November 17, 2008

Trade Liberalization, Economic Growth, and Income Distribution in A Multiple-cone Neoclassical Growth Model*

Kozo Kiyota†

Faculty of Business Administration, Yokohama National University

Abstract

The empirical literature on trade liberalization reflects two puzzles. First, the effect of trade liberalization on economic growth is ambiguous. Second, the effect of trade liberalization by developing countries on their income distribution is also ambiguous. This paper attempts to explain these two puzzles at the same time, based on a multiple-cone neoclassical growth model. The model shows that countries that are labor abundant in a global sense may see a rise in income inequality and a decline in per-capita GDP and per-capita consumption with liberalization if they are capital abundant in a local sense. The results suggest that two puzzles can be explained by the existence of global and local factor abundances.

Key words: Trade Liberalization; Medium-run Growth; Income Distribution; Multiple-cone Model; Factor Price Equalization
JEL classification code: F1, O41

*Special thanks to Alan Deardorff and Robert Stern for many fruitful discussions and comments on earlier versions of this paper. Thanks as well to seminar participants at Kobe University, GRIPS, and the Fall 2008 Midwest International Economics Meeting. The first draft of this paper was written while the author was visiting Gerald R. Ford School of Public Policy, University of Michigan, whose hospitality is gratefully acknowledged. Financial support from the Japan Society for the Promotion of Science (JSPS) 2006 Postdoctoral Fellowships for Research Abroad is gratefully acknowledged as well. The usual disclaimer applies.

†Address: Faculty of Business Administration, Yokohama National University, 79-4 Tokiwadai, Hodogaya, Yokohama 240-8501, Japan; Phone: +81-45-339-3770; Fax: +81-45-339-3707; E-mail: kiyota [at] ynu.ac.jp

1 Introduction

The empirical literature on trade liberalization reflects two puzzles. First, the effect of trade liberalization on economic growth is ambiguous. A number of theoretical studies such as Baldwin (1992) have argued that trade liberalization leads to dynamic gains from greater capital accumulation as well as static efficiency gains. This in turn implies that trade liberalization has a positive effect on economic growth.[1] Empirical studies, however, have found that this theoretical prediction does not necessarily hold. While some studies such as Edwards (1998) and Frankel and Romer (1999) stressed the positive relationship between trade liberalization and economic growth, other studies such as Rodriguez and Rodrik (2000) presented skeptical views about the methodologies and measurements used in previous studies.[2] Therefore, "the nature of the relationship between trade policy and economic growth remains very much an open question. The issue is far from having been settled on empirical grounds" (Rodriguez and Rodrik, 2000, p. 266).

Second, the effect of trade liberalization by developing countries on their income distribution is also ambiguous. The Stolper-Samuelson Theorem states that protection raises the real factor price of a country's scarce factor and lowers that of its abundant factor (Stolper and Samuelson, 1941). In other words, trade liberalization lowers the factor price of a country's scarce factor and increases that of its abundant factor. Given the fact that developing countries are generally more labor abundant than industrialized countries, the Stolper-Samuelson Theorem suggests that trade liberalization leads to a decrease in the rental-wage ratio with the increase in the price of a labor-intensive good and a decrease in the price of a capital-intensive good. Because the rental-wage ratio can be interpreted as a proxy for income inequality,[3] a decrease in the rental-wage ratio implies a decrease in income inequality between workers and the owners of capital. Contrary to the Stolper-Samuelson Theorem, however, there is "a large amount of evidence from several developing countries regarding their exposure to globalization and the parallel evolution of inequality" (Goldberg and Pavcnik, 2007, p. 39).[4]

To solve the first puzzle, a number of studies such as Wacziarg and Welch (2003) have tried to refine the empirical framework. However, little attention has been paid to the theoretical framework. The second puzzle is partly explained by Davis (1996), who focused on multiple factor price equalization (FPE) sets, or multiple cones of diversification. The key insight of his analysis is in the distinction between global and local factor abundances. Global factor abundance is defined as the relative factor abundance of countries in factor space. Local factor abundance is,

[1]Note that, in his critical review of Baldwin (1992), Mazumdar (1996) showed that whether or not trade liberalization lead to growth would depend upon the kind of good that is imported. Section 3 discusses Mazumdar's claim in more detail.

[2]Note that Edwards (1998) examined the effects of openness on total factor productivity growth while Frankel and Romer (1999) and Rodriguez and Rodrik (2000) examined the effects on per-capita gross domestic product (GDP) growth. Winters (2004) provides an excellent literature review of the issues.

[3]See, for example, Jones (1975) and Davis (1996). In order to make the interpretation clear, this paper uses the rental-wage ratio rather than the wage-rental ratio.

[4]According to Goldberg and Pavcnik (2007, p. 40), "while inequality has many different dimensions, all existing measures for inequality in developing countries seem to point to an increase in inequality."

on the other hand, defined as the relative factor abundance within the country's cone of diversification. Based on a static multiple-cone model, he found that trade liberalization could expand income inequality. However, his analysis lacks dynamic aspects. Therefore, the link between trade liberalization, economic growth, and income distribution is not clear and it is thus still an open question of how the link can be modeled comprehensively.

This paper attempts to explain these two puzzles at the same time, based on a multiple-cone neoclassical growth model. The model combines the elements of Davis's (1996) view of local factor abundance together with the elements of Deardorff's (2001) model of trade and growth. Following previous studies such as Mazumdar (1996, JPE), growth in this paper means medium-run growth rather than long-run growth. Therefore, an increase in per-capita GDP is interpreted as a positive effect of trade policy on medium-run economic growth.

Before starting, some terminological matters need to be clarified. That is, the model of this paper consists of industrialized countries and developing countries. The industrialized countries are capital abundant while the developing countries are labor abundant in a global sense. The developing countries are further divided into two groups. One includes locally capital-abundant developing countries that are labor abundant in a global sense but capital abundant in a local sense. The other includes locally labor-abundant developing countries that are labor abundant in both global and local senses. Table 1 summarizes the country classification.

=== Table 1 ===

Figure 1 illustrates the distinction between the global and local factor abundances, based on the Lerner diagram of a three-good two-cone model. Two factors are capital and labor. Three goods are labor-, middle-, and capital-intensive goods. Two cones are $[\tau_1, \tau_2]$ and $[\tau_3, \tau_4]$, where τ_j $(j = 1, ..., 4)$ represents capital-labor ratio and $\tau_1 < \tau_2 < \tau_3 < \tau_4$. Countries locate in the cone $[\tau_3, \tau_4]$ are more capital abundant than countries locate in the cone $[\tau_1, \tau_2]$. To simplify the discussion, assume that "the world is "even" in the sense that there are an equal number of factors and goods in each cone" (Schott, 2003, p. 689). To simplify the terminology, industrialized countries are referred to as high-income countries, locally capital-abundant countries as middle-income countries, and locally labor-abundant countries as low-income countries. Denote the factor endowments of an high-income country as E_H that locates in the cone $[\tau_3, \tau_4]$. Denote the factor endowments of middle- and low-income countries countries as E_M, and E_L, respectively. Both E_M and E_L locate in the cone $[\tau_1, \tau_2]$.

=== Figure 1 ===

The high-income country is globally capital abundant in the sense that it locates in the capital-abundant cone $[\tau_3, \tau_4]$ and thus it can produce the capital- as well as middle-intensive goods. On the other hand, the middle- and low-income countries are globally labor abundant in the sense that they locate in the labor-abundant cone $[\tau_1, \tau_2]$ and thus it can produce the labor- as well as middle-intensive goods. Note, however, that the middle-income country is relatively capital abundant while the low-income country is relatively labor abundant within the cone $[\tau_1, \tau_2]$. Therefore, the middle-income country is globally labor abundant but is locally capital abundant while the low-income country is labor abundant in both global and local sense. This distinction is explained in more detail in Section 3.

This paper focuses on the trade policy by developing countries to explain the two puzzles noted. The contribution of this paper is that it clarifies the effects of trade liberalization on income distribution, per-capita gross domestic product (GDP), and per-capita consumption that are not explored in previous studies. The model shows that countries that are labor abundant in a global sense may see a rise in income inequality and a decline in per-capita GDP and per-capita consumption with liberalization if they are capital abundant in a local sense. The two puzzles can therefore be attributable to the existence of multiple cones and the difference of factor abundance among countries within the same cone.

This paper is structured as follows. I first present a three-good two-cone Heckscher-Ohlin (HO) growth model in Section 2 and discuss some implications for income distribution, economic growth, and per-capita consumption. Section 3 introduces the concept of local factor abundance into the HO growth model and examines the effects of trade policy by a developing country. Concluding remarks are in Section 4.

2 Model

2.1 Setup

The two-good HO growth and trade model was first developed by Oniki and Uzawa (1965). Deardorff (1974) developed a simplified version based on a single-cone model, introducing a small open economy assumption. Deardorff (2001) further extended the analysis from a two-good to a multiple-good model, introducing multiple cones. Following Galor (1996) in which savings come from wage rather than total income, Deardorff (2001) showed that the multiple-cone model became consistent with the existence of multiple steady states. My paper builds upon Deardorff (2001).

This section focuses on the basic features of the model and discusses some implications for income distribution, per-capita GDP, and per-capita consumption. The implications of this section hold irrespective of whether developing countries are locally capital abundant or locally labor abundant. Therefore, this section focuses on the case of global factor abundance. The distinction between global and local factor abundances is introduced in Section 3.

Suppose that there are three goods (labor-intensive good Y_1, middle-intensive good Y_2, and capital-intensive good Y_3) and two factors (labor L and capital K). The capital intensities of the goods are $k_1 < k_2 < k_3$, where $k_i = K_i/L_i$. Assume that one of the three goods is classified as an investment good used for capital accumulation while the other two goods are classified as consumption goods used for consumption. However, the capital intensity of the investment good is unknown. Therefore, the labor-, middle-, or capital-intensive goods could be the investment good.

Denote total capital and labor in the economy as L and K. Denote the production function of industry $i(=1,2,3)$ as $Y_i = F_i(K_i, L_i)$, where $L_1 + L_2 + L_3 = L$ and $K_1 + K_2 + K_3 = K$. Let $p_i(> 0)$

denote the price of good Y_i. Assume that the production function of good i is linear homogeneous: $y_i = Y_i/L_i = F_i(K_i, L_i)/L_i = F_i(K_i/L_i, 1) = f_i(k_i)$. Assume that production functions have the standard properties of a neoclassical production function: $\lim_{k_i \to 0} f_i'(k_i) = \infty$, $\lim_{k_i \to \infty} f_i'(k_i) = 0$, $f_i'(k_i) > 0$, and $f_i''(k_i) < 0$.

Denote the nominal wage and nominal rental rate as $W(>0)$ and $R(>0)$, respectively. Assume that capital accumulation comes from savings S. Note that both savings and capital must be measured in the same units. If savings are measured differently from capital, savings and capital are not comparable directly. This in turn means that the price of the investment good p_I should be the numéraire. Let $\tilde{p}_i(= p_i/p_I)$ be the price of good Y_i normalized by the price of the investment good. Similarly, let $w(= W/p_I)$ and $r(= R/p_I)$ denote the wage and rental rate normalized by the price of the investment good. Let $\tilde{z}_i(= \tilde{p}_i y_i)$ denote the value of production per worker in industry i. Assume also that all markets are perfectly competitive and, thus, firms earn zero profit: $\tilde{p}_i y_i - w - r k_i = 0$.

Based on this setup, Deardorff (2001) showed that the relationship between the capital-labor ratio and sectoral output could be constructed as in Figure 2. The per-capita production functions $\tilde{z}_1$ and $\tilde{z}_2$ are connected by their common tangent AB. Similarly, the per-capita production functions $\tilde{z}_2$ and $\tilde{z}_3$ are connected by their common tangent CD.[5] Perpendiculars $A\tau_1$ and $B\tau_2$ are dropped from the points of tangency to the horizontal axis. Similarly, let $\tau_3(p_2, p_3)$ and $\tau_4(p_2, p_3)$ denote the capital-labor ratios dropped from the points of tangencies for $p_2 f_2(k)$ and $p_3 f_3(k)$ to the horizontal axis. Capital-labor ratios $\tau_1, \ldots \tau_4$ are referred to as "knots." Both the labor- and middle-intensive goods are produced in the interval $[\tau_1, \tau_2]$ while both the middle- and capital-intensive goods are produced in the interval $[\tau_3, \tau_4]$. The interval is called an FPE set, which is analogous to the cone of diversification, or "cone" in the Lerner Diagram.

=== Figure 2 ===

Consider a small open economy where the price of goods is exogenously given and fixed. This in turn implies that $\tau_i \ \forall i$ are also fixed. Maximized per-capita GDP of this economy is described as envelope $OABCDE$ in Figure 3. Denote this per-capita GDP function as $z(k) = (\tilde{p}_1 Y_1 + \tilde{p}_2 Y_2 + \tilde{p}_3 Y_3)/L$:

$$z(k) = \begin{cases} \tilde{p}_1 f_1(k) & \text{if} \quad 0 \le k < \tau_1; \\ \bar{w}_1 + \bar{r}_1 k & \text{if} \quad \tau_1 \le k \le \tau_2; \\ \tilde{p}_2 f_2(k) & \text{if} \quad \tau_2 < k < \tau_3; \\ \bar{w}_2 + \bar{r}_2 k & \text{if} \quad \tau_3 \le k \le \tau_4; \\ \tilde{p}_3 f_3(k) & \text{if} \quad k > \tau_4, \end{cases} \tag{1}$$

where $\bar{w}_1$ and $\bar{r}_1$ are the wage and rental rate within the cone between τ_1 and τ_2 and thus constant. Similarly, $\bar{w}_2$ and $\bar{r}_2$ are the wage and rental rates within the cone between τ_3 and τ_4 and also constant.

[5] To simplify the discussion, this paper excludes the case of no common tangent or multiple common tangents, possibly because of factor-intensity reversal.

Some of the important properties of this model are summarized as follows. First, the slope of the common tangent indicates the rental rate r while its intercept indicates the wage w.[6] Therefore, factor prices are written as follows:

$$r(k) = \frac{\partial z(k)}{\partial k} = \begin{cases} \tilde{p}_1 f_1'(k) & \text{if} \quad 0 \leq k < \tau_1; \\ \bar{r}_1 = \tilde{p}_1 f_1'(\tau_1) = \tilde{p}_2 f_2'(\tau_2) & \text{if} \quad \tau_1 \leq k \leq \tau_2; \\ \tilde{p}_2 f_2'(k) & \text{if} \quad \tau_2 < k < \tau_3; \\ \bar{r}_2 = \tilde{p}_2 f_2'(\tau_3) = \tilde{p}_3 f_3'(\tau_4) & \text{if} \quad \tau_3 \leq k \leq \tau_4; \\ \tilde{p}_3 f_3'(k) & \text{if} \quad k > \tau_4; \end{cases} \tag{2}$$

and

$$w(k) = \begin{cases} \tilde{p}_1 f_1(k) - \tilde{p}_1 k f_1'(k) & \text{if} \quad 0 \leq k < \tau_1; \\ \bar{w}_1 = \tilde{p}_1 f_1(\tau_1) - \tilde{p}_1 \tau_1 f_1'(\tau_1) = \tilde{p}_2 f_2(\tau_2) - \tilde{p}_2 \tau_2 f_2'(\tau_2) & \text{if} \quad \tau_1 \leq k \leq \tau_2; \\ \tilde{p}_2 f_2(k) - \tilde{p}_2 k f_2'(k) & \text{if} \quad \tau_2 < k < \tau_3; \\ \bar{w}_2 = \tilde{p}_2 f_2(\tau_3) - \tilde{p}_2 \tau_3 f_2'(\tau_3) = \tilde{p}_3 f_3(\tau_4) - \tilde{p}_3 \tau_4 f_3'(\tau_4) & \text{if} \quad \tau_3 \leq k \leq \tau_4; \\ \tilde{p}_3 f_3(k) - \tilde{p}_3 k f_3'(k) & \text{if} \quad k > \tau_4. \end{cases} \tag{3}$$

Second, per-capita GDP is an increasing function of k. From equation (2), we have:

$$\frac{\partial z(k)}{\partial k} = r(k) > 0. \tag{4}$$

That is, as an economy accumulates capital (relative to labor), per-capita GDP also increases.

Third, from equations (2) and (3), factor prices take the following relationships:

$$\frac{\partial w(k)}{\partial k} \begin{cases} > 0 & \text{if } k \text{ locates outside the cones;} \\ = 0 & \text{if } k \text{ locates inside the cones;} \end{cases} \tag{5}$$

and

$$\frac{\partial r(k)}{\partial k} \begin{cases} < 0 & \text{if } k \text{ locates outside the cones;} \\ = 0 & \text{if } k \text{ locates inside the cones.} \end{cases} \tag{6}$$

Let $\omega(k) = r(k)/w(k)$ denote the rental-wage ratio, which is interpreted as a proxy for income inequality. Equations (5) and (6) imply the following general motonic relationship between rental-wage ratio and capital-labor ratio (Jones, 1974):

$$\frac{\partial \omega(k)}{\partial k} \begin{cases} < 0 & \text{if } k \text{ locates outside the cones;} \\ = 0 & \text{if } k \text{ locates inside the cones.} \end{cases} \tag{7}$$

If an economy locates outside the cones, capital accumulation raises wage, lowers rental ratio,

[6] See Hahn and Matthews (1964) for the proof.

and therefore lowers income inequality. On the other hand, if the economy locates inside the cones, capital accumulation has no effect on factor prices and income inequality.

2.2 Growth in the small open economy

Now assume that population growth is $\dot{L} = nL(> 0)$, where $\dot{L} = dL/dt$. Assume that capital accumulation is $\dot{K} = S - \delta K$, where $\dot{K} = dK/dt$, S is savings, and $\delta(> 0)$ is the depreciation rate. Suppose that savings come from the wage: $S = swL$, where s $(0 < s \leq 1)$ is the savings rate.[7] Savings are equal to the demand for the investment good that is used for capital accumulation. The rest of the income is used for the consumption goods. The dynamics of the capital-labor ratio are written as:

$$\dot{k} = S/L - (n+\delta)k = sw(k) - (n+\delta)k \quad \text{or} \quad \frac{\dot{k}}{k} = s\frac{w(k)}{k} - (n+\delta). \tag{8}$$

Let k^* denote the capital-labor ratio at the steady state (i.e., $\dot{k} = 0$).

Based on this setup, Deardorff (2001) has provided a geometric explanation that developing countries converge to a low steady state while industrialized countries converge to a high steady state, which is shown in Figure 3. If the $(n+\delta)k$ line crosses the wage curve inside the two cones, there exist three steady states: k_1^*, k_2^*, and k_3^*.[8] If the initial endowment of an economy is in the interval $(0, k_2^*)$, the economy converges to a low steady state k_1^*. Therefore, its wage and per-capita GDP will be $\bar{w}_1$ and z_1^*. If, on the other hand, the initial endowment of an economy is greater than k_2^*, the economy converges to a high steady state k_3^*. Its wage and per-capita GDP will be $\bar{w}_2$ and z_3^*, respectively. Because k_2^* is unstable equilibrium, it is not examined in this paper.

=== Figure 3 ===

Note that the failure of a single FPE set is regarded as one of the important reasons why the HO model sometimes performs poorly in empirical analysis (e.g., Davis, Weinstein, Bradford, and Shimpo (1997)). The present paper thus does not assume that all countries are in a single FPE set. In other words, like Figure 3, I consider the case where some countries are in a low steady state while others are in a high steady state. Countries in a high steady state k_3^* are referred to as industrialized countries because they have high per-capita GDP z_3^*. Similarly, countries in a low steady state k_1^* are referred to as developing countries because they have low per-capita GDP z_1^*.

[7]This assumption was introduced by Galor (1996) in order to explain the existence of multiple steady states and extended by Deardorff (2001) to incorporate international trade. Overlapping generations can be one possible justification for this assumption. For more detail, see Deardorff (2001).

[8]The multiple equilibria arise because savings come from wages rather than income. If savings are proportional to income, the per-capita savings curve is a proportional downward shift of the per-capita GDP function. Because of the concavity of the GDP function, like in the Solow one-sector model, the savings curve crosses the wage curve only once. With Galor's assumption of savings out of wages, the wage curve becomes constant within cones, which causes the multiple crosses with the $(n+\delta)k$ line. It is also possible to obtain multiple equilibria from the savings out of the rental rate. Note, however, that in this case the savings curve will be a decreasing function of capital accumulation.

This paper focuses on countries whose capital-labor ratios locate within the cones (i.e., incomplete specialization: $\tau_1 \leq k^* \leq \tau_2$ or $\tau_3 \leq k^* \leq \tau_4$). From equations (3) and (8),

$$s\bar{w}_j - (n+\delta)k^* = 0 \qquad j = 1,2. \tag{9}$$

Therefore,

$$\frac{\partial k^*}{\partial s} = \frac{\bar{w}_j}{n+\delta} > 0 \qquad j = 1,2. \tag{10}$$

Savings have positive effects on capital accumulation if the economy locates inside one of the cones. Let c^* denote per-capita consumption at the steady state. Because the income is used either for consumption or savings:

$$c^*(k^*) = z(k^*) - S/L = z(k^*) - (n+\delta)k^*. \tag{11}$$

This in turn means

$$\frac{\partial c^*(k^*)}{\partial k^*} = \frac{\partial z(k^*)}{\partial k^*} - (n+\delta) = \bar{r}_j - (n+\delta) \begin{cases} > 0 & \text{if} \quad \bar{r}_j > n+\delta; \\ = 0 & \text{if} \quad \bar{r}_j = n+\delta; \\ < 0 & \text{if} \quad \bar{r}_j < n+\delta \end{cases} \quad j = 1,2. \tag{12}$$

The relationship between steady-state per-capita consumption and capital-labor ratio depends upon the relationship between $\bar{r}_j$ and $n+\delta$.

2.3 Trade patterns

Assume that the preferences of the economy are homothetic. Let d_i and t_i denote the value of per-capita domestic demand for good i (either a consumption good or an investment good) and the net export of good i, respectively: $t_i = \tilde{z}_i - d_i$. Assume that trade is balanced: $t_1 + t_2 + t_3 = 0$. The per-capita net export of the consumption good is $t_i = \tilde{z}_i - c_i$ while that of the investment good is $t_i = \tilde{z}_i - S/L$.

Deardorff (2000) showed that trade patterns for the three-good two-cone model can be presented as in Figure 4. The steady state of developing countries locates inside the cone $[\tau_1, \tau_2]$ and, therefore, these countries export the labor-intensive good and import the capital-intensive good. The steady state of industrialized countries locates inside the cone $[\tau_3, \tau_4]$ and, therefore, they export the capital-intensive good and import the labor-intensive good. Whether the middle-intensive good is exported by industrialized or developing countries depends upon their steady-state capital-labor ratios.

=== Figure 4 ===

2.4 Changes in the price of goods

For a small open economy, a protective tariff causes a change in the domestic price of imports. To examine the effects of trade policy, therefore, it is important to clarify the effects of price changes on the steady state. Because developing countries are not able to produce the capital-intensive good, the changes in its price do not have any effects on the domestic prices of the labor- and middle-intensive goods and factor prices in developing countries. The following analysis thus examines the changes in the prices of the labor- and middle-intensive goods.

Note that Uzawa (1961) found that if the investment good sector was more capital intensive than the consumption good sector, the steady state could be unstable in the sense that initial capital-labor ratio may not converge to the steady-state capital-labor ratio or there exist multiple steady-state capital-labor ratios. However, this paper would not assume the capital intensity of the investment good to examine multiple equilibria.

Suppose that the price of the middle-intensive good increases, holding the price of the labor- and capital-intensive goods constant. Assume that this increase is not large enough to cause a single FPE in the world. In other words, the world consists of two FPE sets before and after the change in the price. Regardless of whether or not the labor-(or capital-)intensive good is the investment good, however, the following lemmas are obtained at the steady state.

LEMMA 1: *An increase in the price of the middle-intensive good decreases per-capita GDP and increases income inequality for developing countries.*
PROOF. See Appendix A1.

LEMMA 2: *An increase in the price of the middle-intensive good 1) decreases per-capita consumption if $\bar{r}_1 > n+\delta$; 2) increases if $\bar{r}_1 < n+\delta$; and 3) has no effect if $\bar{r}_1 = n+\delta$ for developing countries.*
PROOF. See Appendix A1.

Next, suppose that the price of the labor-intensive good increases, holding the price of the middle- and capital-intensive goods constant. Similar to the case of the price change in the middle-intensive good, the following lemmas are obtained at the steady state.

LEMMA 3: *An increase in the price of the labor-intensive good increases per-capita GDP and decreases income inequality for developing countries.*
PROOF. See Appendix A2.

LEMMA 4: *An increase in the price of the labor-intensive good 1) increases per-capita consumption if $\bar{r}_1 > n+\delta$; 2) decreases if $\bar{r}_1 < n+\delta$; and 3) has no effect if $\bar{r}_1 = n+\delta$ for developing countries.*
PROOF. See Appendix A2.

3 Trade and Trade Policy

3.1 Local factor abundance and trade patterns

This section introduces the local factor abundance into the model. As was dicussed in Section 1, the local factor abundance means that developing countries locate in the same cone but have different steady-state capital-labor ratios because of, for example, different savings rate. Suppose that developing countries are divided into two groups. One group has a high savings rate. Countries in this group have a relatively high steady-state capital-labor ratio (i.e., locally capital abundant) and, therefore, have a relatively high steady-state per-capita GDP among developing countries. The other group has a low savings rate. Countries in this group have a relatively low steady-state capital-labor ratio (i.e., locally labor abundant) and, therefore, have a relatively low steady-state per-capita GDP among developing countries.

To simplify the terminology, industrialized countries are referred to as high-income countries. The locally capital-abundant countries are referred to as middle-income countries. The locally labor-abundant countries are referred to as low-income countries. The classification of countries is summarized in Table 1. Denote the savings rates of the high-, middle-, and low-income countries as s_H, s_M, and s_L, respectively. Denote the steady-state capital-labor ratios of the high-, middle-, and low-income countries as k_H^*, k_M^*, and k_L^*, respectively. For analytical simplicity, assume that the high- and middle-income countries have the same savings rates ($s_H = s_M = s$). This, in turn, means that the middle-income countries have the same behavioral parameters as the high-income countries.

Figure 5 presents the global and local factor abundances in the three-good two-cone model. Because savings come from wages, the high-income countries converge to the higher steady state k_H^* while the middle-income countries converge to the lower steady state k_M^*. In addition, due to the different savings rates, the low-income countries converge to further lower steady state k_L^*. These are dynamic equilibria analogous to the static equilibria in Figure 1.

=== Figure 5 ===

Assume that the difference in savings rates between the middle- and low-income countries is large enough to generate the different trade patterns between them. Figure 6 shows these patterns. The low-income countries export the labor-intensive good while they import the middle-intensive good and the capital-intensive good. The middle-income countries export the middle-intensive good while they import the labor-intensive good and the capital-intensive good. High-income countries export the capital-intensive good while they import the labor-intensive good and the middle-intensive good.

=== Figure 6 ===

3.2 Effects of trade policy

In this model, there are three types of protection by a developing country. First, the low- and middle-income countries restrict the imports of the capital-intensive good from the high-income countries. Second, the low-income countries restrict the imports of the middle-intensive good from the middle-income countries. Third, the middle-income countries restrict the imports of the labor-intensive good from the low-income countries. For analytical simplicity, following Deardorff (2001), assume that tariff revenue is used for consumption.[9]

[9]This assumption implies that the tariff revenue is not saved such that the savings are a constant fraction of the wages. If tariff revenue is used for savings, trade policy causes changes in prices and savings. The increase in

First, consider the case when the middle- and low-income countries restrict the imports of the capital-intensive good from the high-income countries. At the steady state, I obtain the following propositions.

PROPOSITION 1: *Protection by a low- or middle-income country on the imports of the capital-intensive good from high-income countries has no effect on its per-capita GDP if the capital-intensive good is the consumption good. On the other hand, protection lowers per-capita GDP if the capital-intensive good is the investment good.*
PROOF: See Appendix A3.

PROPOSITION 2: *Protection by a low- or middle-income country on the imports of the capital-intensive good from high-income countries has no effect on its per-capita consumption if a capital-intensive good is the consumption good. If the capital-intensive good is the investment good, per-capita consumption decreases when* $\bar{r}_1 > n+\delta$*; 2) increases when* $\bar{r}_1 < n+\delta$*; and 3) is constant when* $\bar{r}_1 = n+\delta$*.*
PROOF: See Appendix A3.

PROPOSITION 3: *Protection by a low- or middle-income country on the imports of the capital-intensive good from high-income countries has no effect on its income inequality irrespective of whether the capital-intensive good is the consumption good or the investment good.*
PROOF: See Appendix A3.

The intuition of Proposition 3 is that the price of the capital-intensive good p_3 either has no effect on the price of other goods or causes proportional increases in factor prices. The proportional increases do not affect the rental-wage ratio and, therefore, income inequality is not affected.

Note that trade liberalization has opposite effects from protection. Three findings stand out from Propositions 1-3. First, trade liberalization by a developing country is not harmful for its per-capita GDP growth. If the capital-intensive good is the investment good, trade liberalization raises per-capita GDP. If the capital-intensive good is not the investment good, trade liberalization has no effect on per-capita GDP.

Second, the effect of trade liberalization by a developing country on its consumption is ambiguous in the sense that the effect depends upon the relationship between $\bar{r}_1$ and $n+\delta$. If $\bar{r}_1 > n+\delta$, trade liberalization has a positive effect on per-capita consumption. However, if $\bar{r}_1 < n+\delta$, trade liberalization has a negative effect. This in turn implies that the effect on per-capita consumption is different from the effect on economic growth. If the capital-intensive good is the investment good and if $\bar{r}_1 > n+\delta$, trade liberalization raises per-capita GDP and per-capita consumption at the same time.

Finally, the Stolper-Samuelson effect does not necessarily work in the three-good two-cone neoclassical growth model. Because developing and industrialized countries operate in different cones, developing countries import the capital-intensive good that is produced outside the

savings causes the increase in per-capita GDP. The effect on consumption becomes more complex. However, income inequality is not affected by the changes in savings so long as the steady state locates in the cone of diversification.

developing countries' cone. Therefore, the increase in the price of the capital-intensive good either has no effect on the price of goods produced in the developing countries or causes proportional changes. The rental-wage ratio thus is not affected by the change in the price of the capital-intensive good.

Next, consider the case when a low-income country restricts imports from the middle-income countries. At the steady states, following propositions are obtained.

PROPOSITION 4: *Protection by a low-income country on the imports of the middle-intensive good from the middle-income countries raises its income inequality and lowers its per-capita GDP.*
PROOF: Protection by a low-income country on the imports of the middle-intensive good from the middle-income countries means increases in the price of the middle-intensive good in the low-income country. Proposition 4 then is immediately derived from Lemma 1. ■

PROPOSITION 5: *Protection by a low-income country on the imports of the middle-intensive good from the middle-income countries 1) lowers its per-capita consumption if* $\bar{r}_1 > n+\delta$*; 2) raises if* $\bar{r}_1 < n+\delta$*; and 3) has no effect if* $\bar{r}_1 = n+\delta$*.*
PROOF: Like the proof of Proposition 4, protection by a low-income country on the imports from the middle-income countries means an increase in the price of the middle-intensive good in the low-income country. Proposition 5 thus is immediately derived from Lemma 2. ■

Finally, consider the case when a middle-income country restricts imports from the low-income countries. At the steady state, following propositions are obtained.

PROPOSITION 6: *Protection by a middle-income country on the imports of the labor-intensive good from the low-income countries lowers its income inequality and raises its per-capita GDP.*
PROOF: Protection by a middle-income country on the imports of the labor-intensive good from the low-income countries means an increase in the price of the labor-intensive good in the middle-income country. Proposition 6 then is immediately derived from Lemma 3. ■

PROPOSITION 7: *Protection by a middle-income country on the imports of the labor-intensive good from the low-income countries 1) raises its per-capita consumption if* $\bar{r}_1 > n+\delta$*; 2) lowers if* $\bar{r}_1 < n+\delta$*; and 3) has no effect if* $\bar{r}_1 = n+\delta$*.*
PROOF: Like the proof of Proposition 6, protection by a middle-income country on the imports from low-income countries means an increase in the price of the labor-intensive good in the middle-income country. Proposition 7 thus is immediately derived from Lemma 4. ■

Figure 7 presents protection by a middle-income country on the imports of the labor-intensive good from the low-income countries. For illustrative purposes, Figure 7 assumes that s is unity so that the wage curve can be treated as the per-capita savings curve. An increase in p_1 causes the upward shift of the sectoral per-capita production function of the labor-intensive good $\tilde{z}_1$ if Y_1 is not the investment good. If Y_1 is the investment good, an increase in p_1 causes the downward shift of the sectoral per-capita production functions of the middle-intensive good $\tilde{z}_2$ and capital-intensive good $\tilde{z}_3$. In both cases, the increase in p_1 results in the upward shift of the wage curve from $\bar{w}_{1A}$ to $\bar{w}_{1B}$ while decreasing the rental rate from $\bar{r}_{1A}$ to $\bar{r}_{1B}$. This causes an increase in the steady-state capital-labor ratio from k_A^* to k_B^* and thus raises the per-capita GDP from z_A^* to z_B^*.

=== Figure 7 ===

Trade liberalization has opposite effects from protection. Therefore, Proposition 6 states that trade liberalization by a middle-income country on imports from the low-income countries *increases* its income inequality while *decreasing* its per-capita GDP. Moreover, Propositions 5 and 7 states that the effect of trade liberalization by a developing country (either the middle- or low-income country) on its per-capita consumption is ambiguous.

Note that Propositions 4-7 hold irrespective of whether the imported good is the consumption or investment good. This result is different from Mazumdar (1996) in which he showed that trade liberalization would increase growth only if it lowers the price of the investment good. This is because of the following two reasons. First, Mazumdar (1996) considered an economy in which factor intensities are the same between two sectors while this paper considers an economy in which factor intensities are different. Second, Mazumdar (1996) assumed that savings come from income rather than wages while the model in this paper assumed that savings come from wages. If two sectors have different factor intensities and savings come from wages, the change in the price of the consumption and investment goods have the same effects on factor prices regardless of the type of goods. The results of this paper do not depend upon what kinds of goods are imported.

Table 2 summarizes the effect of trade liberalization by a developing country. Propositions 1-7 together imply that the effect of trade liberalization by a developing country on economic growth is mixed, because of local factor abundance. Since cross-country regression studies do not take into account local factor abundance, the result explains the first empirical puzzle: the effect of trade liberalization on economic growth is ambiguous. The effect on income inequality is either nothing or negative. This explains the second empirical puzzle: the effect of trade liberalization by developing countries on their income distribution is also ambiguous.

=== Table 2 ===

Table 2 also indicates that these propositions are "robust" in the sense that the effects on income inequality depend upon neither the relationship between $\bar{r}_1$ and $n+\delta$ nor the kind of good: whether or not the import is a numéraire good. The effect on economic growth does not depend upon the relationship between $\bar{r}_1$ and $n+\delta$. It is thus not surprising that cross-country regressions generate ambiguous results. The existence of multiple cones and the difference of factor endowment within the same cone can be a possible explanation to solve these puzzles.

One may concern that these results are simply attributable to the difference of savings rate between the low-income and middle-income countries. However, these propositions can be obtained if the low-income countries have a higher population growth rate than the middle-income countries even when they have the same savings rate so long as the low income countries are small in the sense that their trade policy does not affect the prices of other countries.[10] The results thus do not necessarily depend upon the difference of savings rate. Rather, the existence of global and local factor abundances is an important factor.

4 Concluding Remarks

The empirical literature on trade liberalization reflects two puzzles. First, the effect of trade liberalization on economic growth is ambiguous. Second, the effect of trade liberalization by developing countries on their income distribution is also ambiguous. This paper attempts to explain the two puzzles at the same time, based on a multiple-cone neoclassical growth model.

My model combines the elements of Davis's (1996) view of static multiple equilibria together with the elements of Deardorff's (2001) model of trade and growth. I focus on new aspects that are not explored in these previous studies: income distribution, per-capita gross domestic product (GDP), and per-capita consumption. My model shows that if developing countries locate in different steady states within the same factor price equalization (FPE) set, or the same diversification cone, trade liberalization by a developing country could increase its income inequality while decreasing its per-capita GDP and per-capita consumption. My results suggest that the existence of multiple cones and the multiple steady states within the same cone, or the existence of global and local factor abundances, can be a possible explanation to solve these puzzles.

Note that the results of this paper do not necessarily support protection by a developing country because of the following two reasons. First, the effects of protection by the middle-income country on economic growth and income inequality hold only when the country continues to protect imports from the low-income countries. However, it is unlikely that such protection is allowed permanently. Second, while my paper clarifies the two empirical puzzles at the same time, I do not examine the welfare effects involved. In addition, identifying the local factor abundance of developing countries is an important empirical question. These issues will be explored in the next stage of my research.

References

Baldwin, Richard E. (1992) "Measurable Dynamic Gains from Trade," *Journal of Political Economy*, 100(1): 162-174.

Davis, Donald R. (1996) "Trade Liberalization and Income Distribution," NBER Working Paper, No. 5693.

Davis, Donald R., David E. Weinstein, Scott C. Bradford, and Kazushige Shimpo (1997) "Using International and Japanese Regional Data to Determine When the Factor Abundance Theory of Trade Works," *American Economic Review*, 87(3): 421-446.

[10]The difference in growth rates between countries is not addressed in many studies of trade and growth. An exception may be Deardorff (1994) who focused on different population growth rates and international capital mobility.

Deardorff, Alan V. (1973) "The Gains from Trade In and Out of Steady-State Growth," *Oxford Economic Papers*, 25(2): 173-191.

Deardorff, Alan V. (1974) "A Geometry of Growth and Trade," *Canadian Journal of Economics*, 7(2): 295-306.

Deardorff, Alan V. (1994) "Growth and International Investment with Diverging Populations," *Oxford Economic Papers*, 46(3): 477-491.

Deardorff, Alan V. (2000) "Patterns of Trade and Growth across Cones," *De Economist*, 148(2): 141-166.

Deardorff, Alan V. (2001) "Rich and Poor Countries in Neoclassical Trade and Growth," *Economic Journal*, 111(470): 277-294.

Edwards, Sebastian (1998) "Openess, Productivity and Growth: What Do We Really Know?" *Economic Journal*, 108(447): 383-398.

Frankel, Jeffrey A. and David Romer (1999) "Does Trade Cause Growth?" *American Economic Review*, 89(3): 379-399.

Galor, Oded (1996) "Convergence? Inferences from Theoretical Models," *Economic Journal*, 106(437): 1056-69.

Goldberg, Pinelopi Koujianou and Nina Pavcnik (2007) "Distributional Effects of Globalization in Developing Countries," *Journal of Economic Literature*, 45(1): 39-82.

Hahn, F.H. and R.C.O. Matthews (1964) "The Theory of Economic Growth: A Survey," *Economic Journal*, 74(296): 779-902.

Jones, Ronald W. (1974) "The Small Country in A Many-Commodity World," *Australian Economic Papers*, 13(23): 225-236.

Jones, Ronald W. (1975) "Income Distribution and Effective Protection in a Multi-Commodity Trade Model," *Journal of Economic Theory*, 11(1): 1-15.

Kiyota, Kozo (2007) "Paths of Development and Wage Variations," RSIE Discussion Paper, No. 572, University of Michigan.

Mazumdar, Joy (1996) "Do Static Gains from Trade Lead to Medium-Run Growth?" *Journal of Political Economy*, 104(6): 1328-1337.

Oniki, Hajime and Hirofumi Uzawa (1965) "Patterns of Trade and Investment in a Dynamic Model of International Trade," *Review of Economic Studies*, 32(1): 15-38.

Rodriguez, Francisco and Dani Rodrik (2000) "Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence," *NBER Macroeconomics Annual*, 15: 261-325.

Schott, Peter K. (2003) "One Size Fits All? Heckscher-Ohlin Specialization in Global Production," *American Economic Review*, 93(3): 686-708.

Stolper, Wolfgang F. and Paul A. Samuelson (1941) "Protection and Real Wages," *Review of Economic Studies*, 9(1): 58-73.

Uzawa, Hirofumi (1961) "On a Two-Sector Model of Economic Growth," *Review of Economic Studies*, 29(1): 40-47.

Wacziarg, Romain and Karen Horn Welch (2003) "Trade Liberalization and Growth: New Evidence," NBER Working Paper, No. 10152.

Winters, Alan L. (2004) "Trade Liberalization and Economic Performance: An Overview," *Economic Journal*, 114(493): F4-F21.

Appendix

A1 Proof of Lemma 1 and 2

Figure 3 shows two common tangents. One has a slope of $\tilde{p}_1 f_1'(\tau_1) = \tilde{p}_2 f_2'(\tau_2)$ and crosses points $A\ (\tau_1, \tilde{p}_1 f_1(\tau_1))$ and $B\ (\tau_2, \tilde{p}_2 f_2(\tau_2))$. For given prices, this tangent thus is written as:

$$\tilde{p}_2 f_2(\tau_2) - \tilde{p}_1 f_1(\tau_1) = \tilde{p}_1 f_1'(\tau_1)(\tau_2 - \tau_1). \tag{A-1}$$

The other has a slope of $\tilde{p}_2 f_2'(\tau_3) = \tilde{p}_3 f_3'(\tau_4)$ and crosses points $C\ (\tau_3, \tilde{p}_2 f_2(\tau_3))$ and $D\ (\tau_4, \tilde{p}_3 f_3(\tau_4))$. For given prices, this tangent thus is written as:

$$\tilde{p}_3 f_3(\tau_4) - \tilde{p}_2 f_2(\tau_3) = \tilde{p}_2 f_2'(\tau_3)(\tau_4 - \tau_3).$$

Industrialized countries locate in the cone $[\tau_3, \tau_4]$ while developing countries locate in the cone $[\tau_1, \tau_2]$. The effects on developing countries thus can be analyzed from equation (A-1). Note also that the capital intensity of the investment good is unknown, I need to consider two cases of any price change: whether or not the labor-intensive good is the investment good.

A1.1 Case I: The middle-intensive good is not the investment good

First, assume that the middle-intensive good is not the investment good (i.e., $p_2 \neq p_I$). To examine the effect of an increase in the price of the middle-intensive good, suppose that the prices of the labor- and the capital-intensive goods are fixed. Therefore, $\tau_1(\tilde{p}_2)$, $\tau_2(\tilde{p}_2)$, and $\tilde{p}_2' = \tilde{p}_2'(p_2) = 1/p_I > 0$. From equation (A-1), we have:

$$g(p_2) = \tilde{p}_2 f_2(\tau_2(\tilde{p}_2)) - \tilde{p}_1 f_1(\tau_1(\tilde{p}_2)) - \tilde{p}_1 f_1'(\tau_1(\tilde{p}_2))\{\tau_2(\tilde{p}_2) - \tau_1(\tilde{p}_2)\} = 0. \tag{A-2}$$

To obtain common tangent, the condition (A-2) needs to be held after changes in the price $\tilde{p}_2$. This means $\partial g(\cdot)/\partial p_2 = 0$.

$$\frac{\partial g(\cdot)}{\partial p_2} = \tilde{p}_2' \{ f_2 - \tilde{p}_1 f_1'' \tau_1' (\tau_2 - \tau_1) \} = 0, \tag{A-3}$$

where $f'_i = f'_i(\tau_i)$, $f''_i = f''_i(\tau_i)$, and $\tau'_i = \tau'_i(p_2)$. Therefore,

$$\tau'_1 = \frac{f_2}{\tilde{p}_1 f''_1(\tau_2 - \tau_1)} < 0. \tag{A-4}$$

We thus have:

$$\frac{\partial \tau_2}{\partial p_1} = \tau'_1 \tilde{p}'_2 < 0. \tag{A-5}$$

Substitute $\tilde{p}_1 f'_1(\tau_1(\tilde{p}_2))$ in equation (A-2) to $\tilde{p}_2 f'_2(\tau_2(\tilde{p}_2))$ and take partial derivative with respect to p_2, we have:

$$\frac{\partial g(\cdot)}{\partial p_2} = \tilde{p}'_2 \left[f_2 - \left\{ f'_2 + \tilde{p}_2 f''_2 \tau'_2(\tau_2 - \tau_1) \right\} \right] = 0. \tag{A-6}$$

Therefore,

$$\tau'_2 = \frac{1}{\tilde{p}_2 f''_2} \left(\frac{f_2}{\tau_2 - \tau_1} - f'_2 \right). \tag{A-7}$$

Note that, from equation (A-2), we have:

$$\tilde{p}_2 \{ f_2 - f'_2(\tau_2 - \tau_1) \} = \tilde{p}_1 f_1 \quad \text{or} \quad \frac{f_2}{\tau_2 - \tau_1} - f'_2 = \frac{\tilde{p}_1}{\tilde{p}_2} \frac{f_1}{\tau_2 - \tau_1} > 0.$$

This in turn implies

$$\tau'_2 < 0. \tag{A-8}$$

Therefore,

$$\frac{\partial \tau_2}{\partial p_2} = \tau'_2 \tilde{p}'_2 < 0. \tag{A-9}$$

From equation (2), the effect of an increase in the price p_2 on the rental rate within the cone is:[11]

$$\frac{\partial \bar{r}_1(p_2)}{\partial p_2} = \tilde{p}'_2 f''_1 \tau'_1 > 0. \tag{A-10}$$

From equation (3), the effect of an increase in the price p_2 on the rental rate within the cone is:

$$\frac{\partial \bar{w}_1(p_2)}{\partial p_2} = -\tilde{p}_1 \tilde{p}'_2 \tau_1 f''_1 \tau'_1 < 0. \tag{A-11}$$

The effect of an increase in the price p_2 on the steady-state capital-labor ratio is:

$$\frac{\partial k^*(p_2)}{\partial p_2} = \frac{s}{n+\delta} \frac{\partial \bar{w}_1(p_2)}{\partial p_2} < 0. \tag{A-12}$$

[11]Note that the Stolper-Samuelson effect is also confirmed. From equation (A-49), $\frac{\partial \bar{r}_1}{\partial p_1}\frac{p_1}{\bar{r}_1} = \tilde{p}'_2(f'_2 + f''_2\tau'_2)(\tilde{p}_2 f'_2/p_2) = 1 + (p_2 f''_2 \tau'_2/\tilde{p}_2 f'_2) > 1$. Therefore, $\partial \bar{r}_1/\bar{r}_1 > \partial p_2/p_2 (> 0 > \partial \bar{w}_1/\bar{w}_1)$.

The effect on the rental-wage ratio is:

$$\frac{\partial \omega(\cdot)}{\partial p_2} = \frac{1}{\bar{w}_1^2}\left\{\frac{\partial \bar{r}_1(p_2)}{\partial p_2}\bar{w}_1 - \frac{\partial \bar{w}_1(p_2)}{\partial p_2}\bar{r}_1\right\} > 0. \tag{A-13}$$

The effect on the steady-state per-capita GDP is:

$$\frac{\partial z(\cdot)}{\partial p_2} = \frac{\partial z(k^*(p_2))}{\partial k^*(p_2)}\frac{\partial k^*(p_2)}{\partial p_2} < 0. \tag{A-14}$$

The effect on the steady-state per-capita consumption is:

$$\frac{\partial c^*(\cdot)}{\partial p_2} = \frac{\partial c^*(p_2)}{\partial k^*(p_2)}\frac{\partial k^*(p_2)}{\partial p_2}\begin{cases} < 0 & \text{if} \quad \bar{r}_1 > n+\delta; \\ = 0 & \text{if} \quad \bar{r}_1 = n+\delta; \\ > 0 & \text{if} \quad \bar{r}_1 < n+\delta. \end{cases} \tag{A-15}$$

A1.2 Case II: The middle-intensive good is the investment good

Next, assume that the middle-intensive good is the investment good (i.e., $p_2 = p_I$). Suppose that the prices of the labor- and the capital-intensive goods are fixed. Therefore, $\tau_1(\tilde{p}_1)$, $\tau_2(\tilde{p}_1)$, and $\tilde{p}_1' = \tilde{p}_1'(p_2) = -\tilde{p}_1/p_2 < 0$. From equation (A-1), we have:

$$g(p_2) = f_2(\tau_2(\tilde{p}_1)) - \tilde{p}_1 f_1(\tau_1(\tilde{p}_1)) - \tilde{p}_1 f_1'(\tau_1(\tilde{p}_1))\{\tau_2(\tilde{p}_1) - \tau_1(\tilde{p}_1)\} = 0. \tag{A-16}$$

To obtain common tangent, the condition (A-16) needs to be held after changes in the price p_2. This means $\partial g(\cdot)/\partial p_2 = 0$.

$$\frac{\partial g(\cdot)}{\partial p_2} = -\tilde{p}_1'\{-f_1 - (f_1' + \tilde{p}_1 f_1'' \tau_1')(\tau_2 - \tau_1)\} = 0. \tag{A-17}$$

Therefore,

$$\tau_1' = -\frac{1}{\tilde{p}_1 f_1''}\left(\frac{f_1}{\tau_2 - \tau_1} + f_1'\right) > 0. \tag{A-18}$$

We thus have:

$$\frac{\partial \tau_1}{\partial p_2} = \tau_1' \tilde{p}_1' < 0. \tag{A-19}$$

Similarly, substitute $\tilde{p}_1 f_1'(\tau_1(\tilde{p}_1))$ in equation (A-16) to $f_2'(\tau_2(\tilde{p}_1))$ and take partial derivative with respect to p_2, we have:

$$\frac{\partial g(\cdot)}{\partial p_2} = -\tilde{p}_2\{f_1 - f_2'' \tau_2'(\tau_2 - \tau_1)\} = 0. \tag{A-20}$$

Therefore,

$$\tau_2' = -\frac{f_1}{f_2''(\tau_2 - \tau_1)} > 0. \tag{A-21}$$

Therefore,

$$\frac{\partial \tau_2}{\partial p_2} = \tau_2' \tilde{p}_1' < 0. \tag{A-22}$$

The effects on the rental rate and wage are:

$$\frac{\partial \bar{r}_1(p_2)}{\partial p_2} = f_2'' \tau_2' \tilde{p}_1' > 0 \quad \text{and} \quad \frac{\partial \bar{w}_1(p_2)}{\partial p_2} = -\tau_2 f_2'' \tau_2' \tilde{p}_1' < 0, \tag{A-23}$$

respectively. The effect of an increase in p_2 on the steady-state capital-labor ratio is:

$$\frac{\partial k^*(p_2)}{\partial p_2} = \frac{s}{n+\delta} \frac{\partial \bar{w}_1(p_2)}{\partial p_2} < 0. \tag{A-24}$$

The effect on the rental-wage ratio is:

$$\frac{\partial \omega(\cdot)}{\partial p_2} = \frac{1}{\bar{w}_1^2} \left\{ \frac{\partial \bar{r}_1(p_2)}{\partial p_2} \bar{w}_1 - \frac{\partial \bar{w}_1(p_2)}{\partial p_2} \bar{r}_1 \right\} > 0. \tag{A-25}$$

The effect on the steady-state per-capita GDP is:

$$\frac{\partial z(\cdot)}{\partial p_2} = \frac{\partial z(k^*(p_2))}{\partial k^*(p_2)} \frac{\partial k^*(p_2)}{\partial p_2} < 0. \tag{A-26}$$

The effect on the steady-state per-capita consumption is:

$$\frac{\partial c^*(\cdot)}{\partial p_2} = \frac{\partial c^*(k^*(p_2))}{\partial k^*(p_2)} \frac{\partial k^*(p_2)}{\partial p_2} \begin{cases} < 0 & \text{if} \quad \bar{r}_1 > n+\delta; \\ = 0 & \text{if} \quad \bar{r}_1 = n+\delta; \\ > 0 & \text{if} \quad \bar{r}_1 < n+\delta. \end{cases} \tag{A-27}$$

Equations (A-13) and (A-25) indicate that an increase in the price of the middle-intensive good lowers income inequality irrespective of whether the middle-intensive good is the consumption good or the investment good. Similarly, equations (A-14) and (A-26) indicate that the increase in the price of the middle-intensive good raises per-capita GDP irrespective of whether the middle-intensive good is the consumption good or the investment good. Therefore, Lemma 1 is obtained. On the other hand, equations (A-15) and (A-27) indicate that if the price of the middle-intensive good increases, per-capita consumption 1) decreases when $\bar{r}_1 > n+\delta$; 2) increases when $\bar{r}_1 < n+\delta$; and 3) is constant when $\bar{r}_1 = n+\delta$. Therefore, Lemma 2 is obtained. ■

A2 Proof of Lemma 3 and 4

A2.1 Case I: The labor-intensive good is not the investment good

Similar to the proof of Lemma 1 and 2, assume first that the labor-intensive good is not the investment good (i.e., $p_1 \neq p_I$). Suppose that the prices of the middle- and capital-intensive goods are fixed. Therefore, $\tau_1(\tilde{p}_1)$, $\tau_2(\tilde{p}_1)$, and $\tilde{p}_1' = \tilde{p}_1'(p_1) = 1/p_I > 0$. Rewrite (A-1) as:

$$g(p_1) = \tilde{p}_2 f_2(\tau_2(\tilde{p}_1)) - \tilde{p}_1 f_1(\tau_1(\tilde{p}_1)) - \tilde{p}_1 f_1' \tau_1(\tilde{p}_1)\left\{\tau_2(\tilde{p}_1) - \tau_1(\tilde{p}_1)\right\} = 0.$$

To obtain common tangent, the condition (A-28) needs to be held before and after changes in the price p_1. This means $\partial g(p_1)/\partial p_1 = 0$.

$$\frac{\partial g(\cdot)}{\partial p_1} = -\tilde{p}_1' \left\{f_1 + (f_1' + \tilde{p}_1 f_1'' \tau_1')(\tau_2 - \tau_1)\right\} = 0, \tag{A-28}$$

where $f_i' = f_i'(\tau_i)$, $f_i'' = f_i''(\tau_i)$, and $\tau_i' = \tau_i'(\tilde{p}_1)$. Therefore,

$$\tau_1' = -\frac{1}{\tilde{p}_1 f_1''}\left(\frac{f_1}{\tau_2 - \tau_1} + f_1'\right) > 0. \tag{A-29}$$

Hence,

$$\frac{\partial \tau_1}{\partial p_1} = \tau_1' \tilde{p}_1' > 0. \tag{A-30}$$

Similarly, substitute $\tilde{p}_1 f_1'(\tau_1(\tilde{p}_1))$ in equation (A-28) to $\tilde{p}_2 f_2'(\tau_2(\tilde{p}_1))$ and take partial derivative with respect to p_1, we have:

$$\frac{\partial g(\cdot)}{\partial p_1} = -\tilde{p}_1' \left\{f_1 + \tilde{p}_2 f_2'' \tau_2'(\tau_2 - \tau_1)\right\} = 0. \tag{A-31}$$

Hence,

$$\tau_2' = -\frac{f_1}{\tilde{p}_2 f_2''(\tau_2 - \tau_1)} > 0. \tag{A-32}$$

We thus have:

$$\frac{\partial \tau_2}{\partial p_1} = \tau_2' \tilde{p}_1' > 0. \tag{A-33}$$

These results indicate an increase in the price p_1 causes the rightward shift of the diversification cone in Figure 3.

From equation (2), the effect of increase in the price p_1 on the rental rate within the cone is:

$$\frac{\partial \bar{r}_1(p_1)}{\partial p_1} = \tilde{p}_2 f_2'' \tau_2' \tilde{p}_1' < 0. \tag{A-34}$$

This in turn implies:

$$\frac{\partial \bar{r}_1(p_1))}{\partial p_1} = \tilde{p}_1'(f_1' + \tilde{p}_1 f_1'' \tau_1') < 0 \tag{A-35}$$

Similarly, from equations (3) and (A-35), the effect of an increase in the price p_1 on the wage within the cone is:

$$\frac{\partial \bar{w}_1(p_1)}{\partial p_1} = \tilde{p}_1' \left\{f_1 - \tau_1(f_1' + \tilde{p}_1 f_1'' \tau_1')\right\} > 0. \tag{A-36}$$

Hence,

$$\frac{\partial \bar{w}_1(\tilde{p}_1)}{\partial p_1} = -\tilde{p}_2 \tau_2 f_2'' \tau_2' \tilde{p}_1' > 0. \tag{A-37}$$

Note that the steady state within the cone means $k^* = \{s/(n+\delta)\}\bar{w}_1$. Therefore,

$$\frac{\partial k^*(p_1)}{\partial p_1} = \frac{s}{n+\delta}\frac{\partial \bar{w}_1(p_1)}{\partial p_1} > 0. \tag{A-38}$$

From equations (A-34) and (A-36), the effect of an increase in p_1 on the rental-wage ratio is:

$$\frac{\partial \omega(\cdot)}{\partial p_1} = \frac{1}{\bar{w}_1^2}\left\{\frac{\partial \bar{r}_1(p_1)}{\partial p_1}\bar{w}_1 - \frac{\partial \bar{w}_1(p_1)}{\partial p_1}\bar{r}_1\right\} < 0. \tag{A-39}$$

From equations (4) and (A-38), the effect of an increase in p_1 on the steady-state per-capita GDP is:

$$\frac{\partial z(\cdot)}{\partial p_1} = \frac{\partial z(k^*(p_1))}{\partial k^*(p_1)}\frac{\partial k^*(p_1)}{\partial p_1} > 0. \tag{A-40}$$

On the other hand, an increase in p_1 on the steady-state per-capita consumption is:

$$\frac{\partial c^*(\cdot)}{\partial p_1} = \frac{\partial c^*(k^*(p_1))}{\partial k^*(p_1)}\frac{\partial k^*(p_1)}{\partial p_1}\begin{cases} > 0 & \text{if} \quad \bar{r}_1 > n+\delta; \\ = 0 & \text{if} \quad \bar{r}_1 = n+\delta; \\ < 0 & \text{if} \quad \bar{r}_1 < n+\delta. \end{cases} \tag{A-41}$$

An increase in the price of the labor-intensive good p_1 thus results in the increase in the steady-state per-capita GDP and the decline in income inequality. The effect on steady-state per-capita consumption depends upon the relationship between $\bar{r}_1$ and $n+\delta$.

A2.2 Case II: The labor-intensive good is the investment good

Next, assume that the labor-intensive good is the investment good (i.e., $p_1 = p_I$). Suppose that the prices of the middle- and capital-intensive goods are fixed. Therefore, $\tau_1(\tilde{p}_2)$, $\tau_2(\tilde{p}_2)$, and $\tilde{p}_2' = \tilde{p}_2'(p_1) = -\tilde{p}_2/p_1 < 0$. Rewrite (A-1) as:

$$g(p_1) = \tilde{p}_2 f_2(\tau_2(\tilde{p}_2)) - f_1(\tau_1(\tilde{p}_2)) - f_1'(\tau_1(\tilde{p}_2))\{\tau_2(\tilde{p}_2) - \tau_1(\tilde{p}_2)\} = 0. \tag{A-42}$$

To obtain common tangent, the condition (A-42) needs to be held after changes in the price p_1. This means $\partial g(p_1)/\partial p_1 = 0$.

$$\frac{\partial g(p_1)}{\partial p_1} = \tilde{p}_2'\{f_2 - f_1''\tau_1'(\tau_2 - \tau_1)\} = 0. \tag{A-43}$$

Therefore,

$$\tau_1' = \frac{f_2}{f_1''(\tau_2 - \tau_1)} < 0. \tag{A-44}$$

Hence,

$$\frac{\partial \tau_1}{\partial p_1} = \tau_1' \tilde{p}_2' > 0. \tag{A-45}$$

On the other hand, substitute $f_1'(\tau_1(\tilde{p}_2))$ in equation (A-42) to $\tilde{p}_2 f_2'(\tau_2(\tilde{p}_2))$ and take partial derivative with respect to p_1, we have:

$$\frac{\partial g(p_1)}{\partial p_1} = \tilde{p}_2' \left\{ f_2 - (f_2' + \tilde{p}_2 f_2'' \tau_2')(\tau_2 - \tau_1) \right\}. \tag{A-46}$$

Therefore,

$$\tau_2' = \frac{1}{\tilde{p}_2 f_2''} \left(\frac{f_2}{\tau_2 - \tau_1} - f_2' \right) < 0. \tag{A-47}$$

We thus have:

$$\frac{\partial \tau_2}{\partial p_1} = \tau_2' \tilde{p}_2' > 0. \tag{A-48}$$

From equation (2) and (A-46), the effect of an increase in the price $\tilde{p}_2$ on the rental rate r and wage w inside the cone is:

$$\frac{\partial \bar{r}_1(p_1)}{\partial p_1} = f_1'' \tau_1' \tilde{p}_2' < 0 \tag{A-49}$$

and

$$\frac{\partial \bar{w}_1(p_1)}{\partial p_1} = -\tau_1 f_1'' \tau_1' \tilde{p}_2' > 0, \tag{A-50}$$

respectively.

From $k^* = \{s/(n+\delta)\}\bar{w}_1$ and equations (A-49) and (A-50), at the steady state, we have:

$$\frac{\partial k^*(p_1)}{\partial p_1} = \frac{s}{n+\delta} \frac{\partial \bar{w}_1(p_1)}{\partial p_1} > 0. \tag{A-51}$$

From equations (A-49) and (A-50), the effect of an increase in the price p_1 on the rental-wage ratio is:

$$\frac{\partial \omega(\cdot)}{\partial p_1} = \frac{1}{\bar{w}_1^2} \left\{ \frac{\partial \bar{r}_1(p_1)}{\partial p_1} \bar{w}_1 - \frac{\partial \bar{w}_1(p_1)}{\partial p_1} \bar{r}_1 \right\} < 0. \tag{A-52}$$

From equations (4) and (A-51), the effect of an increase in the price of the labor-intensive good p_1 on the steady-state per-capita GDP is:

$$\frac{\partial z(\cdot)}{\partial p_1} = \frac{\partial z(k^*(p_1))}{\partial k^*(p_1)} \frac{\partial k^*(p_1)}{\partial p_1} > 0. \tag{A-53}$$

On the other hand, the effect of an increase in p_1 on the steady-state per-capita consumption is:

$$\frac{\partial c^*(\cdot)}{\partial p_1} = \frac{\partial c^*(k^*(p_1))}{\partial k^*(p_1)} \frac{\partial k^*(p_1)}{\partial p_1} \begin{cases} > 0 & \text{if} \quad \bar{r}_1 > n+\delta; \\ = 0 & \text{if} \quad \bar{r}_1 = n+\delta; \\ < 0 & \text{if} \quad \bar{r}_1 < n+\delta. \end{cases} \tag{A-54}$$

These results suggest that an increase in the price of the labor-intensive good raises per-capita GDP while lowering income inequality. Like Case I, the effect on consumption depends upon the relationship between $\bar{r}_1$ and $n+\delta$.

Equations (A-39) and (A-52) indicate that an increase in the price of the labor-intensive good lowers income inequality irrespective of whether the labor-intensive good is the consumption good or the investment good. Similarly, equations (A-40) and (A-53) indicate that the increase in the price of the labor-intensive good raises per-capita GDP irrespective of whether the labor-intensive good is the consumption good or the investment good. Therefore, Lemma 3 is obtained. On the other hand, equations (A-41) and (A-54) indicate that if the price of the labor-intensive good increases, per-capita consumption 1) increases when $\bar{r}_1 > n+\delta$; 2) decreases when $\bar{r}_1 < n+\delta$; and 3) is constant when $\bar{r}_1 = n+\delta$. Therefore, Lemma 4 is obtained. ■

A3 Proof of Propositions 1-3

A3.1 Case I: The capital-intensive good is <u>not</u> the investment good

Suppose that the capital-intensive good is <u>not</u> the investment good (i.e., $p_3 \neq p_I$). Suppose that the prices of the labor- and the middle-intensive goods are fixed. Note that neither τ_1 nor τ_2 is a function of p_3. This in turn implies:

$$\frac{\partial \tau_1}{\partial p_3} = 0 \quad \text{and} \quad \frac{\partial \tau_2}{\partial p_3} = 0. \tag{A-55}$$

In addition, the common tangent is also not the function of p_3. Therefore,

$$\frac{\partial w(\cdot)}{\partial p_3} = 0, \quad \frac{\partial r(\cdot)}{\partial p_3} = 0, \quad \text{and} \quad \frac{\partial k^*(\cdot)}{\partial p_3} = 0. \tag{A-56}$$

Hence,

$$\frac{\partial \omega(\cdot)}{\partial p_3} = 0, \quad \frac{\partial z(\cdot)}{\partial p_3} = 0, \quad \text{and} \quad \frac{\partial c^*(\cdot)}{\partial p_3} = 0. \tag{A-57}$$

If the capital-intensive good is not the investment good, an increase in the price of capital-intensive good does not have any effects on the inequality, per-capita GDP, and per-capita consumption in developing countries.

A.3.2 Case II: The capital-intensive good <u>is</u> the investment good

Next, suppose that capital-intensive good <u>is</u> the investment good (i.e., $p_3 = p_I$). Suppose that the prices of the labor- and middle-intensive goods are fixed. Therefore, $\tau_1(\tilde{p}_1, \tilde{p}_2)$, $\tau_2(\tilde{p}_1, \tilde{p}_2)$, $\tilde{p}_1' = \tilde{p}_1'(p_3) = -\tilde{p}_1/p_3 < 0$, and $\tilde{p}_2' = \tilde{p}_2'(p_3) = -\tilde{p}_2/p_3 < 0$. Rewrite equation (A-1),

$$\tilde{p}_2 f_2(\tau_2(\tilde{p}_1, \tilde{p}_2)) - \tilde{p}_1 f_1(\tau_1(\tilde{p}_1, \tilde{p}_2)) = \tilde{p}_1 f_1'(\tau_1(\tilde{p}_1, \tilde{p}_2))(\tau_2(\tilde{p}_1, \tilde{p}_2) - \tau_1(\tilde{p}_1, \tilde{p}_2)). \tag{A-58}$$

Therefore,

$$\begin{aligned} g(p_3) &= \tilde{p}_2 f_2(\tau_2(\tilde{p}_1,\tilde{p}_2)) - \tilde{p}_1 f_1(\tau_1(\tilde{p}_1,\tilde{p}_2)) \\ &\quad -\tilde{p}_1 f_1'(\tau_1(\tilde{p}_1,\tilde{p}_2))(\tau_2(\tilde{p}_1,\tilde{p}_2) - \tau_1(\tilde{p}_1,\tilde{p}_2)). \end{aligned} \tag{A-59}$$

To obtain common tangent, the condition (A-59) needs to be held after the changes in the price p_3. This means

$$\frac{dg(p_3)}{dp_3} = \frac{1}{dp_3}\left\{\frac{\partial g(\cdot)}{\partial \tilde{p}_1}d\tilde{p}_1 + \frac{\partial g(\cdot)}{\partial \tilde{p}_2}d\tilde{p}_2\right\} = -\frac{1}{p_3}\left\{\frac{\partial g(\cdot)}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial g(\cdot)}{\partial \tilde{p}_2}\tilde{p}_2\right\} = 0. \tag{A-60}$$

Therefore,

$$\frac{\partial g(\cdot)}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial g(\cdot)}{\partial \tilde{p}_2}\tilde{p}_2 = 0. \tag{A-61}$$

Note that

$$\frac{\partial g(\cdot)}{\partial \tilde{p}_1} = -f_1 - \left\{f_1' + \tilde{p}_1 f_1'' \frac{\partial \tau_1}{\partial \tilde{p}_1}(\tau_2 - \tau_1)\right\} \quad \text{and} \quad \frac{\partial g(\cdot)}{\partial \tilde{p}_2} = f_2 - \tilde{p}_1 f_1'' \frac{\partial \tau_1}{\partial \tilde{p}_2}(\tau_2 - \tau_1). \tag{A-62}$$

We thus have:

$$\begin{aligned} \frac{\partial g(\cdot)}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial g(\cdot)}{\partial \tilde{p}_2}\tilde{p}_2 &= \left\{\tilde{p}_2 f_2 - \tilde{p}_1 f_1 - \tilde{p}_1 f_1'(\tau_2 - \tau_1)\right\} - \tilde{p}_1 f_1''(\tau_2 - \tau_1)\left(\frac{\partial \tau_1}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \tau_1}{\partial \tilde{p}_2}\tilde{p}_2\right) \\ &= 0. \end{aligned} \tag{A-63}$$

Therefore,

$$\frac{\partial \tau_1}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \tau_1}{\partial \tilde{p}_2}\tilde{p}_2 = 0. \tag{A-64}$$

Similarly,

$$\frac{\partial g(\cdot)}{\partial \tilde{p}_2} = -f_1 - \tilde{p}_2 f_2'' \frac{\partial \tau_2}{\partial \tilde{p}_1}(\tau_2 - \tau_1) \tag{A-65}$$

and

$$\frac{\partial g(\cdot)}{\partial \tilde{p}_2} = f_2 - \left(f_2' + \tilde{p}_2 f_2'' \frac{\partial \tau_2}{\partial \tilde{p}_2}\right)(\tau_2 - \tau_1). \tag{A-66}$$

This in turn implies:

$$\begin{aligned} \frac{\partial g(\cdot)}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial g(\cdot)}{\partial \tilde{p}_2}\tilde{p}_2 &= \left\{\tilde{p}_2 f_2 - \tilde{p}_1 f_1 - \tilde{p}_1 f_1'(\tau_2 - \tau_1)\right\} - \tilde{p}_2 f_2''(\tau_2 - \tau_1)\left(\frac{\partial \tau_1}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \tau_1}{\partial \tilde{p}_2}\tilde{p}_2\right) \\ &= 0. \end{aligned} \tag{A-67}$$

Therefore,

$$\frac{\partial \tau_2}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \tau_2}{\partial \tilde{p}_2}\tilde{p}_2 = 0. \tag{A-68}$$

The effect on the wage is:

$$\frac{d\bar{w}_1(p_3)}{dp_3} = -\frac{1}{p_3}\left\{\frac{\partial \bar{w}_1(\tilde{p}_1)}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \bar{w}_1(\tilde{p}_2)}{\partial \tilde{p}_2}\tilde{p}_2\right\} \tag{A-69}$$

Note that

$$\frac{\partial w_1(\cdot)}{\partial \tilde{p}_1} = f_1 - \tau_1 f_1' \tilde{p}_1 \tau_1 f_1'' \frac{\partial \tau_1}{\partial \tilde{p}_1} \quad \text{and} \quad \frac{\partial w_1(\cdot)}{\partial \tilde{p}_2} = -\tilde{p}_1 \tau_1 f_1'' \frac{\partial \tau_1}{\partial \tilde{p}_2}. \tag{A-70}$$

Therefore,

$$\frac{d\bar{w}_1(p_3)}{dp_3} = -\frac{1}{\tilde{p}_1}(f_1 - \tau_1 f_1') - \frac{\tilde{p}_1}{p_3}\tau_1 f_1''\left(\frac{\partial \tau_1}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \tau_1}{\partial \tilde{p}_2}\tilde{p}_2\right) = -\frac{\bar{w}_1}{p_3} < 0. \tag{A-71}$$

Similarly, the effect of increase in p_3 is:

$$\frac{d\bar{r}_1}{dp_3} = -\frac{1}{p_3}\left\{\frac{\partial \bar{r}_1(\tilde{p}_1)}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \bar{r}_1(\tilde{p}_2)}{\partial \tilde{p}_2}\tilde{p}_2\right\}. \tag{A-72}$$

Note that

$$\frac{\partial \bar{r}_1(\cdot)}{\partial \tilde{p}_1} = f_1' + \tilde{p}_1 f_1'' \frac{\partial \tau_1}{\partial \tilde{p}_1} \quad \text{and} \quad \frac{\partial \bar{r}_1(\cdot)}{\partial \tilde{p}_2} = \tilde{p}_1 f_1'' \frac{\partial \tau_1}{\partial \tilde{p}_2}. \tag{A-73}$$

We thus have:

$$\frac{d\bar{r}_1}{dp_3} = -\frac{1}{p_3}\left\{\tilde{p}_1 f_1' + \tilde{p}_1 f_1''\left(\frac{\partial \tau_1}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \tau_1}{\partial \tilde{p}_2}\tilde{p}_2\right)\right\} = -\frac{\bar{r}_1}{p_3} < 0. \tag{A-74}$$

The effect on the steady-state capital-labor ratio is:

$$\frac{dk^*(p_3)}{dp_3} = \frac{s}{n+\delta}\frac{d\bar{w}_1(\cdot)}{dp_3} < 0. \tag{A-75}$$

The effect on the income inequality is:

$$\frac{d\omega(p_3)}{dp_3}\left\{\frac{\partial \omega(\cdot)}{\partial \tilde{p}_1}\tilde{p}_1 + \frac{\partial \omega(\cdot)}{\partial \tilde{p}_2}\tilde{p}_2\right\} = -\frac{dp_3}{p_3}\frac{1}{w_2}\left(\frac{d\bar{r}_1}{dp_3}\bar{w}_1 - \frac{d\bar{w}_1}{dp_3}\bar{r}_1\right) = 0. \tag{A-76}$$

The effect of an increase in p_3 on the steady-state per-capita GDP is written as:

$$\frac{dz(k^*(p_3))}{dp_3} = \frac{\partial z(k^*(p_3))}{\partial k^*(p_3)}\frac{dk^*(p_3)}{dp_3} < 0. \tag{A-77}$$

The effect on the steady-state per-capita consumption is:

$$\frac{dc(k^*(p_3))}{dp_3} = \frac{\partial c(k^*(p_3))}{\partial k^*(p_3)}\frac{dk^*(p_3)}{dp_3}\begin{cases} < 0 & \text{if} \quad \bar{r}_1 > n+\delta; \\ = 0 & \text{if} \quad \bar{r}_1 = n+\delta; \\ > 0 & \text{if} \quad \bar{r}_1 < n+\delta. \end{cases} \tag{A-78}$$

The effect on the steady-state per-capita consumption thus depends upon the relationship between $\bar{r}_1$ and $n+\delta$.

The effects of protection on income inequality, the stead-state per-capita GDP, and the steady-state per-capita consumption are confirmed from equations (A-57) and (A-76), equations (A-57) and (A-77), and equations (A-57) and (A-78), respectively. Propositions 1-3 are derived from these equations. ■

Table 1. Country Classification

	Global factor abundance	Local factor abundance	Classification	Trade
Industrialized countries	Globally capital abundant	(Not examined in this paper)	High-income countries	Export capital-intensive good and import middle- and labor-intensive goods
Developing countries	Globally labor abundant	Locally capital abundant	Middle-income countries	Export middle-intensive good and import capital- and labor-intensive goods
		Locally labor abundant	Low-income countries	Export labor-intensive good and import middle- and capital-intensive goods

Table 2. Effects of Trade Liberalization

Trade liberalization	Income inequality	Per-capita GDP	Per-capita consumption	Source
Liberalization by the low- and middle-income countries on imports from the high-income countries	No effect	1) Increase if the import is the numeraire good 2) No effect otherwise	1) Increase if $r > n + \delta$ 2) Decrease if $r < n + \delta$ 3) No change if $r = n + \delta$	Propositions 1-3
Liberalization by the low-income countries on imports from the middle-income countries	Decrease	Increase	1) Decrease if $r > n + \delta$ 2) Increase if $r < n + \delta$ 3) No change if $r = n + \delta$	Propositions 4 and 5
Liberalization by the middle-income countries on imports from the low-income countries	Increase	Decrease	1) Increase if $r > n + \delta$ 2) Decrease if $r < n + \delta$ 3) No change if $r = n + \delta$	Propositions 6 and 7

Figure 1. Global and Local Factor Abundance

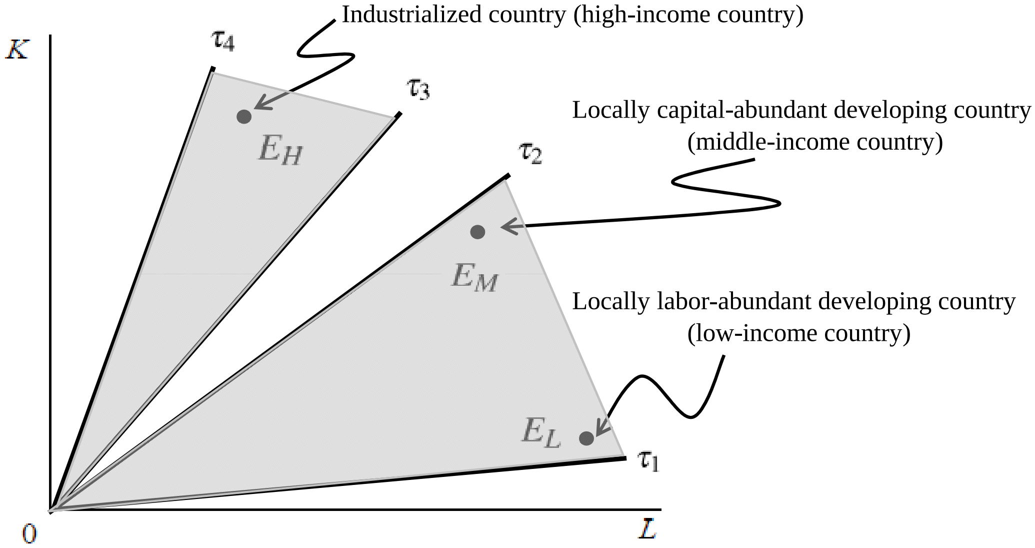


Figure 2. Relationship between Per-capita GDP and Capital-labor Ratio in the Three-good Two-cone Model

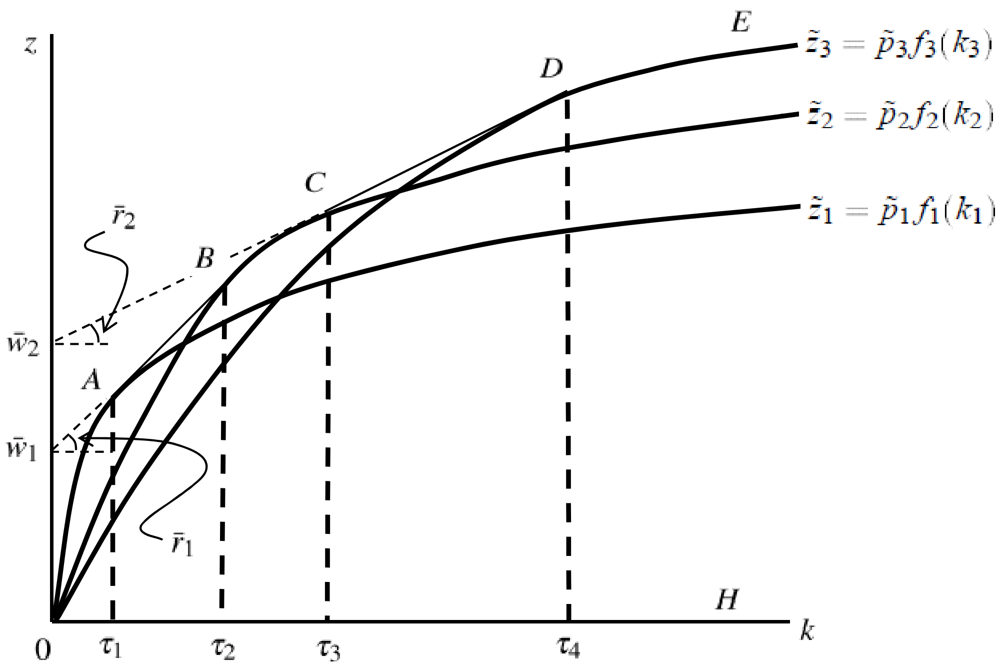


Figure 3. Multiple Equilibria in the Three-good Two-cone Model

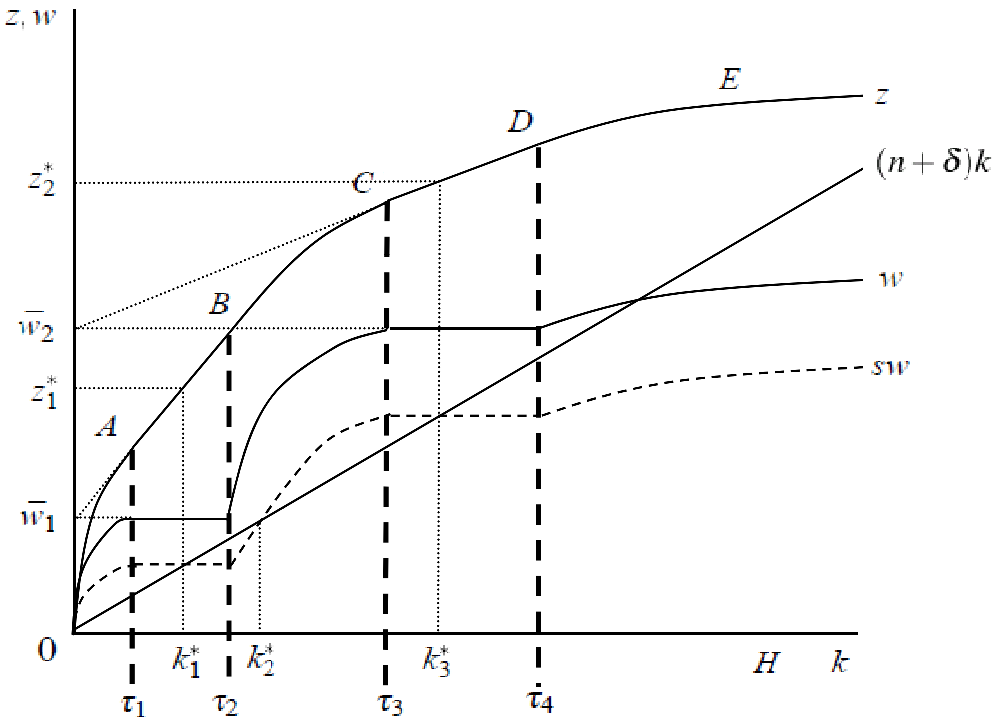


Figure 4. Patterns of Trade for the Three-good Two-cone Model

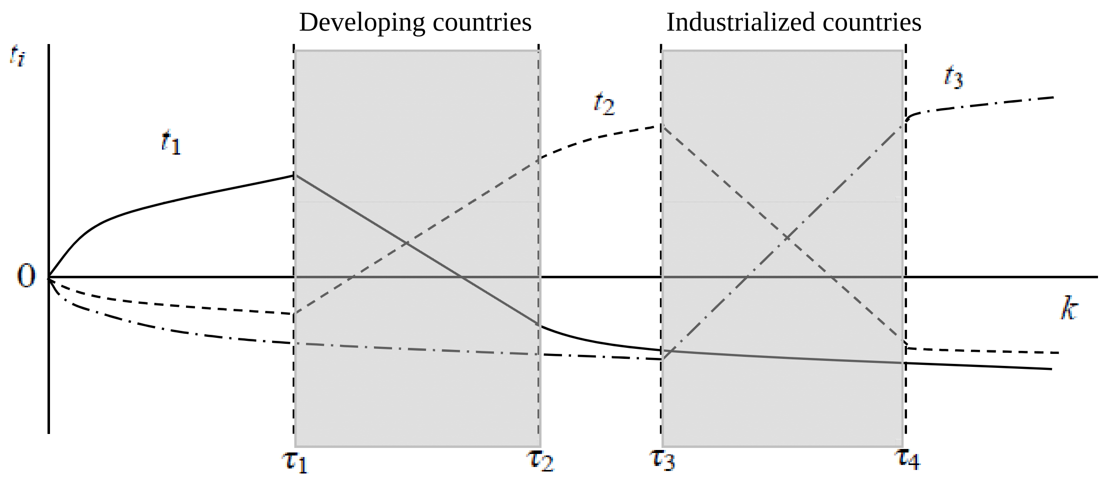


Figure 5. Global and Local Factor Abundances in the Three-good Two-cone Multiple-cone Model

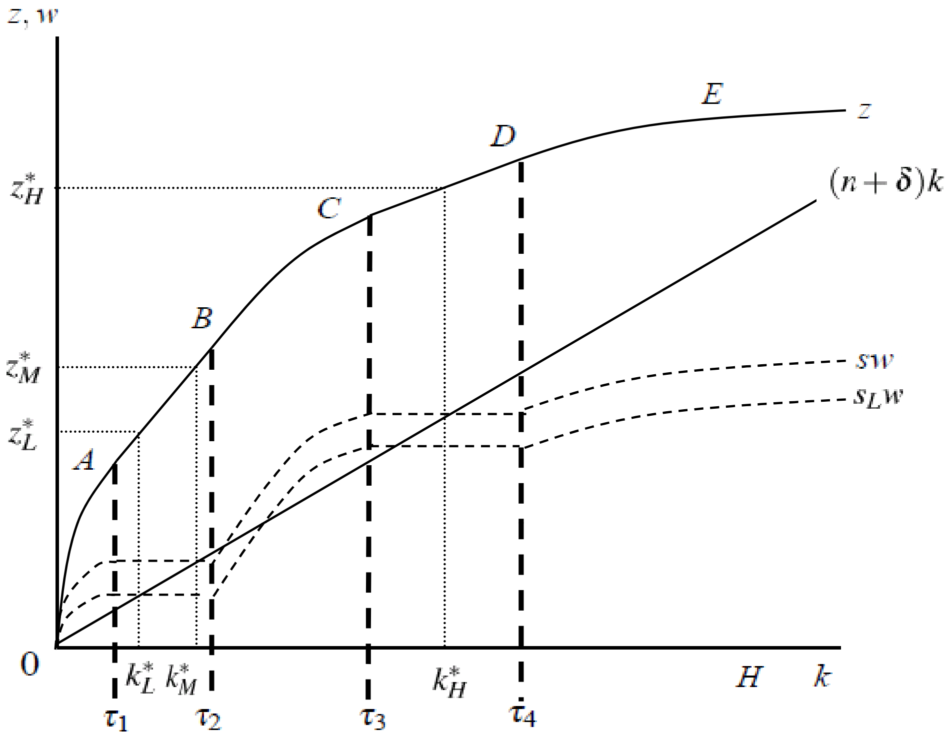


Figure 6. Patterns of Trade for the Three-good Two-cone Model: Global and Local Factor Abundances

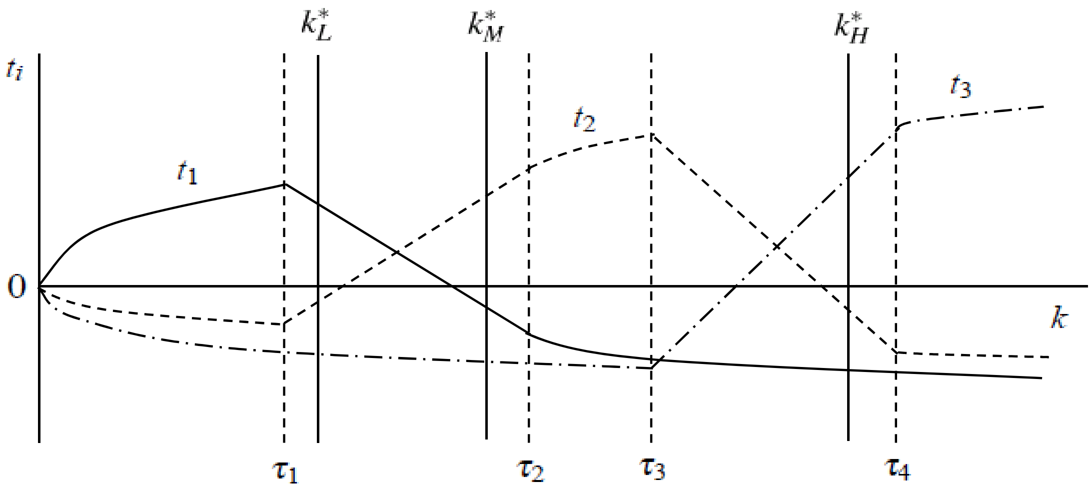
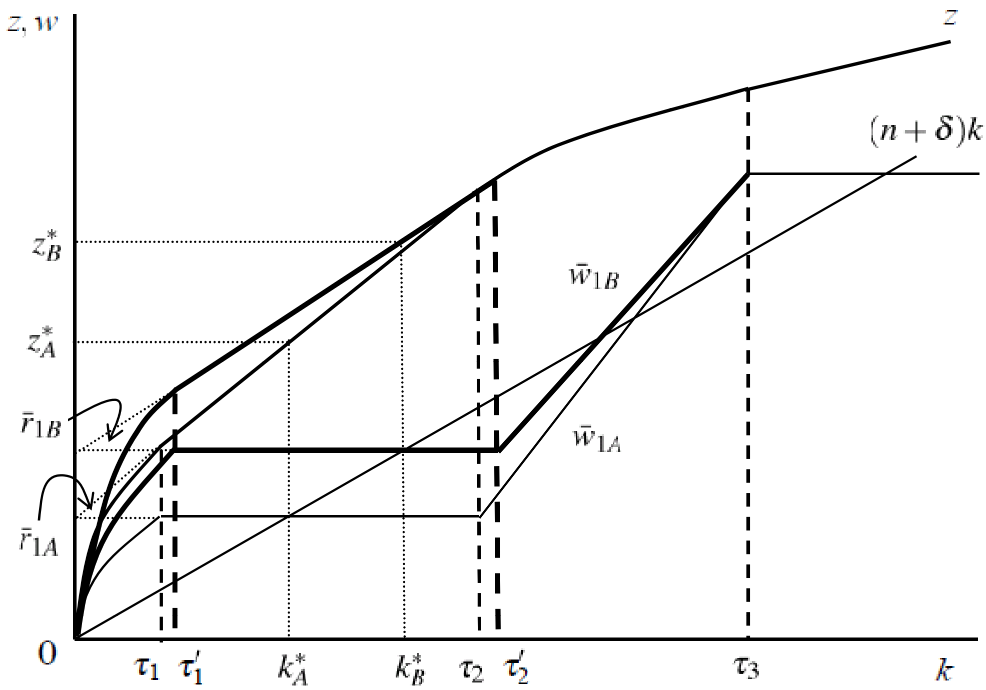


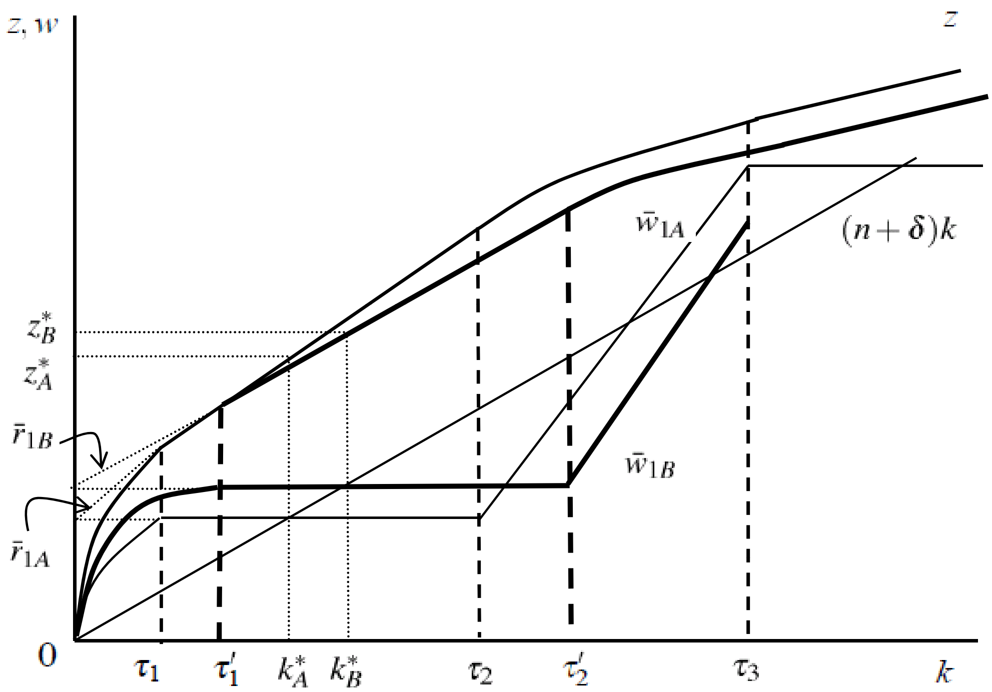
Figure 7. Protection by A Middle-income Country on Imports from Low-income Countries

(a) Y_1 is <u>not</u> the investment good



Note: For illustrative purposes, $s = 1$ is assumed.

(b) Y_1 <u>is</u> the investment good



Note: For illustrative purposes, $s = 1$ is assumed.