AUSTRALIA

MONASH UNIVERSITY

AN INFRAMARGINAL ANALYSIS OF THE HECKSCHER-OLIN MODEL

Xiaokai Yang

and

Wenli Cheng
New Zealand Treasury

SEMINAR PAPER NO. 18/97

For Limited Distribution Only

DEPARTMENT OF ECONOMICS

SEMINAR PAPERS

An Inframarginal Analysis of the Heckscher-Olin Model

Xiaokai Yang
Monash University

&

Wenli Cheng
New Zealand Treasury

Abstract

In the paper we check if the four core theorems of trade, the Heckscher-Olin (HO) theorem, the Stopler-Samuelson theorem, the Rybczynski theorem, and factor equalization theorem, hold in a general equilibrium analysis with endogenous prices of goods and factors and if they hold when all trade patterns outside the diversification cone and discontinuous jumps of general equilibrium between different trade patterns are considered. Also, comparative advantage in technology between countries is added to comparative advantage in endowments to accommodate empirical evidences that are incompatible with the core theorems. The HO theorem can stand the test though it needs to be refined when technical comparative advantage is introduced. The other core theorems cannot stand the test.

Keywords: HO theorem, factor equalization theorem, Stolper-Samuelson theorem, Rybczynski theorem

JEL classification: F10, F11

1. Introduction

This paper concerns with the four core theorems in trade theory, namely, the Heckscher-Olin (HO) theorem, Stolper-Samuelson (SS) theorem, and Rybczynski (RY) theorem[1].

The four core theorems are derived from the traditional 2×2×2 HO model. The model has some standard neoclassical assumptions (such as perfect competition and constant return to scale) and several somewhat restrictive assumptions (which will be discussed later). Given its assumptions, the theorems do not require specific functional forms; yet, they are able to identify several regularities in general equilibrium comparative statics.

Because of its generality and its ability to derive unambiguous comparative static results, the traditional HO model has dominated the trade theory in the past few decades. However, the predictions generated by the model appear to be at odds with a well-known theorem in general equilibrium theory, which states that in the absence of explicit model specifications, we can say nothing about the properties of the equilibrium comparative statics except that Walras' law holds, and that the excess demand function is homogenous of degree zero (See Sonnenschein, 1973, Mantel, 1974, and Debreu, 1974). In view of the theorem, the four core theorems of trade theory seem too good to be true.

How can the traditional HO model in its general forms lead to unambiguous comparative statics results, while, as a rule, no definite regularities can be found in general equilibrium comparative statics? We believe that the answer is closely related to three restrictive assumptions of the traditional HO model, namely, (1) that output or factor prices are exogenous if trading countries are small; (2) that each country is assumed to produce both goods when the core theorems are proved; and (3) that trading countries share identical technologies. The main purpose of this paper is to examine whether the four core theorems in trade theory remain valid if these restrictive assumptions are relaxed. But first we explain the reasons for and the implication of relaxing these assumptions.

---

[1] The background of the SS theorem and related core trade theorems, their extensions, empirical tests, reflections about them, and a comprehensive annotated bibliography can be found in Deardorff and Stern (1994).

(1) Output or factor prices are exogenous if trading countries are small

The traditional HO model assumes that the trading countries are small, thus each country is a price taker, and the equilibrium prices of goods can be treated as exogenous when the SS and RY theorems are proved or the equilibrium prices of factors can be treated as exogenous when the HO theorem is proved. Since exogenous product or factor prices exclude from the analysis the interactions between prices and other parameters (such as endowment), the general equilibrium comparative statics become less unambiguous. However, it is unjustified, in our opinion, to infer exogenous prices of goods or factors from the small country assumption for the same reason that perfect competition (price taking behavior) cannot be used to justify exogenous equilibrium prices in a general equilibrium model. In other words, we believe that prices of goods and factors in the HO model should be endogenously determined even if all trading nations are small. With endogenous prices, the core theorems of trade theory may or may not hold; certainly they cannot be derived in the same way as in the traditional way for the following reasons.

a. Because factor prices are endogenous in a general equilibrium model, it is appealing to criticism to assume exogenous factor prices when some trade economists prove the HO theorem (see Jones, 1965 and Dixit and Norman, 1980).
b. Because both product prices and factor prices are endogenous, a change in factor prices must be explained by changes in parameters rather than by changes of product prices. Hence, the SS theorem can no longer be a comparative statics result.
c. Because product price is endogenous, it cannot be held constant in general equilibrium when a parameter (e.g. endowment) changes. Hence the RY theorem which describes how equilibrium outputs change as an endowment changes holding product price constant, has to be refined.

(2) Specialization is incomplete at trade equilibrium

The traditional HO model assumes that specialization between the trading countries is incomplete, that is, both countries produce both goods at the trade equilibrium. This assumption significantly narrows down the scope of analysis by excluding other possible patterns of specialization and trade. And it is not surprising that less ambiguous results are obtained within a narrowed scope of analysis.

As depicted in Figure 1, there are 8 possible trade structures in the HO model. Only the first 2 structures involve incomplete specialization for both countries. The last 6 structures involve complete specialisation in at least one country. We can refer to the first 2 structures as interior structures since the output choices of each goods for both countries are strictly positive, ie, they are based on interior solutions. And the last 6 structures can be referred to as corner structures as at least one country chooses zero value of output level of one good, ie, corner solutions are involved.

To find the general equilibrium of the model, we need to know which of the 8 structures (or trade patterns) occurs within which parameter subspace and also the prices and quantities in that structure. Correspondingly, the comparative statics analysis of general equilibrium should investigate not only marginal changes of quantities and prices in response to parameter changes within each structure, but also inframarginal changes (discontinuous jumps) of trade patterns across structures as parameters reach some critical values (or as parameter values shift between parameter subspaces that demarcate the structures). The comparative statics that relate to changes within a given structure are referred to as marginal comparative statics and those related to changes between structures are referred to as inframarginal comparative statics.

For some purposes, inframarginal comparative statics are more important than marginal comparative statics since the latter involve only marginal changes in quantities and prices within a trade structure, while the former involve discontinuous jumps of all endogenous variables including prices and quantities as well as changes of trade structure. For instance, inframarginal comparative statics can be used to explore the implications of parameter changes (including changes in policy parameters, such as tariff rates, and regional free trade arrangements and WTO arrangements) for the equilibrium size and pattern of the trade network.

The four core theorems in trade theory are derived under the assumption of incomplete specialization, the comparative statics are restricted to the interior structure and are of the marginal type (see Jones, 1965 and Dixit and Norman, 1980). To test whether the core theorems hold when the assumption of incomplete specialization is relaxed, we need to use inframaginal comparative statics, that is, we need find out if the theorems remain valid when each trade pattern is considered and when parameter values shift from a parameter subspace to another leading to discontinuous jumps of general equilibrium from a structure to another.

The work to partition the parameter space into subspaces within each of which a particular trade pattern is general equilibrium is important for working out comparative statics of general equilibrium. The parameter subspace within which an unambiguous negative sign of the derivative of the equilibrium value of an endogenous variable with respect to a parameter occurs may have no intersection set with the parameter subspace within which the trade pattern concerned is the general equilibrium. This implies that identifying the sign of the derivative is not enough and the partition of the parameter space is essential for working out the comparative statics of general equilibrium. But the implications of the partition of the parameter space did not receive deserved attention when the four core theorems were proved.

(3) Trading countries share identical technologies

This assumption is obviously inconsistent with empirical observation, and it has contributed to the poor empirical performance of the HO theorem. According to Trefler (1995), the HO theorem is consistent with empirical findings only 50% of the time. Despite the unsatisfactory performance, the HO theorem has retained its dominance in international economics simply because economists have not found anything that performs better (Bowen et. al., 1987). In a recent attempt to improve the performance of the HO theorem, Trefler (1995) demonstrated empirically that a modification is desirable that allows for consumption bias and technology difference between countries.

To complement Trefler's work, we introduce technology differences between countries to the traditional HO model. We shall show that if the trading countries differ in both productivity and factor endowments, the equilibrium trade pattern may be opposite to what the traditional HO theorem predicts; and we shall propose a refined HO theorem.

The main findings of this paper are: (1) the HO theorem continues to hold when prices of goods and factors are endogenized and inframargianl comparative statics of general equilibrium are considered, though it needs to be refined when differences in technology are introduced; (2) the SS theorem remains valid within the diversification cone if the changes in prices are due to a change in taste or endowment, but no longer holds if the changes in prices are due to changes in production parameters (this is true even if technical difference is absent: a surprising result that invalidates the SS theorem within the original HO model); and the SS theorem does not always hold outside the diversification cone (a well known result); (3) the part of the RY theorem which states that an increase in a factor endowment leads to an expansion of the sector that uses the factor intensively remains valid, but the other part which states that such an increase leads to a contraction of the other sector is no longer true; (4) the factor price equalization theorem does not hold outside the diversification cone (a well established result). It does not always hold within the diversification cone if differences in technology is introduced (a new finding).

We hope the findings will alert economists and policy makers to treat the core theorems with extreme caution. For instance, the SS theorem has been often used to analyse the impact of trade on domestic income distribution. Our results show that the SS theorem does not always hold, and indeed that all four of the core theorems are only true under certain conditions since the comparative statics of general equilibrium are model structure specific, functional form specific, and for a given specific model they are parameter value specific.

The rest of the paper is organized as follows. Section 2 presents the HO model that incorporates technology differences and checks the validity of the HO theorem. Section 3 discusses the concept of the diversification cone and analyzes the conditions for factor price equalization in our model. Sections 4 and 5 check the Stolper-Samuelson theorem and the Rybczynski theorem, respectively. Section 6 concludes the paper.

2. The HO model with differences in technology

In this section, we develop an HO model with two countries differing in production technology. The assumptions are similar to those in a standard 2×2×2 HO model, namely, that perfect competition prevails in both goods and factor markets; that factors are mobile within a country but immobile between countries; that factors are fully employed; and that the production technology exhibits constant returns to scale. In our model, prices of goods and factors are endogenized.

We start by finding the autarky product price in each country as reference, and then proceed to solve for the trade equilibrium.

2.1 Autarky

Assume that country i (i =1, 2) is endowed with labor L_i and capital K_i, which can be used to produce two consumer goods X and Y. In autarky, the decision problem of a representative consumer in country i is

$$\max_{x_i, y_i} U_i = x_i^{\theta} y_i^{1-\theta}$$
$$s.t.\ px_i + y_i = w_i L_i + r_i K_i \tag{1}$$

where p is the price of good X in terms of good Y; w_i and r_i are wage rate and rental of capital, respectively.

Assume that the production functions for X and Y in country i are:

$$x_i = a_{ix} L_{ix}^{\alpha} K_{ix}^{1-\alpha}; \qquad y_i = a_{iy} L_{iy}^{\beta} K_{iy}^{1-\beta} \quad . \tag{2}$$

where $a_{ij}\,(i = 1,2; j = x,y)$ is the total factor productivity coefficient. Since a_{ij} is country specific, it captures the productivity difference between the two countries. Constrained by the production technology, the representative firm producing X in country i maximizes its profit, i.e.,

$$\max_{L_{ix}, K_{ix}} \pi_{ix} = px_i - w_i L_{ix} - r_i K_{ix} = pa_{ix} L_{ix}^{\alpha} K_{ix}^{1-\alpha} - w_i L_{ix} - r_i K_{ix}\,. \tag{3}$$

The decision problem for a firm producing Y is similar to (3).

From the first order conditions of the firms' decisions problems, we obtain:

$$\frac{K_{ix}}{L_{ix}} = [p_i \frac{a_{ix}}{a_{iy}} (\frac{\alpha}{\beta})^{\beta} (\frac{1-\alpha}{1-\beta})^{1-\beta}]^{\frac{1}{\alpha-\beta}}$$
$$\frac{K_{iy}}{L_{iy}} = \frac{\alpha(1-\beta)}{\beta(1-\alpha)} \frac{K_{ix}}{L_{ix}} \tag{4}$$

It is easy to see that $\frac{K_{ix}}{L_{ix}} > \frac{K_{iy}}{L_{iy}}$ (that is, the X industry is capital intensive and the Y industry is labor intensive) if and only if $\alpha < \beta$. Without loss of generality, we assume that the X industry is capital intensive, ie., $\alpha < \beta$.

Using (4) and the market clearing conditions for factors and goods in each country, we obtain the autarky price in country i (p_i):

$$p_i = \frac{a_{iy}}{a_{ix}}[\frac{L_i}{K_i}\frac{(1-\alpha)\theta+(1-\beta)(1-\theta)}{\alpha\theta+\beta(1-\theta)}]^{\beta-\alpha}\frac{\beta^{\beta}(1-\beta)^{1-\beta}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \quad (5)$$

Clearly, $p_1<p_2$ if and only if $(\frac{a_{1x}}{a_{1y}})^{\frac{1}{\beta-\alpha}}\frac{K_1}{L_1} > (\frac{a_{2x}}{a_{2y}})^{\frac{1}{\beta-\alpha}}\frac{K_2}{L_2}$ under our assumption that $\alpha<\beta$. Suppose also that there is no comparative advantage in production technology in the two country, (ie., $\frac{a_{1x}}{a_{1y}}=\frac{a_{2x}}{a_{2y}}$), then $p_1<p_2$ if and only if $\frac{K_1}{L_1}>\frac{K_2}{L_2}$. In other words, if country 1 is capital abundant, it will have comparative advantage in the capital intensive good X. This is the content of the HO theorem. However, if there is a comparative technological difference between the two countries, which country has comparative advantage in what good depends on *both* relative factor endowments and relative technological difference. In this case the traditional HO theorem may give the wrong prediction about comparative advantage.

Autarky price differences provide a clue for the direction of trade flows between the 2 countries, but to examine the exact trade pattern, we need to look at the trade equilibrium.

2.2 Trade equilibrium

With international trade, the nature of the decisions for consumers and firms is similar to that with autarky except that there is a single relative price of good X in terms of Y, p, in the world market.

Using the first order conditions for the decisions problems of two types of firms (producing X or producing Y) in each country and the market clearing conditions for factors in each country, we can solve for factor prices and relative factor allocation as functions of product price (p). We then use the world market clearing condition for goods to solve for the equilibrium value of p.

The general equilibrium is summarized as follows:

$$x_i = Aa_{ix}(a_{ix}/a_{iy})^{\alpha/(\beta-\alpha)}[\beta K_i-(1-\beta)L_i(a_{iy}/a_{ix})^{1/(\beta-\alpha)}/\gamma\mu](\gamma\mu)^{\alpha}/(\beta-\alpha), \quad (6a)$$

$$y_i = Ba_{iy}(a_{iy}/a_{ix})^{(1-\beta)/(\beta-\alpha)}[(1-\alpha)(L_i/\gamma\mu)-\alpha K_i(a_{ix}/a_{iy})^{1/(\beta-\alpha)}](\gamma\mu)^{\beta}/(\beta-\alpha),$$

$$L_{ix} = [\alpha/(\beta-\alpha)][\beta K_i(a_{ix}/a_{iy})^{1/(\beta-\alpha)}\gamma\mu-(1-\beta)L_i], \quad (6b)$$

$$L_{iy} = [\beta/(\beta-\alpha)][(1-\alpha)L_i-\alpha K_i(a_{ix}/a_{iy})^{1/(\beta-\alpha)}\gamma\mu].$$

$$K_{ix} = (1\text{-}\alpha)\, L_{ix} w_i / r_i \alpha, \quad K_{iy} = (1\text{-}\beta) L_{iy} w_i / r_i \beta.$$

$$p = (r_i/w_i)^{(\beta-\alpha)} B a_{iy} / a_{ix} A, \qquad r_i/w_i = \gamma\mu (a_{ix}/a_{iy})^{1/(\beta-\alpha)} \tag{6c}$$

where $A \equiv \alpha^{\alpha}(1\text{-}\alpha)^{1-\alpha}$, $B \equiv \beta^{\beta}(1\text{-}\beta)^{1-\beta}$, $\mu \equiv [(\beta\text{-}\alpha)\theta+1\text{-}\beta]/[\beta\text{-}\theta(\beta\text{-}\alpha)]>0$,

$$\gamma \equiv \frac{\left(\dfrac{a_{1y}^{1-\alpha}}{a_{1x}^{1-\beta}}\right)^{1/(\beta-\alpha)} L_1 + \left(\dfrac{a_{2y}^{1-\alpha}}{a_{2x}^{1-\beta}}\right)^{1/(\beta-\alpha)} L_2}{\left(\dfrac{a_{1x}^{\beta}}{a_{1y}^{\alpha}}\right)^{1/(\beta-\alpha)} K_1 + \left(\dfrac{a_{2x}^{\beta}}{a_{2y}^{\alpha}}\right)^{1/(\beta-\alpha)} K_2}.$$

L_{ix} and L_{iy} can be greater or equal to zero. Correspondingly, there are 8 possible trade structures as depicted in Figure 1.

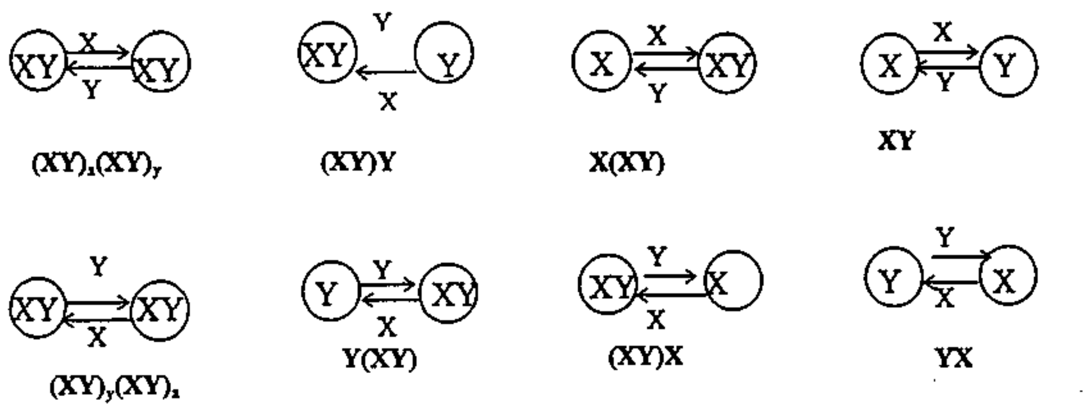

Figure 1: Possible Trade Structures

where $(XY)_x(XY)_y$ denotes that each country produces two goods, country 1 exports good X and country 2 exports good Y. XY denotes that each country produces only one good and country 1 exports X and imports Y. Other notations for structures in Fig. 1 have similar meaning.

Let relevant variables in (6b), which are functions of eleven parameters, be greater than or equal to 0, we can partition the eleven dimension space of parameters β, α, θ, K_i, L_i, a_{iy} , a_{ix} into subspaces. There may be a parameter subspace within which a particular structure is the general equilibrium structure. For instance, let L_{ix} , $L_{iy} > 0$ for i=1,2, we can identify the parameter subspace for the interior structure, which is associated with the diversification cone, to be the general equilibrium structure, and let L_{ix}, $L_{1y} > 0$ and $L_{2y} = 0$, we can identify the parameter subspace for structure (XY)X to be the general equilibrium structure.

Throughout the paper, we assume

$$(\frac{a_{1x}}{a_{1y}})^{\frac{1}{\beta-\alpha}}\frac{K_1}{L_1} > (\frac{a_{2x}}{a_{2y}})^{\frac{1}{\beta-\alpha}}\frac{K_2}{L_2} \tag{7}$$

which implies that the autarky price of X in terms of Y is lower in country 1 than in country 2. Under this assumption, we can show that the parameter subspace for structure (XY)X to be general equilibrium is empty. In structure (XY)X, L_{1x} , $L_{1y} > 0$ and $L_{2y} \le 0$ which requires that $\gamma\mu \in (v_{2x}, v_{1x})$ where $v_{1x} \equiv (1\text{-}\alpha)(a_{1y}/a_{1x})^{1/(\beta-\alpha)}L_1/\alpha K_1$ and $v_{2x} \equiv (1\text{-}\alpha)(a_{2y}/a_{2x})^{1/(\beta-\alpha)}L_2/\alpha K_2$. Parameter subspace (v_{2x}, v_{1x}) is empty if $v_{2x} > v_{1x}$, or if our assumption (7) holds. Similarly, we can show that the parameter subspaces for structures Y(XY) and YX to be general equilibrium are empty. In addition, we can rule out structure $(XY)_y(XY)_x$ because under assumption (7), it can be shown that country 1's demand for Y is greater than its production of Y.

For the remaining structures, we can identify their corresponding parameter subspaces within which each structure is the general equilibrium structure. This is summarized in Table 1.

Table 1: General Equilibrium and Its Inframarginal Comparative Statics

Parameter subspace	$[(1\text{-}\alpha)\beta/\alpha(1\text{-}\beta)](a_{2x}/a_{2y})^{1/(\beta-\alpha)}K_2/L_2 > (a_{1x}/a_{1y})^{1/(\beta-\alpha)} K_1/L_1$.			$[(1\text{-}\alpha)\beta/\alpha(1\text{-}\beta)](a_{2x}/a_{2y})^{1/(\beta-\alpha)}K_2/L_2 < (a_{1x}/a_{1y})^{1/(\beta-\alpha)} K_1/L_1$.		
$\gamma\mu\in$	(v_{1y}, v_{2y})	(v_{2y}, v_{1x})	(v_{1x}, v_{2x})	(v_{1y}, v_{1x})	(v_{1x}, v_{2y})	(v_{2y}, v_{2x})
Equilibrium structure	XY_1Y_2	$YX_1\,XY_2$	$X_1\,XY_2$	XY_1Y_2	X_1Y_2	$X_1\,XY_2$

where γ and μ are given in (6), $v_{1y}<v_{2y}$, $v_{1x}<v_{2x}$, $v_{2x}>v_{2y}$, $v_{1y}<v_{1x}$ if (7) holds, $v_{1x} \equiv (1\text{-}\alpha)(a_{1y}/a_{1x})^{1/(\beta-\alpha)}L_1/\alpha K_1$, $v_{2x} \equiv (1\text{-}\alpha)(a_{2y}/a_{2x})^{1/(\beta-\alpha)}L_2/\alpha K_2$, $v_{1y} \equiv (1\text{-}\beta)(a_{1y}/a_{1x})^{1/(\beta-\alpha)}L_1/\beta K_1$, $v_{2y} \equiv (1\text{-}\beta)(a_{2y}/a_{2x})^{1/(\beta-\alpha)}L_2/\beta K_2$.

Table 1 indicates that under our assumption (7), four different trade patterns can occur in equilibrium depending on parameter values. All the trade patterns feature country 1 exporting good X. (It can be shown that if we reverse our assumption (7), the other four trade patterns will occur in equilibrium each featuring country 1 exporting good Y.)

Our assumption (7) holds if we assume that country 1 is capital abundant ($K_1/L_1>K_2/L_2$) and X is capital intensive ($\beta>\alpha$) and that country 1 has no comparative technological disadvantage in producing X, ($a_{1x}/a_{1y} \geq a_{2x}/a_{2y}$). Hence, the results in Table 1 are consistent with the traditional HO theorem, that is, country 1 exports the good (X) that uses its abundant factor (K) intensively, if $a_{1x}/a_{1y} \geq a_{2x}/a_{2y}$. However, if country 1 has comparative technological disadvantage in producing X (ie, $a_{1x}/a_{1y} < a_{2x}/a_{2y}$), then whether the traditional HO theorem holds depends on whether country 1's comparative endowment advantage dominates the comparative technological disadvantage in producing X.

Hence, our model shows that the HO theorem can stand the test of the endogenization of prices of goods and factors as well as the test of inframarginal comparative statics analysis of general equilibrium. However, it needs to be refined if there are comparative differences in production technology. The refined HO theorem can take the following form.

Proposition 1: *A capital abundant country exports capital intensive good if it has no comparative technological disadvantage in producing this good or if the technological disadvantage is outweighed by its comparative endowment advantage. Otherwise the country exports labor intensive good.*

3. The Factor Price Equalization Theorem

The factor price equalization theorem predicts that international trade will equalize factor prices in the trading countries even though the factors are immobile across countries (Samuelson, 1948, 1953). This prediction has been mostly inconsistent with empirical evidence. There are various explanations for the inconsistence. We look at two here. The first explanation is the well-recognized result that if the general equilibrium occurs outside the diversification cone, the factor price equalization theorem does not hold. The second was that international productivity differences account for much of the differences in factor prices (Leontief, 1956 and Trefler, 1993). We analyze the two explanations in turn.

The concept of the diversification cone was developed in the 1950s (see Lerner, 1952, and McKenzie, 1956). It is defined as the range of factor endowments within which a country produces both goods for given prices. The focus of the concept on factor endowments is probably due to that factor endowments are the only exogenous variables besides commodity prices in those early trade models. In our model, however, the diversification cone should be understood as the parameter subspace within which both countries produce both goods in equilibrium. The parameters include relative consumer preference, technology and endowments. Specifically, the diversification cone in our model is defined by the following system of inequalities:

$$L_{1x} > 0;\ L_{1y} > 0;\ \ L_{2x} > 0; L_{2y} > 0.$$

Under our assumption (7), ie., $(\frac{a_{1x}}{a_{1y}})^{\frac{1}{\beta-\alpha}} \frac{K_1}{L_1} > (\frac{a_{2x}}{a_{2y}})^{\frac{1}{\beta-\alpha}} \frac{K_2}{L_2}$, the above inequalities imply (refer to Table 1):

$$[(1-\alpha)\beta/\alpha(1-\beta)](a_{2x}/a_{2y})^{1/(\beta-\alpha)}K_2/L_2 > (a_{1x}/a_{1y})^{1/(\beta-\alpha)}K_1/L_1 \quad (8a)$$

and $\quad \gamma\mu \in (v_{2y}, v_{1x}).$ (8b)

where $v_{2y} \equiv (1-\beta)(a_{2y}/a_{2x})^{1/(\beta-\alpha)}L_2/\beta K_2$, $v_{1x} \equiv (1-\alpha)(a_{1y}/a_{1x})^{1/(\beta-\alpha)}L_1/\alpha K_1$ are given under Table 1, $\mu \equiv [(\beta-\alpha)\theta+1-\beta]/[\beta-\theta(\beta-\alpha)]$ and

$$\gamma \equiv \frac{\left(\frac{a_{1y}^{1-\alpha}}{a_{1x}^{1-\beta}}\right)^{1/(\beta-\alpha)} L_1 + \left(\frac{a_{2y}^{1-\alpha}}{a_{2x}^{1-\beta}}\right)^{1/(\beta-\alpha)} L_2}{\left(\frac{a_{1x}^{\beta}}{a_{1y}^{\alpha}}\right)^{1/(\beta-\alpha)} K_1 + \left(\frac{a_{2x}^{\beta}}{a_{2y}^{\alpha}}\right)^{1/(\beta-\alpha)} K_2}$$

are given in (6). Note that in condition (8a), $[(1-\alpha)/\alpha]/[(1-\beta)/\beta] > 1$ iff $\beta>\alpha$ (iff good X is capital intensive). $[(1-\alpha)/\alpha]/[(1-\beta)/\beta]$ can be interpreted as labor intensity in the Y sector relative to the X sector, or the capital intensity in the X sector relative to the Y sector. We may measure technological comparative advantage by $a_{1x}a_{2y}/a_{1y}a_{2x}$ and comparative endowment advantage between the two countries by K_1L_2/L_1K_2. Condition (8a) implies each country's comparative advantage in producing the good that is intensive of the factor which is abundant in this country is not too great and/or the capital intensity of good X relative to good Y is great. (8b) implies that relative taste for two goods is in balance with relative population size and relative productivity between the two countries. If the comparative advantage is too great and/or the relative intensity is too small, equilibrium will be structure XY which is outside the diversification cone and involves complete specialization of each country. If the relative taste is not in balance with relative population size and relative productivity, one country will be completely specialized in structure X(XY) or (XY)Y. This condition in terms of a parameter subspace for the diversification cone is much more accurate than the conventional condition in terms of prices. It, together with (7), indicates that the parameter subspace for the diversification cone is very small. This subspace requires comparative advantage in technology and in endowment is nether too great nor too small.

Outside the diversification cone, the factor price equalization theorem does not hold. For instance, in structure XY, factor prices in country 1 are,

$$w_1 = \alpha\, p a_{1x}(K_1/L_1)^{1-\alpha},\ r_1 = (1-\alpha)\, p a_{1x}(K_1/L_1)^{-\alpha},$$

where $p = \theta a_{2y} K_2^{1-\beta} L_2^{\beta}/(1-\theta) a_{1x} K_1^{1-\alpha} L_1^{\alpha}$ is the equilibrium price of good X in terms of good Y.

Factor prices in country 2 are:

$$w_2 = \beta a_{2y}(K_2/L_2)^{1-\beta},\ r_2 = (1-\beta) a_{2y}(K_2/L_2)^{-\beta}.$$

Clearly, $w_1 \neq w_2$, $r_1 \neq r_2$, except for trivial razor edge cases.

Even within the diversification cone, the factor prices are still not equalized. The factor prices in country 1 and country 2 in structure $(XY)_x(XY)_y$ are:

$$w_1 = \alpha\, p a_{1x}(K_{1x}/L_{1x})^{1-\alpha},\ r_1 = (1-\alpha)\, p a_{1x}(K_{1x}/L_{1x})^{-\alpha}, \tag{9a}$$

$$w_2 = \alpha\, p a_{2x}(K_{1x}/L_{1x})(a_{1x}a_{2y}/a_{2x}a_{1y})^{(1-\alpha)/(\beta-\alpha)},$$

$$r_2 = (1-\alpha)\, p a_{2x}(K_{1s}/L_{1s})^{-\alpha}\,(a_{1x}a_{2y}/a_{2x}a_{1y})^{(1-\alpha)/(\beta-\alpha)} \tag{9b}$$

where p is given in (6). A comparison between (9a) and (9b) shows

$$w_1 \le w_2 \text{ iff } (a_{1x}/a_{2x})^{(1-\beta)}(a_{2y}/a_{1y})^{1-\alpha} \ge 1 \tag{9c}$$

$$r_1 \ge r_2 \text{ iff } (a_{1x}/a_{2x})^{\beta}(a_{2y}/a_{1y})^{\alpha} \ge 1 \tag{9d}$$

(9c) and (9d) implies that the country that has comparative technological advantage in the capital intensive good is likely to have higher rental rate and lower wage rate than the other country. This is consistent with Leontief's (1956) view that the difference between factor prices can be explained by productivity differences.

The analysis in this section is summarized in the following proposition.

Proposition 2 *The general equilibrium occurs within the diversification cone if each country's comparative advantage is not too great, the relative intensity of capital to labor in X sector is sufficiently greater than in Y sector, and relative taste is in balance with the two country's relative population size and relative productivity. If comparative advantage is sufficiently great and/or the relative factor intensity is sufficiently small, the general equilibrium entails complete specialization of each* *country. If relative taste is not in balance with relative population size and relative productivity, one country completely specializes and the other produces both goods in equilibrium.*

Within the diversification cone, the factor price equalization theorem holds only if there are no productivity difference between the trading countries or the relative productivity between two countries in producing two goods is in balance according to equalities in (9c, d). If a country has comparative technological advantage in the capital (labor) intensive good, its rental (wage) is likely to be higher and its wage (rental) lower than the other country.

4. The Stolper-Samuelson Theorem

The SS theorem states that if the price of the capital-intensive (or labor-intensive) good rises, the price of capital (or labor) rises, and in greater proportion to the commodity price increase; the price of labor falls, but necessarily in greater proportion to the commodity price increase (Stolper and Sammuelson, 1941). Since with the opening-up of international trade, the price of a country's comparative advantage good rises, a corollary of the SS theorem is that international trade benefits a country's abundant factor and hurts its scarce factor or a tariff benefits a country's scarce factor. [2]

We check the validity of the SS theorem in our model in 3 steps: we examine whether it holds (1) within the diversification cone; (2) outside the diversification cone; and (3) when the general equilibrium jumps from one structure to another.

(1) Does the SS theorem hold within the diversification cone?

First, consider an increase in total factor productivity of X in country 1 due to a neutral technological progress (ie., an increase in a_{1x}). Differentiation of (6c) with respect to a_{1x} yields

$dp/da_{1x} < 0$ always holds (10a)

$d(r_1/w_1)/da_{1x} > 0$ iff $[\gamma/a_{1x}(\beta-\alpha)]+(d\gamma/a_{1x})>0$. (10b)

It can be shown that (10) and the condition for general equilibrium to occur within the diversification cone (condition 8a and 8b) can hold simultaneously if

[2] Grossman and Levinsohn (1989) show that the specific factors model captures reality more closely than the SS theorem for many U.S. industries.

$$\mu a_{1x}\{(a_{1y}{}^{1-\alpha}/a_{1x}{}^{1-\beta})^{1/(\beta-\alpha)}L_1K_1+$$
$$(a_{2x}{}^{\beta}/a_{2y}{}^{\alpha})^{1/(\beta-\alpha)}[(1-\beta)(a_{1y}/a_{1x})^{1/(\beta-\alpha)}L_1K_2+\beta(a_{2y}/a_{2x})^{1/(\beta-\alpha)}L_2K_1]\}$$
$$< (1-\alpha)(a_{1y}/a_{1x})^{1-\alpha/(\beta-\alpha)}L_1[(a_{1x}{}^{\beta}/a_{1y}{}^{\alpha})^{1/(\beta-\alpha)}K_1+(a_{2x}{}^{\beta}/a_{2y}{}^{\alpha})^{1/(\beta-\alpha)}K_2]^2/\alpha K_1 \qquad (11)$$

(11) holds for a value of α that is sufficiently close to 0, since μ and the left hand side has are limited positive values while the right hand side of (11) tends to infinity as α tends to 0. This means that there exists a parameter subspace within the diversification cone, defined by (11), such that an increase in a_{1x} leads to an increase in the price of capital intensive good (X), but a decrease in the rental for capital. This result is clearly inconsistent with the SS theorem. Similarly, we can prove that there exist parameter subspaces such that other non-neutral technical changes may generate changes in prices that are inconsistent with the SS theorem.

Next, consider a non-neutral technical change that raises the relative productivity of capital to labor in producing X (ie., an increase in α). To show the SS theorem may not hold within the diversification cone even in the original HO model with no technical difference between the countries, we assume $a_{ij} = 1$. The differentiation of (6c) with respect to α yields

$$dp/d\alpha > 0 \text{ iff } -\ln[\alpha/(1-\alpha)][\beta-\theta(\beta-\alpha)][(\beta-\alpha)\theta+1-\beta]>\theta A \qquad (12a)$$

$$d(r/w)/d\alpha < 0 \text{ always holds.} \qquad (12b)$$

It is easy to see that (12a) holds if α is sufficiently close to 0. We can also show that (12) and the condition for the general equilibrium to occur within the diversification cone hold simultaneously if

$$-\ln[\alpha/(1-\alpha)][\beta-\theta(\beta-\alpha)][(\beta-\alpha)\theta+1-\beta]>\alpha[(L_1+L_2)K_1/(K_1+K_2)L_1 \qquad (13)$$

Inequality (13) holds if α is sufficiently close to 0. Hence, for a sufficiently small α, an increase in α raises the price of the capital intensive good and at the same time reduce the rental for capital within the diversification cone.

This result is intuitive. A change in α indirectly affects r/w through interdependence between r/w and p (a change in α affects p which in turn affects r/w), given in the first expression in (6c). This effect is counted by the SS theorem. However, the change in α has a direct effect on r/w too, as shown in the second expression in (6c), which is not counted by the SS theorem. If the direct and indirect effect have the same sign, then the SS theorem holds. But if the two effects are opposite, then the SS theorem does not hold when the direct effect dominates the indirect one. In other words, the SS theorem ignores some interdependencies and feedback loops between factor and commodity markets, between consumption and production, between prices and quantities, and between different agents' self-interested behaviors. The ignorance is due to the assumption of exogenous commodity prices in the SS theorem.

We now consider a change in taste (θ) or endowments (L_i. K_i, i=1,2). From (6c), it is clear that the inter-relationship between p and r/w is independent of changes in taste or endowments, and that a change in taste or endowment affects p and r/w in the same direction. In other words, the SS theorem holds.

Summarizing the above analysis, we have

Proposition 3 *Within the diversification cone, price movements are consistent with the SS theorem if changes in prices are due to changes in taste or endowment; price movements may be inconsistent with the SS theorem if the changes in prices are due to changes in production parameters. This is true even if technological difference is absent.*

(2) Does the SS theorem hold outside the diversification cone?

The well known answer to this question is negative. We need to solve for the local equilibrium in each structure to formalize the answer. The approach is similar to the one we used to solve for the local equilibrium in the interior structure (the solution presented in (6)). The equilibrium in autarky and in structures XY_1Y_2, X_1Y_2, X_1XY_2 are summarized as follows:

Autarky: $p_i = (a_{iy}/a_{ix})(r_i/w_i)^{\beta-\alpha}B/A$, $\quad r_i/w_i = L_i\,\mu\,/K_i$ (14)

$x_i = a_{ix}A(\beta\mu-1+\beta)L_i^{\alpha}K_i^{\,1-\alpha}/(\beta-\alpha)\mu$, $\quad y_i = a_{iy}b(1-\alpha-\alpha\mu)L_i^{\beta}K_i^{\,1-\beta}/(\beta-\alpha)\mu$

$K_{ix} = (1-\alpha)(\beta\mu-1+\beta)K_i/(\beta-\alpha)\mu$, $\quad K_{iy} = (1-\beta)(1-\alpha-\alpha\mu)K_i/(\beta-\alpha)\mu$

$L_{ix} = \alpha K_{ix}\, r_i/w_i(1-\alpha)$, $\quad L_{iy} = \beta K_{iy}\, r_i/w_i(1-\beta)$.

Structure XY: $p = \theta a_{2y}L_2^{\beta}K_2^{1-\beta}/a_{1x}L_1^{\alpha}K_2^{1-\alpha}(1-\theta)$, (15)

$r_1/w_1 = (1-\alpha)L_1/\alpha K_1$, $\quad w_1 = \alpha\theta a_{2y}L_2^{\beta}K_2^{1-\beta}/L_1\,(1-\theta)$,

$r_2/w_2 = (1-\beta)L_2/\beta K_2$, $\quad w_2 = \beta a_{2y}\,(K_2/L_2)^{1-\beta}$,

$x_1 = a_{1x}\,L_1^{\alpha}K_1^{1-\alpha}$, $\quad y_2 = a_{2y}L_2^{\beta}K_2^{1-\beta}$,

Structure (XY)Y: p is given by

$$F \equiv (a_{1y}B)^{-\alpha/(\beta-\alpha)}K_1(a_{1x}Ap)^{\beta/(\beta-\alpha)} - (1/\mu)(a_{1y}B/)^{(1-\alpha)/(\beta-\alpha)}L_1(a_{1x}Ap)^{(\beta-1)/(\beta-\alpha)}$$

$$-\{\theta(\beta-\alpha)/[\beta-\theta(\beta-\alpha)]\}a_{2y}L_2^{\beta}K_2^{1-\beta} = 0 \qquad (16a)$$

$$r_1/w_1 = (a_{1x}Ap/a_{1y}B)^{1/(\beta-\alpha)}, \quad w_1 = a_{1x}Ap(a_{1y}B/a_{1x}Ap)^{(1-\alpha)/(\beta-\alpha)}, \qquad (16b)$$

$$r_2/w_2 = (1-\beta)L_2/K_2\beta, \quad w_2 = a_{2y}B\,[\beta K_2/L_2(1-\beta)]^{1-\beta}. \qquad (16c)$$

Structure X(XY): Symmetric to structure XY_1Y_2.

First consider structure XY. Differentiation of prices in structure XY with respect to different parameters yields

$d(r_i/w_i)/d\theta = 0$ and $dp/d\theta > 0$.

$d(r_i/w_i)/da_{ij} = 0$, $dp/da_{2y} \neq 0$, and $dp/da_{1x} \neq 0$;

$d(r_1/w_1)/d\alpha < 0$ and $dp/d\alpha > 0$ if $K_1 > L_1$;

$d(r_1/w_1)/d L_1 > 0$ and $dp/dL_1 < 0$.

None of the above relationships between r/w and p is consistent with the SS theorem.

Next consider structures (XY)Y and X(XY). Because of the symmetry between the two structures, we can focus on structure (XY)Y. Let's first look at country 1. (16b) indicates that the relationship between r_1/w_1 and p is independent of the taste or endowment parameter. Hence, any change in taste or endowment parameter will affect the prices of goods and the prices of factors in the same direction, that is, the SS theorem holds.

From (16a), we have

$\partial F/\partial p > 0$, $\partial F/\partial\theta > 0$, $\partial F/\partial a_{1x} > 0$, $\partial F/\partial a_{1y} < 0$, $\partial F/\partial a_{2y} < 0$

And the application of the implicit function theorem to the above yields

$$dp/d\theta = -(\partial F/\partial\theta)/(\partial F/\partial p) < 0, \quad dp/da_{1x} = -(\partial F/\partial a_{1x})/(\partial F/\partial p) < 0, \qquad (17a)$$

$$dp/da_{1y} = -(\partial F/\partial a_{1y})/(\partial F/\partial p) > 0, \quad dp/da_{2y} = -(\partial F/\partial a_{2y})/(\partial F/\partial p) > 0.$$

Similarly, we can prove

$$dp/dK_i < 0, \quad dp/dL_i > 0 \text{ for } i = 1, 2. \qquad (17b)$$

Following the method to prove proposition 3, we can prove that there exist parameter subspaces such that changes in a_{1x}, a_{1y}, α, or β will generate changes in prices that are inconsistent with the SS theorem.

For country 2, we have

$$d(r_2/w_2)/d\theta = 0,\ d(r_2/w_2)/da_{1x} = 0,\ d(r_2/w_2)/da_{1y} = 0,\ d(r_2/w_2)/da_{2y} = 0 \qquad (18)$$

$$d(r_2/w_2)/dL_1 = 0,\ d(r_2/w_2)/dL_2 > 0,\ d(r_2/w_2)/dK_1 = 0,\ d(r_2/w_2)/dK_2 < 0$$

(17) and (18) indicate that the changes in prices caused by changes in parameters of tastes, production technology, and endowments may be inconsistent with the SS theorem.

Summarising the above, we have

Proposition 4 *In the structure where both countries completely specialize, price movements are inconsistent with the SS theorem. In the structure where only one country completely specializes, price movements are inconsistent with the SS theorem for the country that completely specializes. For the country which produces both goods, price movements are inconsistent with the SS theorem if the price changes are due to production parameter changes, but consistent if the price changes are due to taste or endowment changes.*

The implications of this proposition are more important if deserved attention is paid to the fact that the parameter subspace for the general equilibrium to occur within the diversification cone is much smaller than the subspace within which the general equilibrium occurs outside the diversification cone.

(3) Does the SS theorem hold when the general equilibrium jumps from one structure to another?

Let us first consider the case that a sufficiently large decrease in tariff causes the general equilibrium to jump from the local equilibrium in autarky to the corner equilibrium in structure XY where both countries completely specialize.

A direct comparison between the prices in autarky, given in (14), and the corner equilibrium prices in structure XY, given in (15), indicates that the capital rental relative to wage in structure XY are higher than in autarky, but the price of capital intensive good relative to labor intensive good is lower in XY than in autarky if

$$\mu^{(\beta-\alpha)}B/A > \theta a_{2y}(L_2/L_1)^{\beta}(K_2/K_1)^{1-\beta}/a_{1y}(1-\theta) \quad (19)$$

It is easy to show that (19) holds if θ is sufficiently close to 0. Since (19) and the condition for structure XY to be the general equilibrium (shown in Table 1) hold simultaneously if

$(1\text{-}\beta)L_2(a_{2y}/a_{2x})^{1/(\beta\text{-}\alpha)}/\beta\gamma K_2 > \theta a_{2y}(L_2/L_1)^{\beta}(K_2/K_1)^{1\text{-}\beta}/a_{1y}(1\text{-}\theta)$ and

$\mu^{(\beta\text{-}\alpha)}B(L_1/L_2)^{\beta}(K_1/K_2)^{1\text{-}\beta}/A > \theta a_{2x}[(1\text{-}\alpha)\beta K_2L_1/\alpha(1\text{-}\beta)L_2K_1]^{\beta\text{-}\alpha}/a_{1x}(1\text{-}\theta)$,

the two inequalities hold too if θ is sufficiently close to 0.

A comparison between the interior equilibrium in the diversification cone, given in (6) and autarky, given in (14), shows that as trade opens up, the price of the capital intensive good (X) increases in country 1, so does the rental to capital.

It should be noted that if there is no transaction cost, autarky cannot be the general equilibrium (or the parameter subspace for autarky to be equilibrium is empty). If we introduce transaction costs for international trade or a sufficiently large differential in transaction cost between domestic and international trade into the model, then the jumps from autarky to other structures can be endogenized.

Suppose a tariff significantly increases transaction costs for international trade compared to domestic trade, then the general equilibrium will jump from structure XY or $(XY)_x(XY)_y$ to autarky. A comparison between per capita real incomes in autarky and in the two structures indicates that this will reduce per capita real incomes of all individuals, though it may increase marginally the returns to a factor compared to another factor.

Now consider the case when general equilibrium jumps from structure $(XY)_x(XY)_y$ where both countries produce both goods, to structure XY where both countries completely specialize.

Comparing the local equilibrium in structure $(XY)_x(XY)_y$ with that in structure XY, we find that for country 1, the ratio of capital rental to wage rate is higher in structure XY than in the interior structure with trade iff

$$\mu\gamma < (1\text{-}\alpha)L_1(a_{1y}/a_{1x})^{1/(\beta\text{-}\alpha)}/K_1\alpha \tag{20}$$

Also, the price of capital intensive good is lower in the former than in the latter iff

$$\mu\gamma > A\theta a_{2y}L_2^{\beta}K_2^{1\text{-}\beta}/L_1^{\alpha}K_1^{1\text{-}\alpha}a_{1x}(1\text{-}\theta)B. \tag{21}$$

(20) and (21) hold simultaneously if

$$(1\text{-}\alpha)a_{1y}^{1/(\beta\text{-}\alpha)} > \alpha a_{1x}^{(1\text{-}\alpha\text{-}\beta)/(\beta\text{-}\alpha)}a_{2y}L_2^{\beta}K_2^{1\text{-}\beta}K_1^{\alpha}/L_1^{1+\alpha}$$

This means that there exists a parameter subspace such that the ratio of capital rental to wage is higher and the price of capital intensive good is lower in structure XY than in structure $(XY)_x(XY)_y$.

It can be shown that within an appropriate interval of parameter values, an increase in α, in K_1/L_1, or in $a_{1x}a_{2y}/a_{1y}a_{2x}$, a decrease in β or in K_2/L_2 will make the general equilibrium discontinuously jump from structure $(XY)_x(XY)_y$ to structure XY. If parameter values are within the subspace that is defined by (20) and (21), then the changes in prices caused by the jump are inconsistent with the SS theorem.

The above analysis is summarized in the following propositions.

Proposition 5: *The SS theorem may not hold when equilibrium jumps from autarky to structure XY with specialization of each country, but the SS theorem always holds when equilibrium jumps from autarky to the interior structure with partial international division of labor. An increase in tariff may reduce all individuals' per capita real income though it marginally increases the returns to a factor compared to another factor.*

And

Proposition 6: *A change in parameters that causes a jump of general equilibrium from the structure with incomplete specialization for both countries to one with complete specialization of each country may generate price changes that are inconsistent with the SS theorem.*

Our analysis in this section suggests that the SS theorem cannot stand the test of the endogenization of commodity prices nor survive the inframarginal comparative statics analysis. The SS theorem holds only within the diversification cone when changes in prices are caused by changes in taste or endowment parameters. It is important to note that as shown in (8), the interior structure $(XY)_x(XY)_y$ is the general equilibrium only within a small parameter subspace where technology and endowment comparative advantage is not too great, capital intensity in the X sector is significantly greater than in the Y sector, and relative taste is in balance with relative population size and relative productivity of the two country. For the larger part of parameter space, general equilibrium involves complete specialization in at least one country.

5. The Rybczynski Theorem

The Rybczynski theorem states that *at given commodity price*, if the endowment of some resources increases, the industry that uses that resource most intensively will increase its output, while the other industry reduces its output (Rybczynski, 1955). We examine whether this theorem remains valid in our model where the commodity price is endogenous.

Consider the autarky structure. Without loss of generality, suppose the capital endowment in country i (K_i) increases. If the content of the Rybczynski theorem holds true, then the capital-intensive X industry would expand, (i.e., $\partial x_i/\partial K_i > 0$), and the labor-intensive Y industry would shrink (i.e., $\partial y_i/\partial K_i < 0$). The differentiation of (8) with respect to K_i yields $\partial x_i/\partial K_i > 0$ and $\partial y_i/\partial K_i > 0$. This implies that part of the RY theorem does not hold when commodity price is endogenized.

Now look at structure XY. From (15), we have $\partial x_1/\partial L_1 > 0$, $\partial x_1/\partial L_2 = 0$, $\partial x_1/\partial K_1 > 0$, $\partial x_1/\partial K_2 = 0$, $\partial y_2/\partial L_1 = 0$, $\partial y_2/\partial K_1 = 0$, $\partial y_2/\partial L_2 > 0$, $\partial y_2/\partial K_2 > 0$. These are clearly inconsistent with the RY theorem. It can also be shown that there exists parameter subspace such that $\partial x_1/\partial L_1 > 0$, and $\partial x_1/\partial K_1 > 0$ in the structure $(XY)_x(XY)_y$. It is not difficult to find an example that a change in an endowment parameter causes a shift of general equilibrium from a structure to another and generates changes in outputs that are inconsistent with the RY theorem. Hence, we conclude:

Proposition 7 *The RY theorem cannot survive the test of endogenization of commodity prices. With endogenous commodity price, the output of both industries can increase in response to an increase in the endowment of some resource. The RY theorem cannot survive the test of inframarginal comparative statics analysis either.*

6. Conclusion

In this paper, we have developed a HO model with endogenous prices of goods and factors and conducted an inframarginal comparative statics analysis of general equilibrium to check four core theorems in trade theory: the HO theorem, factor equalization theorem, the SS theorem, and the RY theorem. The result is not that positive. Except for the HO theorem, other theorems do not always hold. Specifically, the HO theorem holds in all trade structures, but it needs to be refined to accommodate comparative technological advantage. The SS theorem holds only within the diversification cone when changes in prices are caused by changes in taste or endowment parameters. It may not hold if the changes are caused by production parameters, even if technical difference between countries is absent. It holds if the general equilibrium jumps from autarky to the interior structure with trade but does not hold if it jumps to the corner equilibrium with complete specialization of each country. It may not hold for other jumps of general equilibrium between structures. The RY theorem does not always hold either.

This somewhat "unpleasant" result may have a lot to do with an important difference between the HO model and other general equilibrium models. In most general equilibrium models, there is a dichotomy between pure consumers and producers (firms). Each consumer does not produce and therefore has to buy all goods that he consumes from the market. Hence, with the assumption of strictly convex preferences and convex production sets (or production sets can be convexified), corner solution is exceptional. In contrast, in the HO model, each country is a consumer as well as a producer. It can be completely self-sufficient without international trade, or it can choose the range of its production activities and rely on international trade. In other words, a country can choose its size and pattern of network of transactions. This implies that there are many possible corner solutions, all of which should be considered in a general equilibrium analysis.

Our exercise has highlighted the limitations of two types of partial equilibrium analysis. Type I of partial equilibrium analysis is to assume exogenous prices of goods (or factors), then investigate changes in prices of factors (or output) in response to changes in prices of goods (or endowment parameters). This is a partial equilibrium analysis since in general equilibrium all prices are endogenized. Such a partial equilibrium analysis could be misleading since the model is not closed and some interdependencies and feedback loops between prices and quantities, between consumption and production, between the markets for goods and factors, and between different agents' self-interested behaviors are ignored. Type II of partial equilibrium analysis is confined within the interior structure, ignoring corner structures. It does not partition the parameter space into subspaces within each of which a particular interior or corner equilibrium is the general equilibrium; and it totally ignores the implications of the partition of the parameter space for comparative statics. Type II of partial equilibrium analysis also ignores discontinuous jumps of general equilibrium between different trade patterns.

The two types of partial equilibrium analyses differ from Marshallian partial equilibrium analysis which focuses on only one market. The two types of partial equilibrium analyses consider all markets and some (but not all) interactions between the markets. Possibly because in many cases the two types of partial equilibrium analyses provide a fuller picture than the Marshallian partial equilibrium analysis, their limitations have not received much attention, while the shortcomings of the Marshallian analysis is well-known.

We are cautious about implications of our results for policy purposes since our results are obtained from a specific model. If we change the functional forms, the results may change too. However, the value of our exercise lies that it has demonstrated that obsession with very general results can have high costs. As indicated in everything possible theorem (Sonnenschein, 1973, Mantel, 1974, and Debreu, 1974), the comparative statics of general equilibrium that are as general as the compensated demand law (comparative statics of decisions) are impossible to obtain in the absence of explicit specification of models. The comparative statics of general equilibrium, which are the main sources of the explaining power of economics, are model structure specific, functional form specific, and parameter value specific. Thus there is good reason to doubt the validity of some very general comparative statics results of general equilibrium in the absence of explicit specification of models. We should be very cautious when we make policy recommendations on the basis of some comparative statics of general equilibrium, which are valid only for a specific model structure, for specific functional forms, and for a specific subspace of parameter values.

In the current model with no transaction costs, autarky never occurs at general equilibrium. Hence, a jump of equilibrium from autarky to another structure is ad hoc. An extension of our model can explicitly incorporate transaction costs. With transaction costs incorporated, a jump from the interior equilibrium in autarky to a structure with trade can be endogenized. Further research can also introduce increasing returns, which no doubt will enrich the implications of the model, but which is likely to make the model more difficult to manage.

Reference

Bowen, Harry P., Leamer, Edward E. and Sveikauskas, Leo (1987), "Multicountry, Multifactor Tests of the Factor Abundance Theory," *American Economic Review*, 77(5), 791-809.

Debreu, G. (1974), Excess Demand Functions. *Journal of Mathematical Economics*, 1, 15-21.

Deardorff, Alan and Robert Stern eds. (1994), *The Stolper-Samuelson Theorem*, Ann Arbor, University of Michigan Press.

Dixit, A. K. and Norman, V. (1980), *Theory of International Trade*, James Nisbet & Co. Ltd and Cambridge University Press.

Grossman, G. M. and Levinsohn, J. (1989), "Import Competition and the Stock Market Return to Capital," *American Economic Review*, 79, 1065-87.

Heckscher, E. (1919), "The Effect of Foreign Trade on the Distribution of Income," *Economic Tidskrift*, 21, 497-512.

Jones, Ronald (1965), "The Structure of Simple General Equilibrium Models," *Journal of Political Economy*, 73, 557-72.

Lerner, A. P.(1952), "Factor Prices and International Trade," *Economica*, 19(1), 1-15.

Leontief, Wassily W. (1956), "Domestic Production and Foreign Trade: the American Capital Position Re-examined," in *Readings in International Economics*, edited by Richard E. Caves and Harry G. Johnson. Homewood: Irwin, 1968.

Mantel, R. (1974), On the Characterization of Aggregate Excess Demand. *Journal of Economic Theory*, 7, 348-53.

McKenzie, L. W. (1955), "Equality of Factor Prices in World Trade," *Econometrica*, 23(3), 239-257.

Ohlin, B. (1933), *Interreginal and International Trade*, Cambridge, Harvard University Press.

Samuelson, P.A. (1948), "International Trade and the Equalisation of Factor Prices," *Economic Journal*, 58(230), 163-84.

Samuelson, P. A. (1953), "Prices of Factors and Goods in General Equilibrium", *Review of Economic Studies*, 21(1), 1-20.

Sonnenschein, H. (1973), Do Walras' identity and continuity characterize the class of community excess demand functions? *Journal of Economic Theory*, 6, 345-54.

Stolper, Wolfgang and Sammuelson, Paul (1941), "Protection and Real Wages," *Review of Economic Studies*, 9, 58-73.

Trefler, Daniel (1993), "International Factor Price Differences: Leontief was Right!" *Journal of Political Economy*, 10(6), 961-87.

Trefler, Daniel (1995), "The Case of the Missing Trading and Other Mysteries," American Economic Review, 85(5), 1029-1046.

Rybczynski, T. M. (1955), "Factor Endowments and Relative Commodity Prices," *Economica*, 22, 336-41.

MONASH UNIVERSITY, DEPARTMENT OF ECONOMICS, SEMINAR PAPERS

18/97 Xiaokai Yang and Wenli Cheng, An Inframarginal Analysis of the Heckscher-Olin Model.
17/97 Jamie R. Haag, Capital Market Imperfections and The Regional Transmission of Monetary Policy.
16/97 Russell Smyth, The Township and Village Enterprise Sector As A Specific Example of Regionalism -Some General Lessons For Socialist Transformation.
15/97 Satish Chand, Trade Liberalisation and Productivity Growth: Time-Series Evidence From Australian Manufacturing.
14/97 Prasad V. Bidarkota and J. Huston McCulloch, Real Stock Returns: Non-Normality, Seasonality, and Volatility Persistence, But No Predictability.
13/97 Trond Petersen, Eva M. Meyerson and Vemund Snartland, Are Female Workers Less Productive Than Male Workers? Productivity and the Gender Wage Gap.
12/97 Yimin Zhao and Yew Kwang Ng, Output Collapse in Transitional Economies: A Possible Explanation Using a Two-sector Mesoeconomic Model.
11/97 Keith Jakee and Martin Kenneally, Do Economists Lead or Lag? Some Evidence from Citations to the Calculation Debate.
10/97 Ross S. Guest and Ian M. McDonald, The Socially Optimal Level of Saving in Australia, 1960-61 to 1994-95.
9/97 Takutoshi Inoue, W.S. Jevons and his Japanese Students.
8/97 Been-Lon Chen, Chien-fu Jeff Lin and Xiaokai Yang, Empirical Evidences for the Endogenous Growth Generated by Evolution in Division Labor.
7/97 Terrie L. Walmsley, Long Run Simulations of GTAP: Initial Results for APEC in a Horridge-Style Closure.
6/97 Fang Li, An Empirical Analysis of the Government Securities Market in China.
5/97 Sau-Him Paul Lau, Aggregate Pattern of Time-dependent Adjustment Rules, II: Strategic Complementarity and Endogenous Nonsynchronization
4/97 E. Kwan Choi and Sugata Marjit, Tariff-Quota Non-Equivalence in a Competitive General Equilibrium Framework. (Revised)
3/97 E. Kwan Choi and Sugata Marjit, Tariff-Quota Non-Equivalence In a Competitive General Equilibrium Framework
2/97 George Fane, APEC: Much Ado About Nothing
1/97 Poh Lee, The Allocation of Forest Functions and Conflicts: A Case Study on Sarawak, Malaysia

11/96 Wenli Cheng and Haiyang Xu, The Efficiency Wage Hypothesis: A Mesoeconomic Analysis.
10/96 Monchi Lio, Uncertainty, Insurance and the Division of Labor.
9/96 Monchi Lio, Increasing Returns, Specialization, and the Theory of the Allocation of Time.
8/96 Wenli Cheng and Xiaokai Yang, An Infra-marginal Analysis of the Ricardian Model.
7/96 Sandra Denis, Workplace Health and Safety: Some Economic Implications.
6/96 Steve Dowrick and John Quiggin, True Measures of GDP and Convergence.
5/96 Michael Bradfield, Raising Prices when Demand is Falling: Who's Kinky Now, Business or Economics?
4/96 Kerry Anne McGeary, The Effect of Preventive Care on the Demand for Health Services in a Developing Country
3/96 Robert Rice, The Urban Informal Sector: Theory, Characteristics, and Growth from 1980 to 1990 with a Special Emphasis on Indonesia
2/96 J_rg Niehans, Adam Smith and the Welfare Cost of Optimism
1/96 Yew-Kwang Ng, The Paradox of Interpersonal Cardinal Utility: A Proposed Solution

26/95 J. Boymal, The Economics of Alcohol Addiction
25/95 N. Haralambopoulos, The Monetary Transmission Mechanism
24/95 X. Yang and S. Ng, Specialisation and Division of Labour: A Survey
23/95 Wenli Cheng and Yew-Kwang Ng, Intra-Firm Branch Competition for a Monopolist
22/95 Joel M Guttman, Rational Actors, Tit-for-Tat Types, and the Evolution of Cooperation
21/95 Stephen King & Rohan Pitchford, Economic Theories of Privatisation and Corporatisation
20/95 Anne O. Krueger, Free Trade Agreements Versus Customs Unions.
19/95 Andrew Comber, Estimates of the Elasticity of Substitution between Imported and Domestically Produced Goods in New Zealand.
18/95 Peter Hartley and Chris Jones, Asset Demands of Heterogeneous Consumers with Uninsurable Idiosyncratic Risk.
17/95 Yew-Kwang Ng, Non-Neutrality of Money Under Non-Perfect Competition: Why Do Economists Fail to See the Possibility?
16/95 Yew-Kwang Ng, Relative-Income and Diamond Effects: A Case for Burden-Free Taxes and Higher Public Expenditures.
15/95 Wen Mei, Per Capita Resource, Division of Labor, and Productivity.
14/95 Deborah A. Cobb-Clark, Clinton R. Shiells & B. Lindsay Lowell, Immigration Reform: The Effects of Employer Sanctions and Legalization on Wages.
13/95 Murray C. Kemp & Hans-Werner Sinn, A Simple Model of Privately Profitable But Socially Harmful Speculation.
12/95 Harold O. Fried, Suthathip Yaisawarng, Hospital Mergers and Efficiency.
11/95 Yew-Kwang Ng, From Separability to Unweighted Sum: A Case for Utilitarianism.
10/95 Gerald T. Garvey, Michael S. McCorry, Peter L. Swan, Stock Market Liquidity and Optimal Management Compensation: Theory and Evidence
9/95 Siang Ng, Specialisation, Trade, and Growth
8/95 X Yang, Economies of Specialization and Downward Sloping Supply Curves: An Infra-Marginal Analysis

7/95 Viv Hall, Economic Growth Performance and New Zealand's Economic Reforms
6/95 Farzana Naqvi, Social Welfare Effects of Taxes on Energy Products in Pakistan: A Computable General Equilibrium Approach
5/95 Mei Wen, An Analytical Framework of Producer-Consumers, Economies of Specialization and Transaction Costs
4/95 Marc Lavoie, Interest Rates in Post-Keynesian Models of Growth and Distribution
3/95 Marcus Berliant and Miguel Gouveia, On the Political Economy of Income Taxation
2/95 Russell Smyth, Estimating the Deterrent Effect of Punishment using New South Wales Local Court Data
1/95 Rod Maddock, The Access Regime and Evaluation of the Hilmer Report

30/94 Barry A. Goss and S. Gulay Avsar, Price Determination in the Australian (Non-Storble) Line Cattle Market
29/94 D.K. Fausten & Robert D. Brooks, The Balancing Item in Australian Balance of Payments Accounts: An Impressionistic View.
28/94 Sugata Marjit & Hamid Beladi, A Game Theoretic Analysis of South-South Cooperation.
27/94 Sugata Marjit, Transferring Personalised Knowledge or Guru's Dilemma.
26/94 Richard H. Snape, Globalisation and Internationalisation of the Australian Economy: Trade and Trade Policy.
25/94 Eric O'N Fisher, Crowding Out in a Model of Endogenous Growth.
24/94 Yew-Kwang Ng, Ranking Utility Streams of Infinite Length: the Immunity of Utilitarianism from some Recent Attacks.
23/94 Krueger, Anne O & Roderick Duncan, The Political Economy of Controls: Complexity.
22/94 Xiangkang Yin, A Micro-Macroeconomic Analysis of the Chinese Economy with Imperfect Competition.
21/94 Brendon Riches, Price Wars and Petroleum: A 'structure Conduct' Analysis.
20/94 Xiaokai Yang, An Equilibrium Model of Hierarchy.
19/94 Ronald W. Jones & Tapan Mitra, Share Ribs and Income Distribution.
18/94 Dagobert Brito & Peter Hartley, In Defence of Contributory Negligence.
17/94 Michihiro Ohyama and Ronald W. Jones, Technology Choice, Overtaking and Comparative Advantage.
16/94 Xiaokai Yang, Two Notes on New Growth Models.
15/94 Xiaokai Yang, The Nature of Capital, Investment, and Saving.
14/94 Walter Y. Oi, Towards a Theory of the Retail Firm.
13/94 Matthew W. Peter & George Verikios, Quantifying the Effect of Immigration on Economic Welfare in Australia.
12/94 Xiaokai Yang, A Theory of the Socialist Economic System and the Differences Between the Economic Reforms in China and Russia.
11/94 Xiaokai Yang, Learning Through the Division of Labour and Interrelationship between Trade and Productivity Progress.
10/94 Sugata Marjit & Heling Shi, Non-Cooperative, Cooperative and Delegative R & D
9/94 Richard H. Snape, Which Regional Trade Agreement?
8/94 Richard H. Snape, Trade and Multilateral Trade Agreements: Effects on the Global Environment
7/94 Barry A. Goss & Jane M. Fry, Expectations and Forecasting in the US Dollar/British Pound Market.
6/94 Ronald W. Jones & Sugata Marjit, Labour-Market Aspects of Enclave-Led Growth.
5/94 David Henderson, Economic Liberalism: Australia in an International Setting.
4/94 Reinhard Tietz, Simplification and Complexity: The Dilemma of Economic Theory.
3/94 Ian Wills & Jane Harris, Government Versus Private Quality Assurance for Australian Food Exports.
2/94 Yew-Kwang, Ng & Jianguo Wang, A Case for Cardinal Utility and Non-Arbitrary Choice of Commodity Units.
1/94 Yew-Kwang, Ng, Why Does the Real Economy Adjust Sluggishly? Interfirm Macroeconomic Externality and Continuum of Quasi-Equilibria.

12/93 Yew-Kwang, Ng, Towards Welfare Biology: Evolutionary Economics of Animal Consciousness and Suffering.
11/93 Yew-Kwang Ng, The Necessity, Feasibility and Adequacy of Cost-Benefit Analysis Where Life or Other "Non-Economic" Factors are Concerned.
10/93 John Freebairn, Microeconomic Reform: Progress and Effectiveness.
9/93 K. Abayasiri-Silva & G.M. Richards, Non-Neutrality of Money in Imperfectly Competitive Macroeconomic Models.
8/93 Xiaokai Yang, Economic Organisms and Application of Topology and Graph Theory in Economics.
7/93 Dietrich K. Fausten & Sugata Marjit, The Persistence of International Real Interest Differentials in the Presence of Perfect Financial Arbitrage.
6/93 Barry A. Goss & S. Gulay Avsar, A Simultaneous, Rational Expectations Model of the Australian Dollar/U.S. Dollar Market.
5/93 Xiaokai Yang & Robert Rice, An Equilibrium Model Endogenizing the Emergence of a Dual Structure Between the Urban and Rural Sectors.
4/93 Xiaokai Yang, An Expanded Dixit-Stiglitz Model Based on the Tradeoff Between Economies of Scale and Transaction Costs.
3/93 Sugata Marjit, On the Participation of Local Capital in a Foreign Enclave - a General Equilibrium Analysis **(published December 1993)**
2/93 Sugata Marjit & Hamid Beladi, Foreign Capital Accumulation and Welfare in a Small Economy: Does Employment Matter?
1/93 Dietrich K. Fausten, Exploratory Estimates of the Influence of Economic Activity on German Portfolio Investment Abroad.

17/92 Blair R. Comley, The Australian Film Industry as an Infant Industry.
16/92 Yew-Kwang Ng, Complex Niches Favour Rational Species.
15/92 Yew-Kwang Ng, Population Dynamics and Animal Welfare.
14/92 Yew-Kwang Ng, Happiness Surveys: Ways to Improve Accuracy and Comparability.