.1	t11 = -0.3	t22 = -0.1	t22 = -0.3	t11 = t22 = -0.1	t11 = t22 = -0.3	t11 = -0.1, t22 = -0.3	t11 = -0.3, t22 = -0.1
CASE (iii)								
1) SL1 = 0.2, SK1 = 0.2								
RWW	1.0005	0.9965	1.0053	1.0031	1.0074	1.0146	1.0089	1.0043
RW1	0.9942	0.9579	0.9984	1.0145	0.9939	0.9677	1.0135	0.9422
RW2	1.0019	1.0050	1.0069	1.0005	1.0104	1.0250	1.0079	1.0181
2) SL1 = 0.4, SK1 = 0.2								
RWW	1.0010	1.0010	1.0042	0.9980	1.0074	1.0146	1.0063	1.0078
RW1	0.9937	0.9937	0.9862	0.9646	0.9774	0.9154	0.9601	0.9706
RW2	1.0046	1.0046	1.0129	1.0142	1.0219	1.0627	1.0288	1.0260
3) SL1 = 0.5, SK1 = 0.35								
RWW	1.0017	0.9929	1.0030	0.9937	1.0074	1.0146	1.0042	1.0029
RW1	0.9922	0.9436	0.9964	0.9952	0.9909	0.9571	0.9955	0.9396
RW2	1.0094	1.0324	1.0084	0.9924	1.0206	1.0607	1.0112	1.0537

When the two countries are identical the gain in world welfare is maximized when both countries introduce consumption subsidies, and the gain is greater the greater the overall subsidy level. When both countries introduce a 30% subsidy total welfare increases by 1.46%. When the subsidy rate is higher in one country, the country with the lower rate benefits at the expense of the other country. Therefore there is no incentive for a country to unilaterally introduce a subsidy, or to introduce subsidies at a rate higher than the rate in the other country.

When the two countries have the same relative factor endowments, but differ in size, world welfare increases when the larger country or both countries introduce subsidies. A slight increase in world welfare results (0.03%) when the smaller country introduces a modest (10%) subsidy. However, the smaller country has no incentive to introduce a subsidy, as it is the larger country which benefits, at the smaller country's expense. While the larger country can increase its welfare marginally by introducing a subsidy, most of the gain is achieved by the smaller country.

When the two countries differ in both size and relative factor endowments far greater welfare gains may result from the introduction of subsidies. The welfare gains are greatest in Case (ii), when the larger country has the comparative advantage in production of product X (i.e., when the larger country has relatively more labour). The smaller country gains marginally by introducing a low subsidy (10%), but gains significantly when the larger country, or both countries, introduce subsidies. The greatest gain for the smaller country results when both countries introduce subsidies, a higher subsidy is introduced by the larger country, and the two countries are moderately different in size. The magnitude of these gains declines as the countries become very close in size. In most cases the larger country suffers a welfare loss even when both countries introduce subsidies. When the two countries differ significantly in size the larger country gains slightly if both counties introduce a low subsidy (10%), or if the subsidy rate of the smaller country is greater than that of the larger country.

When it is the smaller country which has the comparative advantage in product X (Case (iii)), the larger country gains under all the subsidy combinations considered, even if it unilaterally introduces a subsidy. However, the gains achieved by the larger country are relatively modest (up to 6.27%), compared to the gains which the smaller country was able to achieve in Case(ii) when the larger country had the advantage in product X (up to 16.2%). In Case (iii) the smaller country does not gain by unilaterally introducing a subsidy, and gains only modestly when the larger country introduces either a relatively high subsidy (30%) or a higher subsidy than that of the smaller country.

The following general conclusion can be drawn, based on the simulation results:

(i) A country gains more by subsidies introduced by its trading partner than by a domestic subsidy of the same size.

(ii) When countries with identical relative factor endowments introduce identical subsidies, the welfare gain is the same, regardless of the relative country size.

(iii) The smaller country gains more by a subsidy introduce by the larger country than the larger country does by a comparable subsidy introduced by the smaller country.

(iv) The world (total) welfare gain is greatest when both countries introduce identical subsidies.

(v) The gains are greatest for the country which does not have a comparative advantage in the product being subsidized. These gains are greatest when the countries are moderately similar in size.

D. <u>Combination of Tariffs and Subsidies</u>

Simulations were also carried out under each of the five tariff scenarios described earlier in Sections A and B. (for tariff rates tij = 0.1, 0.3, 0.7, and 1.5), with one or both countries also introducing subsidies (tij = 0, -0.1, -0.3). Certain tariff/subsidy combinations would, if introduced, produce high welfare gains, in some cases in excess of a 30% gain in welfare relative to the market equilibrium without intervention. In general, the potential for welfare gain is much greater than with only one policy instrument.

As might be expected the maximum gain would be achieved by a country if it unilaterally introduced a tariff, and its trading partner introduced the higher (30%) subsidy rate. However, even if both countries introduce tariffs, there could be relative welfare gains by both countries, providing they both introduce subsidies as well.

When the two countries differ only in size it is the smaller country which has the potential for the greatest welfare gain. When the countries differ both in size and relative factor endowments the country which does <u>not</u> have the comparative advantage in produce X has the greatest potential for welfare gain, with the largest potential gain existing when the two countries are moderately different in size. The magnitude of potential gains (up to approximately 14% gain) is considerably less when it is the larger country which has the comparative advantage in product X.

While there are many tariff/subsidy combinations which offer the potential of significant welfare gains these gains are unlikely to be realized as they depend on benevolent action by the trading partner. More specifically, they involve having the trading partner introducing subsidy rates which are not in their own best interest. The results are interesting nevertheless because they show that the potential exists for welfare gains, not only for an individual country, but also at the global level, under certain policy combinations. This potential provides an incentive for countries to consider a negotiated or cooperative policy regime, which could benefit both countries.

It is possible, using the results obtained from the simulations carried out for specific tariff/subsidy combinations, to estimate a possible "non-cooperative" equilibrium outcome, for the eight alternative relative factor endowments examined. In order to do this it is necessary to make certain assumptions regarding each country's commercial policy behavior. I assumed that each country would introduce that tariff/subsidy combination (from among the limited options for which simulations were carried out) which would offer the maximum gain in national welfare. I also assumed that in assessing the potential welfare gain the country would assume that the existing policy regime of its trading partner would continue (Cournot-type conjectures).

I examined the possible outcome in the case where both countries utilized only a tariff on the differentiated product X, and in the case where they utilized both tariffs and subsidies. The resulting "non-cooperative" equilibrium results for welfare levels of each country and for world welfare, relative to welfare levels in the market equilibrium, are reported in Table 3.8.

Table 3.8

Welfare Levels Relative to Market Equilibrium With Policy Intervention by Both Countries (Non-cooperative Equilibrium)

Alternative Relative Factor Endowments	Tariffs Only	Tariffs and Subsidies
CASE (i)		
SL1=SK1=0.5	(t21=t12=0.3)	(t21=t12=0.3)
RWW	0.9764	0.9764
RW1	0.9764	0.9764
RW2	0.9764	0.9764
SL1=SK1=0.1	(t21=0.15, t12=0.3)	(t21=t12=0.1, t22=-0.1)
RWW	0.9936	1.0043
RW1	0.9080	0.9829
RW2	1.0031	1.0067
CASE (ii)		
1) SL1=0.15, SK1=0.25	(t21=t12=0.1)	(t21=t12=0.1, t11=-0.1)
RWW	0.9968	0.9991
RW1	0.9830	0.9863
RW2	0.9999	1.0021
2) SL1=0.2, SK1=0.45	(t21=0.35, t12=0.7)	(t21=t12=0.3, t11=-0.1)
RWW	0.9847	0.9903
RW1	0.9682	0.9947
RW2	0.9914	0.9885
3) SL1=0.4, SK1=0.65	(t21=t12=0.3)	(t21=t12=0.3, t11=-0.1)
RWW	0.9798	0.9828
RW1	0.9943	1.0039
RW2	0.9658	0.9625
CASE (iii)		
1) SL1=0.2, SK1=0.15	(t21=t12=0.3)	(t21=t12=0.3, t22=-0.1)
RWW	0.9858	0.9923
RW1	0.9059	0.9245
RW2	1.0035	1.0074
2) SL1=0.4, SK1=0.2	(t21=t12=0.3)	(t21=t12=0.3, t22=-0.1)
RWW	0.9791	0.9838
RW1	0.9238	0.9201
RW2	1.0059	1.0147
3) SL1=0.5, SK1=0.35	(t21=0.35, t12=0.7)	(t21=t12=0.3, t22=-0.1)
RWW	0.9581	0.9821
RW1	0.9119	0.9635
RW2	0.9952	0.9971

The procedure I used was to assume first that one country introduced the policy option which provided it the maximum potential for gain (in the absence of retaliation by its trading partner). I assumed that the second country would then counter by choosing the most beneficial policy option it had available, given the policy regime of the first country. This process would continue until neither country was able to improve its position by further policy intervention. The same outcome was obtained, regardless of which country initiated market intervention, in all but one of the alternative relative factor endowments considered. In the case where the larger country has the comparative advantage in product X, and is much larger (4 times the size) than its trading partner, i.e., where SL1 = 0.15 and K1 = 0.25, a higher tariff level resulted when the smaller country initiated market intervention, and the only policy instrument used was an import tariff on product X (t21 = t12 = 0.3). The solution outcome reported in Table 3.8 is that obtained when the larger country initiated market intervention. When both policy instruments were utilized the outcome was the same, regardless of which country began the process.

For all the relative factor endowments considered the use of both subsidies and tariffs resulted in a non-cooperative outcome where both countries introduced identical tariffs, and the country without the comparative advantage in product X introduced a subsidy (10%). In every case world welfare levels improved when two policy instruments were utilized, as did the resulting welfare level in the country without the comparative advantage in product X. For most of the cases considered relative welfare levels were higher when both policy instruments were available.

If one compares the above welfare results with results obtained in Section C, Table 3.7 (from the use of only subsidies), one can see that there are policy scenarios involving subsidies by both countries which would give a welfare improvement over the non-cooperative outcome, and some which involve an improvement for world welfare relative to the market equilibrium level without intervention. This indicates that there exists the potential to improve welfare levels for both countries over the non-cooperative outcome through a negotiated "cooperative" policy regime.

Chapter 4
SUMMARY AND CONCLUSIONS

This thesis has investigated the welfare implications of introducing imperfect competition into the conventional trade model. In order to do this a relatively simple two-country two-product computational general equilibrium trade model was constructed, based on assumptions utilized in the recent theoretical literature on the so-called "new" trade theory, which incorporates monopolistic competition. The model can be characterized as a generalized version of the traditional trade model since, by choosing particular parameter values in the preference and cost functions, it collapses to the familiar Heckscher-Ohlin model, with perfectly competitive markets and homogeneous products.

Simulations were carried out on the generalized C-H-O version of the model to determine how equilibrium welfare levels differed from welfare levels in the more restricted H-O version of the model. Sensitivity analysis was carried out on key parameters of the model (defining the degree of scale economies, and the strength of product differentiation). The resulting equilibrium welfare levels were compared, under alternative combinations of factor endowments.

A simplified version of the generalized model, commonly used in the literature, assumes that the number of varieties of the differentiated product produced is large enough that demand elasticity can be approximated by a constant. Simulations were carried out on this simplified version of the model in order to determine whether it does provide a good approximation to the exact elasticity model specification (CHOEX version). It was found that the constant elasticity specification (CHOCE version) provides a good approximation to the CHOEX version of the model for values of $h \leq 25$.

In addition simulations were carried out for a variety of policy scenarios on the simplier version of the generalized model, with parameter values chosen so as to ensure that it provided a good approximation of the exact model specification. Two policy instruments were introduced - import tariffs and consumption subsidies - on the differentiated product X. Resulting equilibrium welfare levels for each country and for total world welfare were compared to welfare levels in the market equilibrium with no intervention. The purpose was to investigate whether welfare gains are possible with policy intervention, and which policy instrument, or combination of instruments gives the greatest potential for gain.

In general the results were not startling and could be anticipated as they merely served to confirm assertions made in the theoretical literature. However, by using a computational model it was possible to obtain specific numerical results quantifying the magnitude of impacts under the various alternative model specifications, parameter values, and policy intervention scenarios.

The generalized C-H-O model, which incorporates scale economies and product differentiation, provides significantly higher equilibrium welfare levels, than the traditional perfect competition, homogeneous product version of the model. Welfare increases due to increased variety in consumption, and is higher, the lower is the value of parameter β, i.e., the less perfect substitutes the different varieties are for each other. However, increasing the value of parameter h, the scale parameter, lowers welfare levels. Welfare gains are assured in this model due to the particular specification of preferences and production technology chosen, as has been demonstrated in the models developed by Krugman and Helpman which have utilized similar specifications.

Furthermore, for the particular functional specifications of the cost and preference functions chosen in this computational model, the pattern of product specialization, the boundaries of the factor price equilization set and country welfare shares are unaffected by the degree of scale economies (value of h) or by the strength of product differentiation (value of β). However, as was discussed in the Introduction, results in these models are very dependent on specific model specifications.

The result with respect to country welfare shares may be due to the particular preference specification used, i.e., the modelling of inter-product preferences by a Cobb-Douglas upper tier utility function. While this follows the approach taken by virtually all the theoretical literature, it results in a constant proportion of income being spent on each product regardless of how many varieties of the differentiated product are consumed. As a result product differentiation does not influence spending decisions between products X and Y. This limits the flexibility of the model.

An alternative preference specification which might be investigated is use of a nested CES utility function of the form:

$$U = (\Sigma x_i^{\beta})^{\alpha/\beta} + y^{\alpha} \qquad 0 < \alpha < \beta < 1.$$

This would give demand functions for the differentiated product of the form:

$$Dx_i^j = \frac{(n^1+n^2)^{\frac{\beta-\alpha}{\beta(\alpha-1)}} \, p^{\frac{1}{\alpha-1}}}{[(n^1+n^2)^{\frac{\alpha(\beta-1)}{\beta(\alpha-1)}} \, p^{\frac{\alpha}{\alpha-1}} + 1]} \quad I^j$$

With this specification the income share of product X is not ficed, but increases with the number of varieties consumed. It is possible that this demand specification could result in a greater potential for gains in utility when the number of varieties of product X consumed increases, and that changing the strength of product differentiation (the value of β) could change country welfare shares.

A very simple approach to modelling preferences with a differentiated product has been taken in this thesis - by assuming that all product varieties contribute equally to utility, i.e., there are no preferred varieties as in the "ideal" product approach mentioned in the Introduction and no "superior" or "inferior" varieties. There are in fact a vast number of ways in which preferences might have been modelled, and the above mentioned variation is only one alternative possibility which could be investigated.

The simulations involving policy intervention (tariffs and/or subsidies on the differentiated product X) were carried out on the CHOCE version of the model. For the parameter values chosen (β = 0.7, h = 5) this model specification provides a very close approximation of the exact elasticity specification. Simulation for selected factor endowment combinations on the CHOEX version of the model yielded identical results to four decimal places to results obtained using the CHOCE version approximation.

Unlike the case of perfectly competitive markets, even a small country is able to benefit from the unilateral imposition of a tariff on imported varieties of the differentiated product. This confirms assertions made to this effect in the literature, in particular by Lancaster (1984) and Gros (1987), regarding the potential for any economy, regardless of size, to gain by the unilateral imposition of a tariff exploiting the monopoly power of the domestic industry. The simulation results also showed that the "optimal" tariff rate for the smaller country is either the same or only slightly less than the rate for the larger country, even when the two countries differed significantly in size. The relative size of the optimal tariff for countries of differing size could not be specifically determined without use of a computational model.

The theoretical literature has not attempted to discuss the magnitude of welfare gains possible from the unilateral imposition of tariffs, and how this changes as relative country size and endowments change. Again specific results of this nature require a general computational model, such as was utilized in this thesis. Simulation results showed that higher welfare gains are possible when countries have different relative factor endowments than when they are similar, and when it is the smaller country that has the comparative advantage in the differentiated product.

Potential welfare gains are greater when countries are close rather than very different in size, but the greatest potential for gains by both countries exists when the two countries are moderately different in size (when the countries have different relative factor endowments).

Although potential welfare gains exist for a wide range of tariff rates when there is no retaliation, regardless of country size, as might be expected from the extensive literature on tariffs, this is not the case when both countries introduce tariffs. However in certain instances a country may still gain. When the larger country has the comparative advantage in product X, the smaller country is able to gain at very low tariff rates, if the two countries are very close in size, and its tariff rate is higher than that of the larger country. However only a very moderate gain is possible (less than 1%). Even smaller gains are possible for the larger country (< 0.2%), and only when the countries are very different in size. There are greater possible gains for the larger country when the smaller country has the comparative advantage in product X, but the gains are still modest (< 2%). This is contrary from what would be expected with the traditional competition model where only the larger country would have the potential to gain when there is retaliation.

As mentioned in the Introduction, the "distortion" literature has asserted that when there is a domestic market distortion a subsidy is a more effective policy instrument than a tariff. This was confirmed by the simulation results which showed that a far greater potential for welfare gains exist from subsidies than from unilateral tariffs. However, these gains in most cases require benevolent action on the part of the trading partner. This is due to the fact that a country gains more from a subsidy introduced by its trading partner than by a domestic subsidy of the same size, and gains more than the country which introduces the subsidy. When a country has the comparative advantage in product X it suffers a welfare loss by introducing a subsidy and therefore is unlikely to do so.

To my knowledge there has been no work done which analyzes the potential impact on welfare of introducing alternative combinations of policy instruments, for different situations of relative country size and factor endowments, as was done for this model. Simulation results showed that high welfare gains are theoretically possible through various combinations of both tariffs and subsidies. However most of these combinations are unlikely to occur as they involve one of the countries introducing subsidy rates which are not in their best interest. However the fact that a potential for significant gains exist indicates an incentive for negotiated policy intervention. Comparing non-cooperative equilibria with one policy instrument (tariffs) or two possible policy instruments (tariffs and subsidies), the results showed that, in every case, world welfare levels, and the welfare level in the country without the comparative advantage in product X, were higher when both policy instruments were available. For most of the cases considered relative wefare levels were higher for both countries with both tariffs and subsidies, than with tariffs alone.

In this thesis I have introduced tariffs and subsidies as exogenous variables. A more ambitious undertaking, and a possiblility for further study, would be to model tariffs as endogenous variables. It could be assumed that a country would introduce a system of tariffs, with the objective of maximizing national welfare, under some assumption as to the behaviour of its trading partner, i.e., an "optimal" set of tariffs. As was mentioned in the Introduction, in the homogeneous 2-product model, the optimal tariff is given by the inverse of the elasticity of supply of foreign exports. Unfortunately no such simple formula exists in the case of differentiated products.

In a 2-product model which incorporates product differentiation with respect to one of the products, and making use of the same symmetry assumptions with respect to the cost and preference functions as in this thesis, the model could be viewed as having three distinct product groups: homogeneous product Y, imported varieties of product X, and domestically produced varieties of product X. In this case there would be an optimal set of tariffs, rather than one optimal tariff. This optimal set would involve tariffs (some of which could be negative) on all but one product. Since it is normal to use the homogeneous product as numeraire, tariffs could be modelled on the differentiated product: one common tariff rate for the imported varieties and one for the domestically produced varieties. This optimal set of tariffs would be the one which maximized national welfare.

It would be necessary to derive equations (which could be thought of as a reaction functions) for the set of optimal tariffs t_i^j which would maximize country j's welfare. This involves differentiating the indirect utility function of a country with respect to each tariff and setting the partial derivatives equal to zero. This would give two reaction functions for each country, expressing the optimal tariff rates as a function of the model parameters and variables.

Two possible avenues of investigation could be pursued:

(i) One could derive the reaction functions for only one country, and continue to model the tariffs in the second country exogenously. The purpose would be to determine the set of optimal tariffs for the home country, under alternative postulated tariff regimes in its trading partner, and quantification of maximum potential welfare gains (or minimum losses) which could result by use of "optimal" tariff intervention. Unilateral imposition of optimal tariffs, with no retaliation, could be one of the possible scenarios studied.

(ii) One could derive reaction functions for both countries and introduce them into the model, to be solved simultaneously with the other model equations. In this case, some specific assumption would also have to be made regarding each country's conjecture as to how the other country will react. The simplest approach would be to take the tariff rates in the trading partner as remaining at their current level (i.e., Cournot type conjectures, such as were used by Johnson's(1953) analysis of tariff warfare). The purpose would be to investigate resulting equilibrium under conditions of tariff warfare, i.e., when both countries are introducing optimal tariffs so as to maximize their national welfare, and to quantify welfare gains (losses) of each country relative to the market equilibrium without tariff intervention.

1. See for example Kemp (1964) and Chacholiades (1978). Helpman (1984) and Dixit (1984) provide surveys of the literature, with an emphasis on more recent work in the development of trade models which explain intra-industry trade. Helpman and Krugman (1985) attempt to provide a framework for a more generalized trade theory which can incorporate various models of imperfect competition as special cases.

2. Various approaches have been taken in modelling scale economies. Traditionally it was assumed that scale economies were external to individual firms, but internal to the industry at the national level (for example, Kemp (1964), Melvin (1969), Chipman (1970), Markusen and Melvin (1981)) or at the international level (Ethier (1979)). This approach enabled theorists to retain the perfect competition market structure. With internal scale economies a wide variety of market structures are possible. Monopoly is the simplest (See Panagariya (1981), Markusen (1981), Brander and Spencer (1984(a))). Brander (1981), Dixit (1984) and Venables (1985) provide examples of trade models which incorporate oligopolistic competition in a homogeneous product. The most flexible approach to modelling internal economies is that of monopolistic competition in differentiated products. It has been the subject of considerable analysis in the recent literature. Krugman (1979, 1980, 1981), Dixit and Norman (1980), Lancaster (1980) and Helpman (1981) laid the foundation for much of the subsequent work on these models.

3. The implications of scale economies for the shape of the production possibilities frontier (or of the production set) has been the subject of much analysis (Herberg and Kemp (1969), Melvin (1969), Chipman (1970), Markusen and Melvin (1981), Panagariya (1981), Herberg, Kemp and Tawada (1982)). The only robust result is that the frontier must be locally convex in the neighbourhood of zero production of the good(s) exhibiting scale economies. For "mildly" increasing returns to scale the PPF may retain its familiar concavity over most of its range.

4. Grubel and Lloyd (1975) measured intra-industry trade for ten OECD countries using both time series and cross-sectional disaggregated data. They found a high level (63% of total trade) of simultaneous exports and imports in the same industry. They pointed out that the usual approach in testing the H-O model, and in econometric estimates of trade elasticities, has been to consider

only net exports or imports, thereby:
(a) ignoring the fact that intra-industry trade is inconsistent with the theory they are testing, and
(b) netting out a large proportion of the observation points, and so not utilizing all the sample information when estimating elasticities. The "Armington" assumption (i.e., that products of an industry produced in different countries are treated as different products) has been used in AGE models to deal with this problem of estimation of trade elasticities.

5. Examples are provided by the EC and the North American auto pact.

6. These models are generally based on Chamberlin's "large market" case in which firms are able to differentiate their product so that their outputs become imperfect substitutes. With free entry and exit, in equilibrium there will be zero profits (average cost pricing). Liberal use is made of symmetry assumptions with respect to production technology, consumer preferences, and often even relative factor endowments. Dixit and Stiglitz (1977) and Spence (1976) developed models for closed economies. Koenker and Perry (1981) and Horn (1984) generalized their models to incorporate conjectural variations on the part of firms as to rival firms' responses. Although the literature has focused mainly on models of final products, this approach can also be modified to deal with intermediate products (See Ethier (1982)).

7. Scale economies are assumed to be mild (so as to be consistent with a monopolistically competitive market structure). Therefore non-convexities in the production set may be assumed to be limited to points of near-zero output in the differentiated product industry(s).

8. In general, since marginal social costs exceed marginal private costs in imperfect markets, there will be a less than optimal proportion of resources allocated to the production of industries with scale economies. In addition there is a bias in product selection against products with inelastic demand. Trade may or may not re-inforce this bias. To the extent that trade results in a reduction of the degree of monopoly power in the industry, market distortions are reduced. In the case of homogeneous products this comes through concentration of production and expansion of output in industries with scale economies. The effect of trade on the relationship between market equilibrium and the "social" optimum in

the case of differentiated products is not so simple, and has been the subject of some controversy. See Spencer (1976), Dixit and Stiglitz (1977), Koenker and Perry (1982), Horn (1983).

9. In the models developed by Krugman and by Dixit and Norman, where demand elasticity is assumed to be constant and production technology to be homothetic, scale economies are fully exploited in autarky (i.e., equilibrium firm size equals optimal firm size, which is a constant, regardless of market size), gains from trade come from increased variety in consumption.

10. See Shoven and Whalley (1984), Pigott and Whalley (1985), and Srinivasan and Whalley (1986) for a discussion of the evolution of AGE models.

11. Mansur and Whalley (1984) describe the calibration techniques used in deriving the parameter values used in AGE models and some of the problems involved.

12. With perfectly competitive markets, in equilibrium the balanced trade requirement equates marginal rates of transformation in production (MRT_{ij}) and marginal rates of substitution in consumption (MRS_{ij}) with the average rate of transformation through trade ($AFTT_{ij}$), or average world price ratio, for every pair of products i and j. A pareto optimum requires that the marginal rates of transformation in production and consumption be equated with the marginal rate of transformation through trade ($MFTT_{ij}$). For a small economy unable to influence its terms of trade, $AFTT_{ij} = MFTT_{ij}$, and free trade is pareto optimal. However, if an economy is large enough to be able to influence its terms of trade then $AFTT_{ij} \neq MFTT_{ij}$, and the free trade equilibrium is not pareto optimal. When markets are imperfectly competitive, $MRT_{ij} \neq MRS_{ij} = AFTT_{ij}$, and the free trade equilibrium is not pareto optimal, even in the case of small economies.

13. The focus in the literature on optimal tariffs has been on the two (homogeneous) product, two-country model in which one good is exported and one imported. Exceptions include Graff (1950), Kemp (1964), Horwell and Pearce (1970) and Kuga (1973), who analyze the more general case of many (n) homogeneous products. In this case one is looking at an optimal tariff structure of (n - 1) tariffs, with one product designated as numeraire, which might include negative tariffs (subsidies). The optimal tariff, in ad valorem form, for an import (export) product i is the inverse of the weighted sum of the

cross-elasticities of foreign supply (demand) for that product with respect to the price of each of the non-numeraire goods. The weights used are the value of imports (exports) of each product relative to the value of imports (exports) of good i. With only two products, taking the product exported as numeraire, the formula reduces to $t_i = 1/e_i$, where e_i is the supply elasticity of foreign exports of i.

14. For the simple one industry Krugman model, Gros (1987) is able to analytically derive an optimal tariff formula which show the optimal tariff to be an increasing function of the relative size of the home economy and of the degree of product differentiation, as measured by the degree of monopoly power of individual firms, i.e., the tariff must exploit monopoly power resulting from both economy size and scale economies. The derivation of an optimal tariff formula is very difficult for any more complicated models.

15. This is a representative consumer model. Distributional effects are not considered, but could be taken into account by defining sub-utility functions for specified groups of individuals within the economy. Individuals could be distinguished according to a variety of characteristics (eg. sex, age, location of residence, income level) to address a range of (national) social goals. The form of the aggregate (community) welfare function would determine the relative weight (or importance) attached to increasing the welfare of each identified group.

16. With a differentiated product it is necessary to specify the preference structure. Two main approaches have been taken in the literature:
(a) a spatial or "ideal product" approach, often referred to as "Lancaster" type preferences, in which the commodity space is represented by some geometric devise such as a (0,1) line or a unit circle (See Lancaster (1980), Helpman (1981), Eaton and Kierzowski (1984)), and
(b) a "love of variety" approach, also referred to as "Dixit-Stiglitz-Spence" type preferences, in which all varieties contribute symmetrically to welfare through a CES sub-utility function (See Krugman (1979, 1980, 1982), Dixit and Norman (1980), Lawrence and Spiller (1983)).
With the first approach, an increase in the number of product varieties "crowds" the product space and the elasticity of demand increases. In the limit it becomes infinite, with each consumer having a tailor-made

product, and the model collapses to a homogeneous product model. With the D-S-S approach, the elasticity of demand tends to a constant as the number of varieties (firms) becomes larger.

17. This specification has the advantage of providing for a relatively simple representation of demand, as the expenditure on each product is a constant share of income.

18. The CES form is one commonly used in empirical models. It provides for flexibility in representation of factor substitutability in the two-input case.

19. Associated with this cost function is a CES production function of the form:

$$Y^j(K_y^j,\ L_y^j) = \left(\left(\frac{K_y^j}{a_y}\right)^{\frac{\rho}{\rho-1}} + \left(\frac{L_y^j}{1-a_y}\right)^{\frac{\rho}{\rho-1}} \right)^{\frac{\rho-1}{\rho}}$$

See Varian (pp 30-33) for a discussion of CES production technology and associated cost functions.

20. If $ED_z^j > 0$, this signifies import demand of country j for product Z. If $ED_z^j < 0$, it represents export supply by country j of product Z. In equilibrium the export supply of each product must equal the import demand for that product. The diagrammatic representation of excess demand functions are known as offer curves.

21. For country j the total expenditures are:

$$p^1 \sum_{i=1}^{n^1} D_{xi}^j + p^2 \sum_{i=1}^{n^2} D_{xi}^j + D_y^j$$

$$= p^1\, n^1\, D_{x1}^j + p^2\, n^2\, D_{x2}^j + D_y^j$$

$$= \left[\frac{p^1 n^1 \alpha\, (p^1)^{-\sigma_x} I^j + p^2 n^2 \alpha\, (p^2)^{-\sigma_x} I^j}{n^1 (p^1)^{1-\sigma_x} + n^2 (p^2)^{1-\sigma_x}} \right] + (1 - \alpha)\, I^j$$

$$= \alpha\, I^j + (1 - \alpha)\, I^j = I^j$$

Therefore setting $I^j = p^j\, n^j\, x + y^j$ will ensure balance of payments equilibrium.

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APPENDIX I

MODEL SUMMARY

NOTATION:

(Note: superscripts identify country to which variable refers.)

p^j = price of varieties of product X produced in country j, j = 1,2.

t_i^j = ad valorem tariff rate imposed by country j on varieties of product X produced by country i, i ≠ j.

t_i^i = country i subsidy on varieties of product X produced in country i ($t_i^i < 0$).

Y^j = country j's total output of product Y.

X^j = $n^j x^j$ = country j's total output of product X.

n^j = number of varieties of product X (number of firms in industry X) produced in country j.

x^j = country j firm output of each variety of product X.

D_{xi}^j = quantity of each variety of product X produced in country i which is consumed (demanded) by country j.

I^j = national income of country j.

e^j = elasticity of demand for varieties of product X produced by country j.

r^j = capital input price in country j.

w^j = labour input price in country j.

a_{ly}^j = country j's labour input coefficient for product Y.

a_{ky}^j = country j's capital input coefficient for product Y.

a_{lx}^j = country j's labour input coefficient for product X.

a_{kx}^j = country j's capital input coefficient for product X.

L = total world endowment of labour.

K = total world endowment of capital.

sl^1 = country 1's share of world endowment of labour.

sl^2 = 1 - sl^1 = country 2's share of labour.

sk^1 = country 1's share of world endowment of capital.

sk^2 = 1 - sk^1 = country 2's share of capital.

V^j = national welfare level of country j.

MODEL EQUATIONS:

demand equations:

1. $$D_{x1}^{1} - \frac{[p^{1}(1+t_{1}^{1})]^{\frac{1}{\beta-1}}}{n^{1}[p^{1}(1+t_{1}^{1})]^{\frac{\beta}{\beta-1}}+n^{2}[p^{2}(1+t_{2}^{2})(1+t_{2}^{1})]^{\frac{\beta}{\beta-1}}} \cdot \alpha I^{1} = 0$$

2. $$D_{x1}^{2} - \frac{[p^{1}(1+t_{1}^{1})(1+t_{1}^{2})]^{\frac{1}{\beta-1}}}{n^{1}[p^{1}(1+t_{1}^{1})(1+t_{1}^{2})]^{\frac{\beta}{\beta-1}}+n^{2}[p^{2}(1+t_{2}^{2})]^{\frac{\beta}{\beta-1}}} \cdot \alpha I^{2} = 0$$

3. $$D_{x2}^{1} - \frac{[p^{2}(1+t_{2}^{2})(1+t_{2}^{1})]^{\frac{1}{\beta-1}}}{n^{1}[p^{1}(1+t_{1}^{1})]^{\frac{\beta}{\beta-1}}+n^{2}[p^{2}(1+t_{2}^{2})(1+t_{2}^{1})]^{\frac{\beta}{\beta-1}}} \cdot \alpha I^{1} = 0$$

4. $$D_{x2}^{2} - \frac{[p^{2}(1+t_{2}^{2})]^{\frac{1}{\beta-1}}}{n^{1}[p^{1}(1+t_{1}^{1})(1+t_{1}^{2})]^{\frac{\beta}{\beta-1}}+n^{2}[p^{2}(1+t_{2}^{2})]^{\frac{\beta}{\beta-1}}} \cdot \alpha I^{2} = 0$$

income equations:

5. $$I^{1} - p^{1}n^{1}x^{1} - Y^{1} - n^{1}p^{1}t_{1}^{1}(D_{x1}^{1} + D_{x1}^{2}) - n^{2}p^{2}t_{2}^{1}D_{x2}^{1} = 0$$

6. $$I^{2} - p^{2}n^{2}x^{2} - Y^{2} - n^{2}p^{2}t_{2}^{2}(D_{x2}^{1} + D_{x2}^{2}) - n^{1}p^{1}t_{1}^{2}D_{x1}^{2} = 0$$

international product market equilibrium conditions-product X:

7. $$x^{1} - (D_{x1}^{1} + D_{x1}^{2}) = 0$$

8. $$x^{2} - (D_{x2}^{1} + D_{x2}^{2}) = 0$$

producer equilibrium FOC's (profit maximization) - industry Y:

9. $Y^1 - Y^1(a_y(r^1)^\rho + (1 - a_y)(w^1)^\rho) = 0$

10. $Y^2 - Y^2(a_y(r^2)^\rho + (1 - a_y)(w^2)^\rho) = 0$

producer equilibrium FOC's for industry X:

11. $x^1[p^1(1 - (1/e^1))]^\rho - x^1(a_x(r^1)^\rho + (1 - a_x)(w^1)^\rho) = 0$

12. $x^2[p^2(1 - (1/e^2))]^\rho - x^2(a_x(r^2)^\rho + (1 - a_x)(w^2)^\rho) = 0$

13. $x^1 - h(e^1 - 1) = 0$

14. $x^2 - h(e^2 - 1) = 0$

equations for demand elasticity (e^j) of product X:

15. $$e^1-\left(\frac{1}{1-\beta}\right)+\frac{\beta}{x^1(1-\beta)}\left[\frac{D^1_{x1}[p^1(1+t^1_1)]^{\frac{\beta}{\beta-1}}}{n^1[p^1(1+t^1_1)]^{\frac{\beta}{\beta-1}}+n^2[p^2(1+t^2_2)(1+t^1_2)]^{\frac{\beta}{\beta-1}}}+\frac{D^2_{x1}[p^1(1+t^1_1)(1+t^2_1)]^{\frac{\beta}{\beta-1}}}{n^1[p^1(1+t^1_1)(1+t^2_1)]^{\frac{\beta}{\beta-1}}+n^2[p^2(1+t^2_2)]^{\frac{\beta}{\beta-1}}}\right]=0$$

16. $$e^2-\left(\frac{1}{1-\beta}\right)+\frac{\beta}{x^2(1-\beta)}\left[\frac{D^1_{x2}[p^2(1+t^2_2)(1+t^1_2)]^{\frac{\beta}{\beta-1}}}{n^1[p^1(1+t^1_1)]^{\frac{\beta}{\beta-1}}+n^2[p^2(1+t^2_2)(1+t^1_2)]^{\frac{\beta}{\beta-}}}+\frac{D^2_{x2}[p^2(1+t^2_2)]^{\frac{\beta}{\beta-1}}}{n^1[p^1(1+t^1_1)(1+t^2_1)]^{\frac{\beta}{\beta-1}}+n^2[p^2(1+t^2_2)]^{\frac{\beta}{\beta-1}}}\right]=0$$

factor input coefficient equations for industry Y:

17. $a_{1y}{}^1 - (1 - a_y)(w^1)^{\rho-1}(a_y(r^1)^\rho + (1 - a_y)(w^1)^\rho)^{(1/\rho)-1} = 0$

18. $a_{ly}^{2} - (1 - a_y)(w^2)^{\rho-1}(a_y(r^2)^{\rho} + (1 - a_y)(w^2)^{\rho})^{(1/\rho)-1} = 0$

19. $a_{ky}^{1} - a_y(r^1)^{\rho-1}(a_y(r^1)^{\rho} + (1 - a_y)(w^1)^{\rho})^{(1/\rho)-1} = 0$

20. $a_{ky}^{2} - a_y(r^2)^{\rho-1}(a_y(r^2)^{\rho} + (1 - a_y)(w^2)^{\rho})^{(1/\rho)-1} = 0$

<u>factor input coefficient equations for industry X:</u>

21. $a_{lx}^{1} - (1 - a_x)(w^1)^{\rho-1}(a_x(r^1)^{\rho} + (1 - a_x)(w^1)^{\rho})^{(1/\rho)-1} = 0$

22. $a_{lx}^{2} - (1 - a_x)(w^2)^{\rho-1}(a_x(r^2)^{\rho} + (1 - a_x)(w^2)^{\rho})^{(1/\rho)-1} = 0$

23. $a_{kx}^{1} - a_x(r^1)^{\rho-1}(a_x(r^1)^{\rho} + (1 - a_x)(w^1)^{\rho})^{(1/\rho)-1} = 0$

24. $a_{kx}^{2} - a_x(r^2)^{\rho-1}(a_x(r^2)^{\rho} + (1 - a_x)(w^2)^{\rho})^{(1/\rho)-1} = 0$

<u>FOC's for factor market equilibrium:</u>

25. $a_{lx}^{1}\ (x^1 + h)\ n^1 + a_{ly}^{1}\ Y^1 - sl^1\ L = 0$

26. $a_{kx}^{1}\ (x^1 + h)\ n^1 + a_{ky}^{1}\ Y^1 - sk^1\ K = 0$

27. $a_{lx}^{2}\ (x^2 + h)\ n^2 + a_{ly}^{2}\ Y^2 - (1 - sl^1)\ L = 0$

28. $a_{kx}^{2}\ (x^2 + h)\ n^2 + a_{ky}^{2}\ Y^2 - (1 - sk^1)\ K = 0$

<u>national welfare levels as given by the indirect utility function, V^j:</u>

29. $V^1 - (\alpha/1-\alpha)^{\alpha}\ (1 - \alpha)\ I^1\ (\ n^1[p^1(1 + t_1^{\ 1})]^{\beta/(\beta-1)} + n^2[p^2(1 + t_2^{\ 2})(1 + t_2^{\ 1})]^{\beta/(\beta-1)}\ )^{\alpha(1-\beta)/\beta} = 0$

30. $V^2 - (\alpha/1-\alpha)^{\alpha}\ (1 - \alpha)\ I^2\ (\ n^1[p^1(1 + t_1^{\ 1})(1 + t_1^{\ 2})]^{\beta/(\beta-1)} + n^2[p^2(1 + t_2^{\ 2})]^{\beta/(\beta-1)}\ )^{\alpha(1-\beta)/\beta} = 0$

```
/*                        APPENDIX II

                       Gauss Command File

        Neo-Chamberlinian Heckscher-Ohlin Trade Model
   Incorporating Tariffs (exact elasticity specification)      */

#LINESON
LIBRARY NLSYS;
#INCLUDE NLSYS.EXT;
NLSET;

a = 0.6; ax = 0.2; ay = 0.6; b = 0.7; g = 0.2; h = 5; sl1 = 0.5;
sk1 = 0.5; t12 = 0; t21 = 0; t11 = 0; t22 = 0; k = 1000; l = 2000;

PROC fsys(x);
LOCAL f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,f11,f12,f13,f14,f15,f16,
f17,f18,f19,f20,f21,f22,f23,f24,f25,f26,f27,f28,f29,f30;

f1 = x[5] - ((x[1]*(1 + t11))^2)^(0.5/(b - 1))*a*x[9]/(x[3]*
     ((x[1]*(1 + t11))^2)^(0.5*b/(b - 1)) + x[4]*((x[2]*(1 + t22)*
     (1 + t21))^2)^(0.5*b/(b - 1)));
f2 = x[6] - ((x[1]*(1 + t11)*(1 + t12))^2)^(0.5/(b - 1))*a*x[10]/
     (x[3]*((x[1]*(1 + t11)*(1 + t12))^2)^(0.5*b/(b - 1)) + x[4]*
     ((x[2]*(1 + t22))^2)^(0.5*b/(b - 1)));
f3 = x[7] - ((x[2]*(1 + t22)*(1 + t21))^2)^(0.5/(b - 1))*a*x[9]/
     (x[3]*((x[1]*(1 + t11))^2)^(0.5*b/(b - 1)) + x[4]*((x[2]*
     (1 + t22)*(1 + t21))^2)^(0.5*b/(b - 1)));
f4 = x[8] - ((x[2]*(1 + t22))^2)^(0.5/(b - 1))*a*x[10]/(x[3]*
     ((x[1]*(1 + t11)*(1 + t12))^2)^(0.5*b/(b - 1)) + x[4]*((x[2]*
     (1 + t22))^2)^(0.5*b/(b - 1)));
f5 = x[9] - x[1]*x[3]*x[11] - x[15] - t11*x[1]*x[3]*
     (x[5] + x[6]) - t21*x[2]*x[4]*x[7];
f6 = x[10] - x[2]*x[4]*x[12] - x[16] - t12*x[1]*x[3]*x[6] -
     t22*x[2]*x[4]*(x[7] + x[8]);
f7 = x[11] - x[5] - x[6];
f8 = x[12] - x[7] - x[8];
f9 = (x[15]^2)^0.5 - x[15]*(ay*(x[17]^2)^(0.5*g) + (1 - ay)*
     (x[18]^2)^(0.5*g));
f10 = (x[16]^2)^0.5 - x[16]*(ay*(x[19]^2)^(0.5*g) + (1 - ay)*
     (x[20]^2)^(0.5*g));
f11 = ((x[3]^2)^0.5)*((x[1]*(1 - (1/x[13])))^2)^(0.5*g) - x[3]*
     (ax*(x[17]^2)^(0.5*g) + (1 - ax)*(x[18]^2)^(0.5*g));
f12 = ((x[4]^2)^0.5)*((x[2]*(1 - (1/x[14])))^2)^(0.5*g) - x[4]*
     (ax*(x[19]^2)^(0.5*g) + (1 - ax)*(x[20]^2)^(0.5*g));
f13 = x[11] - h*(x[13] - 1);
f14 = x[12] - h*(x[14] - 1);
f15 = x[13] - (1/(1 - b)) + (b/(x[11]*(1 - b)))*(x[5]*((x[1]*
     (1 + t11))^2)^(0.5*(b/(b - 1)))/(x[3]*((x[1]*(1 + t11))^2)^
     (0.5*(b/(b - 1))) + x[4]*((x[2]*(1 + t22)*(1 + t21))^2)^(0.5*
     (b/(b - 1)))) + x[6]*((x[1]*(1 + t11)*(1 + t12))^2)^
     (0.5*(b/(b - 1)))/(x[3]*((x[1]*(1 + t11)*(1 + t12))^2)^(0.5*
     (b/(b - 1))) + x[4]*((x[2]*(1 + t22))^2)^(0.5*(b/(b - 1)))));
```

```
f16 = x[14] - (1/(1 - b)) + (b/(x[12]*(1 - b)))*(x[7]*((x[2]*
     (1 + t22)*(1 + t21))^2)^(0.5*(b/(b - 1)))/(x[3]*((x[1]*
     (1 + t11))^2)^(0.5*(b/(b - 1))) + x[4]*((x[2]*(1 + t22)*
     (1 + t21))^2)^(0.5*(b/(b - 1)))) + x[8]*((x[2]*(1 + t22))^2)
     ^(0.5*(b/(b - 1)))/(x[3]*((x[1]*(1 + t11)*(1 + t12))^2)^(0.5*
     (b/(b - 1))) + x[4]*((x[2]*(1 + t22))^2)^(0.5*(b/(b - 1)))));
f17 = x[21] - (1 - ay)*(x[18]^2)^(0.5*(g - 1))*(ay*(x[17]^2)
     ^(0.5*g) + (1 - ay)*(x[18]^2)^(0.5*g))^((1/g) - 1);
f18 = x[23] - (1 - ay)*(x[20]^2)^(0.5*(g - 1))*(ay*(x[19]^2)
     ^(0.5*g) + (1 - ay)*(x[20]^2)^(0.5*g))^((1/g) - 1);
f19 = x[22] - ay*(x[17]^2)^(0.5*(g - 1))*(ay*(x[17]^2)
     ^(0.5*g) + (1 - ay)*(x[18]^2)^(0.5*g))^((1/g) - 1);
f20 = x[24] - ay*(x[19]^2)^(0.5*(g - 1))*(ay*(x[19]^2)
     ^(0.5*g) + (1 - ay)*(x[20]^2)^(0.5*g))^((1/g) - 1);
f21 = x[25] - (1 - ax)*(x[18]^2)^(0.5*(g - 1))*(ax*(x[17]^2)
     ^(0.5*g) + (1 - ax)*(x[18]^2)^(0.5*g))^((1/g) - 1);
f22 = x[27] - (1 - ax)*(x[20]^2)^(0.5*(g - 1))*(ax*(x[19]^2)
     ^(0.5*g) + (1 - ax)*(x[20]^2)^(0.5*g))^((1/g) - 1);
f23 = x[26] - ax*(x[17]^2)^(0.5*(g - 1))*(ax*(x[17]^2)^(0.5*g)
     + (1 - ax)*(x[18]^2)^(0.5*g))^((1/g) - 1);
f24 = x[28] - ax*(x[19]^2)^(0.5*(g - 1))*(ax*(x[19]^2)^(0.5*g)
     + (1 - ax)*(x[20]^2)^(0.5*g))^((1/g) - 1);
f25 = x[25]*(x[11] + h)*x[3] + x[21]*x[15] - sl1*l;
f26 = x[26]*(x[11] + h)*x[3] + x[22]*x[15] - sk1*k;
f27 = x[27]*(x[12] + h)*x[4] + x[23]*x[16] - (1 - sl1)*l;
f28 = x[28]*(x[12] + h)*x[4] + x[24]*x[16] - (1 - sk1)*k;
f29 = x[29] - ((a/(1 - a))^a)*(1 - a)*x[9]*(x[3]*(x[1]*(1 + t11))
     ^(b/(b - 1)) + x[4]*(x[2]*(1 + t22)*(1 + t21))^(b/(b - 1)))^
     (a*(1 - b)/b);
f30 = x[30] - ((a/(1 - a))^a)*(1 - a)*x[10]*(x[3]*(x[1]*(1 + t11)
     *(1 + t12))^(b/(b - 1))+ x[4]*(x[2]*(1 + t22))^(b/(b - 1)))^
     (a*(1 - b)/b);

RETP(f1|f2|f3|f4|f5|f6|f7|f8|f9|f10|f11|f12|f13|f14|f15|f16|f17|
f18|f19|f20|f21|f22|f23|f24|f25|f26|f27|f28|f29|f30);

ENDP;

/*      Starting Values      */

x0 = { 1.35, 1.35, 55, 55, 5.8, 5.8, 5.8, 5.8, 1450, 1450, 11.7,
       11.7, 3, 3, 580, 580, 1.06, 0.92, 1.06, 0.92, 0.43, 0.57,
       0.43, 0.57, 0.82, 0.18, 0.82, 0.18, 2000, 2000 };

__altnam = { p1, p2, n1, n2, Dx11, Dx12, Dx21, Dx22, I1, I2, x1,
             x2, e1, e2, y1, y2, r1, w1, r2, w2, aly1, aky1,
             aly2, aky2, alx1, akx1, alx2, akx2, V1, V2 };

__title = "Neo-Chamberlinian Heckscher-Ohlin Trade Model,
       Incorporating Tariffs (Exact Elasticity Specification)";
```

```
__OUTPUT = 0;

OUTPUT FILE = choex.out RESET;

print "sl1 =" sl1; print "sk1 =" sk1; print "b =" b;
print "g =" g; print "h =" h;

{ x,f,j,tcode } = NLPRT(NLSYS(&fsys,x0));

OUTPUT OFF;
```

sl1 = 0.50000000
sk1 = 0.50000000
b = 0.70000000
g = 0.20000000
h = 5.0000000

Neo-Chamberlinian Heckscher-Ohlin Trade Model,
Incorporating Tariffs (Exact Elasticity Specification)

NLSYS: Version 2.01 (R1) 5/04/93 1:41 pm

Number of iterations required: 3
||F(x)|| at final solution: 9.138143e-08

Algorithm used: LINE SEARCH
Jacobian calculated using: FORWARD DIFFERENCE

Termination Code = 1:

Norm of the scaled function value is less than _nlfvtol;
Xp given is an approximate root of F(x) (unless _nlfvtol
is too large).

VARIABLE	START	ROOTS	F(ROOTS)
P1	1.35000	1.353524	-6.4424288e-10
P2	1.35000	1.353524	-6.4451822e-10
N1	55.00000	55.483583	-6.4424288e-10
N2	55.00000	55.483583	-6.4451822e-10
DX11	5.80000	5.7807652	3.6210281e-08
DX12	5.80000	5.7807652	3.6222218e-08
DX21	5.80000	5.7807652	-8.8817842e-16
DX22	5.80000	5.7807652	-8.8817842e-16
I1	1450.00000	1447.0867	-1.4244961e-10
I2	1450.00000	1447.0867	-1.4244961e-10
X1	11.70000	11.56153	-1.2753603e-09
X2	11.70000	11.56153	-1.2759926e-09
E1	3.00000	3.3123061	-1.7763568e-15
E2	3.00000	3.3123061	-1.7763568e-15
Y1	580.00000	578.83468	1.9377208e-13
Y2	580.00000	578.83468	1.9377208e-13
R1	1.06000	1.0576529	-2.7905456e-13
W1	0.92000	0.91826024	-2.7583491e-13
R2	1.06000	1.0576529	-4.465317e-13
W2	0.92000	0.91826024	-4.445333e-13
ALY1	0.43000	0.42824013	-5.7731597e-14
AKY1	0.57000	0.57368925	-5.2735594e-14
ALY2	0.43000	0.42824013	-3.9263037e-13
AKY2	0.57000	0.57368925	-3.9057646e-13
ALX1	0.82000	0.8185063	4.7907633e-10
AKX1	0.18000	0.18275115	-2.7557689e-10
ALX2	0.82000	0.8185063	4.8407856e-10
AKX2	0.18000	0.18275115	-2.7552005e-10
V1	2000.00000	2066.507	-1.2404325e-07
V2	2000.00000	2066.507	-1.2404325e-07

```
/*                              APPENDIX III

                            Gauss Command File

         Neo-Chamberlinian Heckscher-Ohlin Trade Model
     Incorporating Tariffs (constant elasticity specification)        */

#LINESON
LIBRARY NLSYS;
#INCLUDE NLSYS.EXT;
NLSET;

a = 0.6; ax = 0.2; ay = 0.6; b = 0.7; g = 0.2; h = 5; t11 = 0;
t22 = 0; t21 = 0; t12 = 0; sk1 = 0.5; sl1 = 0.5; k = 1000; l = 2000;

PROC fsys(x);
LOCAL f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,f11,f12,f13,f14,f15,f16,
f17,f18,f19,f20,f21,f22,f23,f24,f25,f26,f27;

f1 = x[5] - ((x[1]*(1 + t11))^2)^(0.5/(b - 1))*a*x[9]/(x[3]*
     ((x[1]*(1 + t11))^2)^(0.5*b/(b - 1)) + x[4]*((x[2]*(1 + t22)*
     (1 + t21))^2)^(0.5*b/(b - 1)));
f2 = x[6] - ((x[1]*(1 + t11)*(1 + t12))^2)^(0.5/(b - 1))*a*x[10]/
     (x[3]*((x[1]*(1 + t11)*(1 + t12))^2)^(0.5*b/(b - 1)) + x[4]*
     ((x[2]*(1 + t22))^2)^(0.5*b/(b - 1)));
f3 = x[7] - ((x[2]*(1 + t22)*(1 + t21))^2)^(0.5/(b - 1))*
     a*x[9]/(x[3]*((x[1]*(1 + t11))^2)^(0.5*b/(b - 1)) + x[4]*
     ((x[2]*(1 + t22)*(1 + t21))^2)^(0.5*b/(b - 1)));
f4 = x[8] - ((x[2]*(1 + t22))^2)^(0.5/(b - 1))*a*x[10]/(x[3]*
     ((x[1]*(1 + t11)*(1 + t12))^2)^(0.5*b/(b - 1)) + x[4]*
     ((x[2]*(1 + t22))^2)^(0.5*b/(b - 1)));
f5 = x[9] - x[1]*x[3]*x[11] - x[12] - t11*x[1]*x[3]*
     (x[5] + x[6]) -t21*x[2]*x[4]*x[7];
f6 = x[10] - x[2]*x[4]*x[11] - x[13] - t12*x[1]*x[3]*x[6]
     - t22*x[2]*x[4]*(x[7] + x[8]);
f7 = x[11] - x[5] - x[6];
f8 = x[11] - x[7] - x[8];
f9 = (x[12]^2)^0.5 - x[12]*(ay*(x[14]^2)^(0.5*g)
     + (1 - ay)*(x[15]^2)^(0.5*g));
f10 = (x[13]^2)^0.5 - x[13]*(ay*(x[16]^2)^(0.5*g)
     + (1 - ay)*(x[17]^2)^(0.5*g));
f11 = ((x[3]^2)^0.5)*((x[1]*b)^2)^(0.5*g) - x[3]*
     (ax*(x[14]^2)^(0.5*g) + (1 - ax)*(x[15]^2)^(0.5*g));
f12 = ((x[4]^2)^0.5)*((x[2]*b)^2)^(0.5*g) - x[4]*
     (ax*(x[16]^2)^(0.5*g) + (1 - ax)*(x[17]^2)^(0.5*g));
f13 = x[11]*(1 - b) - h*b;
f14 = x[18] - (1 - ay)*(x[15]^2)^(0.5*(g - 1))*(ay*(x[14]^2)
     ^(0.5*g) +(1 - ay)*(x[15]^2)^(0.5*g))^((1/g) - 1);
f15 = x[20] - (1 - ay)*(x[17]^2)^(0.5*(g - 1))*(ay*(x[16]^2)
     ^(0.5*g) +(1 - ay)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f16 = x[19] - ay*(x[14]^2)^(0.5*(g - 1))*(ay*(x[14]^2)
     ^(0.5*g) + (1 - ay)*(x[15]^2)^(0.5*g))^((1/g) - 1);
```

```
f17 = x[21] - ay*(x[16]^2)^(0.5*(g - 1))*(ay*(x[16]^2)
     ^(0.5*g) + (1 - ay)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f18 = x[22] - (1 - ax)*(x[15]^2)^(0.5*(g - 1))*(ax*(x[14]^2)
     ^(0.5*g) + (1 - ax)*(x[15]^2)^(0.5*g))^((1/g) - 1);
f19 = x[24] - (1 - ax)*(x[17]^2)^(0.5*(g - 1))*(ax*(x[16]^2)
     ^(0.5*g) + (1 - ax)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f20 = x[23] - ax*(x[14]^2)^(0.5*(g - 1))*(ax*(x[14]^2)
     ^(0.5*g) + (1 - ax)*(x[15]^2)^(0.5*g))^((1/g) - 1);
f21 = x[25] - ax*(x[16]^2)^(0.5*(g - 1))*(ax*(x[16]^2)
     ^(0.5*g) + (1 - ax)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f22 = x[22]*(x[11] + h)*x[3] + x[18]*x[12] - sl1*l;
f23 = x[23]*(x[11] + h)*x[3] + x[19]*x[12] - sk1*k;
f24 = x[24]*(x[11] + h)*x[4] + x[20]*x[13] - (1 - sl1)*l;
f25 = x[25]*(x[11] + h)*x[4] + x[21]*x[13] - (1 - sk1)*k;
f26 = x[26] - ((a/(1 - a))^a)*(1 - a)*x[9]*(x[3]*(x[1]*
     (1 + t11))^(b/(b - 1))+ x[4]*(x[2]*(1 + t22)*(1 + t21))
     ^(b/(b - 1)))^(a*(1 - b)/b);
f27 = x[27] - ((a/(1 - a))^a)*(1 - a)*x[10]*(x[3]*(x[1]*
     (1 + t11)*(1 + t12))^(b/(b - 1))+ x[4]*(x[2]*(1 + t22))^
     (b/(b - 1)))^(a*(1 - b)/b);

RETP(f1|f2|f3|f4|f5|f6|f7|f8|f9|f10|f11|f12|f13|f14|f15|f16|
f17|f18|f19|f20|f21|f22|f23|f24|f25|f26|f27);

ENDP;

/*      Starting Values      */

x0 = { 1.35, 1.35, 55, 55, 5.8, 5.8, 5.8, 5.8, 1450, 1450,
       11.7, 580, 580, 1.06, 0.92, 1.06, 0.92, 0.43, 0.57, 0.43,
       0.57, 0.82, 0.18, 0.82, 0.18, 2000, 2000 };

__altnam = { p1, p2, n1, n2, Dx11, Dx12, Dx21, Dx22, I1, I2,
             x, y1, y2, r1, w1, r2, w2, aly1, aky1, aly2,
             aky2, alx1, akx1, alx2, akx2, V1, V2 };

__title = "Neo-Chamberlinian Heckscher-Ohlin Trade Model,
        Incorporating Tariffs (Constant Elasticity Specification)";

__OUTPUT = 0;

OUTPUT FILE = choce.out RESET;

print "sl1 =" sl1; print "sk1 =" sk1; print "b =" b;
print "g =" g; print "h =" h;

{ x,f,j,tcode } = NLPRT(NLSYS(&fsys,x0));


OUTPUT OFF;
```

```
sl1 =      0.50000000
sk1 =      0.50000000
b =       0.70000000
g =       0.20000000
h =        5.0000000
```

Neo-Chamberlinian Heckscher-Ohlin Trade Model,
Incorporating Tariffs (Constant Elasticity Specification)

NLSYS: Version 2.01 (R1) 5/04/93 1:40 pm

Number of iterations required:	2
||F(x)|| at final solution:	2.0476299e-08
Algorithm used:	LINE SEARCH
Jacobian calculated using:	FORWARD DIFFERENCE

Termination Code = 1:

Norm of the scaled function value is less than _nlfvtol;
Xp given is an approximate root of F(x) (unless _nlfvtol
is too large).

VARIABLE	START	ROOTS	F(ROOTS)
P1	1.35000	1.3498416	-6.4835159e-10
P2	1.35000	1.3498416	-6.4835337e-10
N1	55.00000	55.133583	-6.4835159e-10
N2	55.00000	55.133583	-6.4835337e-10
DX11	5.80000	5.8333333	9.6889607e-09
DX12	5.80000	5.8333333	9.6890744e-09
DX21	5.80000	5.8333333	-8.8817842e-16
DX22	5.80000	5.8333333	-8.8817842e-16
I1	1450.00000	1447.0867	2.4691644e-09
I2	1450.00000	1447.0867	2.4691644e-09
X	11.70000	11.666667	-3.6885694e-10
Y1	580.00000	578.83468	-3.6886405e-10
Y2	580.00000	578.83468	0
R1	1.06000	1.0576529	-1.7899904e-11
W1	0.92000	0.91826024	-1.7899904e-11
R2	1.06000	1.0576529	-1.5120349e-11
W2	0.92000	0.91826024	-1.5120349e-11
ALY1	0.43000	0.42824013	-6.0503824e-12
AKY1	0.57000	0.57368925	-6.0503824e-12
ALY2	0.43000	0.42824013	-1.447284e-11
AKY2	0.57000	0.57368925	-1.447284e-11
ALX1	0.82000	0.8185063	-1.2821374e-08
AKX1	0.18000	0.18275115	1.1179282e-08
ALX2	0.82000	0.8185063	-1.283513e-08
AKX2	0.18000	0.18275115	1.1168027e-08
V1	2000.00000	2066.5222	2.1170763e-08
V2	2000.00000	2066.5222	2.1170308e-08

```
/*                         APPENDIX IV

                        Gauss Command File

                Heckscher-Ohlin Version of Model              */


#LINESON
LIBRARY NLSYS;
#INCLUDE NLSYS.EXT;
NLSET;

a = 0.6; ax = 0.2; ay = 0.6; g = 0.2; sk1 = 0.5; sl1 = 0.5;
k = 1000; l = 2000;

PROC fsys(x);
LOCAL f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,f11,f12,f13,f14,f15,f16,
f17,f18,f19,f20,f21;

f1 = (x[2] + x[3]) - a*(x[6] + x[7])/x[1];
f2 = (x[4]^2)^0.5 - x[4]*(ay*(x[16]^2)^(0.5*g) +
     (1 - ay)*(x[17]^2)^(0.5*g));
f3 = (x[5]^2)^0.5 - x[5]*(ay*(x[18]^2)^(0.5*g) +
     (1 - ay)*(x[19]^2)^(0.5*g));
f4 = ((x[2]^2)^0.5)*((x[1])^2)^(0.5*g) - x[2]*(ax*(x[16]^2)
     ^(0.5*g) + (1 - ax)*(x[17]^2)^(0.5*g));
f5 = ((x[3]^2)^0.5)*((x[1])^2)^(0.5*g) - x[3]*(ax*(x[18]^2)
     ^(0.5*g) + (1 - ax)*(x[19]^2)^(0.5*g));
f6 = x[6] - x[1]*x[2] - x[4];
f7 = x[7] - x[1]*x[3] - x[5];
f8 = x[8] - (1 - ay)*(x[17]^2)^(0.5*(g - 1))*(ay*(x[16]^2)
     ^(0.5*g) + (1 - ay)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f9 = x[10] - (1 - ay)*(x[19]^2)^(0.5*(g - 1))*(ay*(x[18]^2)
     ^(0.5*g) + (1 - ay)*(x[19]^2)^(0.5*g))^((1/g) - 1);
f10 = x[9] - ay*(x[16]^2)^(0.5*(g - 1))*(ay*(x[16]^2)^(0.5*g)
     + (1 - ay)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f11 = x[11] - ay*(x[18]^2)^(0.5*(g - 1))*(ay*(x[18]^2)^(0.5*g)
     + (1 - ay)*(x[19]^2)^(0.5*g))^((1/g) - 1);
f12 = x[12] - (1 - ax)*(x[17]^2)^(0.5*(g - 1))*(ax*(x[16]^2)
     ^(0.5*g) + (1 - ax)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f13 = x[14] - (1 - ax)*(x[19]^2)^(0.5*(g - 1))*(ax*(x[18]^2)
     ^(0.5*g) + (1 - ax)*(x[19]^2)^(0.5*g))^((1/g) - 1);
f14 = x[13] - ax*(x[16]^2)^(0.5*(g - 1))*(ax*(x[16]^2)^(0.5*g)
     + (1 - ax)*(x[17]^2)^(0.5*g))^((1/g) - 1);
f15 = x[15] - ax*(x[18]^2)^(0.5*(g - 1))*(ax*(x[18]^2)^(0.5*g)
     + (1 - ax)*(x[19]^2)^(0.5*g))^((1/g) - 1);
f16 = x[12]*x[2] + x[8]*x[4] - sl1*l;
f17 = x[13]*x[2] + x[9]*x[4] - sk1*k;
f18 = x[14]*x[3] + x[10]*x[5] - (1 - sl1)*l;
f19 = x[15]*x[3] + x[11]*x[5] - (1 - sk1)*k;
f20 = x[20] - ((a/x[1])^a)*((1 - a)^(1 - a))*x[6];
f21 = x[21] - ((a/x[1])^a)*((1 - a)^(1 - a))*x[7];
```

```
RETP(f1|f2|f3|f4|f5|f6|f7|f8|f9|f10|f11|f12|f13|f14|f15|f16|f17|
f18|f19|f20|f21);

ENDP;

/*      Starting Values      */

x0 = { 1, 500, 500, 500, 500, 1000, 1000, 0.4, 0.6, 0.4, 0.6,
       0.8, 0.2, 0.8, 0.2, 1, 1, 1, 1, 1500, 1500 };

__altnam = { p, x1, x2, y1, y2, I1, I2, aly1, aky1, aly2, aky2,
             alx1, akx1, alx2, akx2, r1, w1, r2, w2, V1, V2 };

__title = "Heckscher-Ohlin Version of the Model";

__OUTPUT = 0;

OUTPUT FILE = h-o.out RESET;

print "sl1 =" sl1; print "sk1 =" sk1;

{ x,f,j,tcode } = NLPRT(NLSYS(&fsys,x0));

OUTPUT OFF;
```

```
sl1 =        0.50000000
sk1 =        0.50000000
```

Heckscher-Ohlin Version of the Model

NLSYS: Version 2.01 (R1) — 5/04/93 1:39 pm

Number of iterations required:	4
||F(x)|| at final solution:	3.535918e-11
Algorithm used:	LINE SEARCH
Jacobian calculated using:	FORWARD DIFFERENCE

Termination Code = 1:

Norm of the scaled function value is less than _nlfvtol;
Xp given is an approximate root of F(x) (unless _nlfvtol
is too large).

VARIABLE	START	ROOTS	F(ROOTS)
P	1.00000	0.94488909	-3.9335646e-11
X1	500.00000	918.89306	1.6825652e-11
X2	500.00000	918.89306	1.5916157e-11
Y1	500.00000	578.83468	1.1937118e-11
Y2	500.00000	578.83468	1.1368684e-11
I1	1000.00000	1447.0867	-3.4333425e-11
I2	1000.00000	1447.0867	-3.4560799e-11
ALY1	0.40000	0.42824013	-7.0110584e-14
AKY1	0.60000	0.57368925	-7.1220807e-14
ALY2	0.40000	0.42824013	3.7747583e-14
AKY2	0.60000	0.57368925	3.5971226e-14
ALX1	0.80000	0.8185063	-4.2299497e-14
AKX1	0.20000	0.18275115	-4.4186876e-14
ALX2	0.80000	0.8185063	1.9678703e-14
AKX2	0.20000	0.18275115	1.8984814e-14
R1	1.00000	1.0576529	-2.2737368e-12
W1	1.00000	0.91826024	-1.4779289e-12
R2	1.00000	1.0576529	-2.1600499e-12
W2	1.00000	0.91826024	-1.3642421e-12
V1	1500.00000	763.80202	1.1368684e-11
V2	1500.00000	763.80202	1.1368684e-11

VITA

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University of Victoria	1988 to 1993

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Dean's Scholarship, University of Victoria	1989
University of Victoria Fellowship	1989-90

Publications:

Title of Thesis: Simulations on a Computational General Equilibrium Trade Model Incorporating Scale Economies and Product Differentiation, with varying factor endowments

Author: [redacted]

BRENDA JOYCE TURMEL

March 25, 1994