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IT, Production Specialization, and Division of Labor:

A Smith-Ricardo Model of International Trade

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Abstract

A simple Smith-Ricardo model is developed that incorporates division of labor into the continuum-good Ricardian model of Dornbusch *et al.*(1977). The trade-off between the efficiency gain and coordination cost associated with production specialization determines the efficient level of division of labor. The model is applied to explain how the recent IT revolution could affect a country's efficient level of production specialization and competitive advantage. In particular, absolute advantage (in division of labor) and relative labor supply plays a crucial role in determining the effects of an IT progress on a country's competitive margin in international trade.

Key Words: Division of labor, Production specialization, Information technology, Coordination cost, International Trade

JEL classification: F10, F11

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1. INTRODUCTION

The significantly high growth rate in trade (especially in manufacturing goods) relative to the production since the second World War has generated huge research interests among international economists. Trade liberalization has certainly played an important role in the growth of trade volume but many believe that the speed of trade liberalization simply cannot explain such a fast growth rate in trade. In their recent studies, Hummels, *et al. (*2001) and Yi (2003) have provided both empirical evidence and theory that attribute the high grow rate in trade to vertical specialization in production.[1] On the other hand, the increase in vertical specialization (including international outsourcing/fragmentation, *etc.*) is also explained by trade liberalization and globalization (e.g., Jones, 2000; McLaren, 2001; Grossman and Helpman, 2002)[2] By building a Smith-Ricardo model of international trade, this paper suggests an alternative explanation for the increase in production specialization and its impact on international trade, based on the recent revolution in communication/information technology.

There is strong evidence that information technology has an impact on the industrial structure of production and firms (Kabmil, 1991; Brynjolfsson *et al.* 1993). To my knowledge, however, its potential impact on international trade (via changes in production structure) has not yet caught formal attention in the literature. Rather, the role of information technology is only considered to be able to reduce trade costs and consequently increase the trade volume.

The model is built on the classic thoughts by Adam Smith (1776) on division of labor because I believe that in essence production specialization is division of labor. Smith's idea

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[1] Schmitt and Yu (2001, 2002) argue that trade liberalization can still explain a significant portion in trade growth if we take into account the role of economies of scale in production and entry of new exporting firms. There is, however, lots of empirical evidence on inreasing production specialization and trade (e.g., Campa and Goldberg, 1997; Hanson, Matoloni, and Slaughter*, 2001).*

[2] Also see Zhao (2001), and Chen, *et al.*(2003) for other explanations of international outsourcing. For an overview on this topic, see Feenstra (2001), and the collections in Jones and Kierzkowski (2001) and Cheng and Kierzkowski (2001).

about the division of labor in a pin-factory is very simple: the specialization and concentration of the workers on their single subtasks leads to greater skill and higher productivity on their particular subtasks than would be achieved by the same number of workers each carrying out the original broad task. According to Smith, the division of labor is limited, however, by the extent of the market.[3] But Smith's theory cannot satisfactorily explain the recent surge in production specialization if in fact most firms are small relative to their global markets.[4] The reason for this is that Smith failed to realize that division of labor is also intrinsically limited by the technology in production coordination (or coordination cost, in modern language).

I incorporate this idea into the continuum-good Ricardian model of Dornbusch, *et al.* (1977) and build a Smith-Ricardo model of international trade, where the division of labor is endogenously determined by the trade-off between the efficiency gain and coordination cost associated with production specialization. A progress in IT that reduces the coordination cost in production increases the efficient level of division of labor, which in turn affects a country's comparative advantage and trade pattern. The result suggests that the recent revolution in IT could be a very important driving force behind the current changes in the patterns of international trade and production (e.g., fragmentation/outsourcing, vertical/horizontal specialization, etc.)

The paper also shows that even if both countries have access to the same information technology, an IT progress tends to reduce the competitive margin of a less-developed country (LDC), and help a developed country (DC) recover its competitive margin lost to the LDC because of its low wage and large labor supply. The result may shed light on the U.S. economy (and some other DCs) that has maintained its competitiveness *vis-a-vis* other low-wage LDCs during the last two decades. In addition, unlike its predecessor (i.e. the Ricardian model of Dornbusch *et al.* 1977), this Smith-Ricardo model retains Smith's spirit in that the absolute advantage (in division of labor) plays a crucial role in determining the

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[3] Also see "The division of labor is limited by the extent of the market" by Stigler (1951).

[4] If firms are small relative to their market, the division of labor is already approaches the limit and a further increase in the market has little impact on the degree of division of labor.

effects of an IT progress on a country's competitive margin in international trade.

Students in international economics know Smith because of his theory on absolute advantage and international trade (though we then tell them that absolute advantage plays a much less important role in international trade compared to comparative advantage). Much less attention is paid to the role of Smith's division of labor in international trade, however. In the modern economic theory, that role has been taken over by overall technology progress. The seminal work by Ethier (1982) is the first paper in international trade literature to formally model the efficiency gain resulting from division of labor *in production*.[5] Instead of directly modelling the simple process in Smith's idea on division of labor, Ethier focuses on the external economies of scale (resulting from specialized inputs) in the production of final goods. In contrast, in this paper I emphasize the simple role of Smith' idea on division of labor, and focus on the interplay of the efficiency gain of division of labor and the costs of production coordination. Furthermore, in this modified Ricardian model, absolute advantage (in division of labor) now plays a crucial role in determining the effects of an IT progress on a country's competitive margin in international trade.

There is relatively small but growing research interests on Smith's theory of division of labor and specialization.[6] Most studies in this literature, however, use the *inframarginal analysis* and focus on specialization (or division of labor) at *individuals'* level. Cheng *et al.* (2000) provides an application of this approach in a 2-good Ricardian model. Instead of modelling specialization at individuals' level, following Ethier and many others, I focus on specialization and division of labor in production process.

My approach is more closely related to Taylor (1994a, 1994b) that extend the continuum-good Ricardian model to incorporate the 'quality ladders' approach of Grossman and Helpman (1991). Assuming industries/sectors have different production and research technologies, Taylor focuses on the innovation that reduces unit production costs. In my model sectors differ in industrial technology but access the same communication/information tech-

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[5] See other influential work by Grossman and Helpman (1989, 1990), and Romer (1986, 1990).

[6] E.g., see Young (1991), an excellent survey of this literature by Yang and Ng (1998), and the pioneering work by Yang himself and his coauthors.

nology. Equilibrium division of labor lowers unit production costs. In Taylor (1994a, 1994b), however, absolute advantage does not play a significant role, but in this model it does.

The rest of the paper is organized as follows. Section 2 first characterizes the efficient division of labor and then develops the general equilibrium model. Section 3 provides some comparative statics focusing on the effects an IT progress and relative labor supply. Section 4 provides some concluding remarks and thoughts on possible directions of future research.

2. THE MODEL

In this section I build up the model based on the continuum-good Ricardian model of Dornbusch, *et al.* (1977), where the goods are indexed by z over the support [0,1]. There are two countries, home and foreign, and I often use variables of the home country to describe the economy. The foreign variables are denoted with an asterisk.

2.1. Production technology

In the absence of division of labor, the unit labor requirement of producing good z in the home country is $a(z, 1)$, $z \in [0, 1]$. Production of good z, however, can also be divided into n subtasks to produce n components first and then they are assembled into the final good. Instead of having to perform the broad task of producing a good, workers now only need to do a particular single subtask. Such production specialization will increase production efficiency due to the division of labor (in the spirit of Adam Smith's pin-factory story).

2.1.1. Smithean Division of labor.—

For the sake of simplicity, suppose that all components are divided in such a way that the unit labor requirement of producing each component is the same,

$$d(z, n) = \frac{a(z, 1)}{n} K(z)^{n-1}, \quad 0 < K(z) < 1, z \in [0, 1] \tag{1}$$

where $K(z)$ is a technological parameter for division of labor, indicating the level of *industrial* technology. The lower the value of $K(z)$, the better the technology. Notice that $1 - K(z)^{n-1}$ measures the efficiency gain due to the division of labor in production. For

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example, when $n = 1$, $d(z, 1) = a(z, 1)$ since there is no production specialization; when $n = 2$, $d(z, 2)$ is equal to $K(z)$ fraction of $a(z, 1)/2$ because of the efficiency gain from the division of labor.

2.1.2. Production coordination and efficient production specialization.—

There is coordination cost associated with subdividing production process and assembly of components. The larger the number of subdivided tasks, the higher the total coordination costs. The costs of production coordination are often affected by more general technology (e.g., communication/information technology, or other general-purpose technology), rather than the specific industrial technology.

Suppose that $y(z)_i$, $i = 1, ..., n$, is the amount of ith component used in producing good z, and that $x(z, n)$ is the output of good z. Assume that the subdivided components are exclusive to each other in the sense that substitution is not allowed among them.[7] Production of final goods from components is assumed to follow the following augmented Leontief production function,

$$x(z, n) = [1 - (n - 1)\Gamma(z)] \min\{y(z)_1, y(z)_2, ..., y(z)_n\}, \ 0 < \Gamma(z) < 1, z \in [0, 1] \quad (2)$$

where $\Gamma(z)$ is a technological parameter for production coordination. Notice that $(n-1)\Gamma(z)$ measures the coordination cost, in units of $x(z, n)$, associated with the specialization of production of good z.

Efficient assembly requires that $y(z) \equiv y(z)_1 = ...y(z)_n$ and therefore, (2) becomes

$$x(z, n) = [1 - (n - 1)\Gamma(z)]y(z), \qquad z \in [0, 1] \quad (3)$$

For example, when $n = 1$, we have $x(z, 1) = y(z)$ since no assembly of components is required; when $n = 2$, one unit of each component together can only produce $1 - \Gamma(z)$ unit of final good z.

In this paper I assume that division of labor takes place within a firm.[8] From (3), to produce one unit of good z requires $1/[1 - (n-1)\Gamma(z)]$ units of each component. Therefore,

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[7] This is more relevant to vertical specialization in production. In this paper we do not focus on the difference between vertical and horizontal specialization.

[8] See further discussion about this assumption in Section 4.

the unit labor requirement for producing good z is [using (1)],

$$
\begin{aligned}
a(z,n) &= \frac{nd(z,n)}{1-(n-1)\Gamma(z)} \\
&= a(z,1)\frac{K(z)^{n-1}}{1-(n-1)\Gamma(z)}, \qquad z \in [0,1]
\end{aligned}
\tag{4}
$$

Given that we have both the efficiency gain and the coordination cost associated with production specialization, the efficient level of specialization (or the division of labor) is endogenously determined by the following optimization problem:

$$
\begin{aligned}
n_e(z) &\equiv \arg\min_{n} a(z,n) = a(z,1)\frac{K(z)^{n-1}}{1-(n-1)\Gamma(z)} \\
&= 1 + \frac{1}{\Gamma(z)} + \frac{1}{\ln K(z)}, \qquad z \in [0,1]
\end{aligned}
\tag{5}
$$

Given the existing technology, $K(z)$ and $\Gamma(z)$, firms have to choose $n = n_e(z)$ to produce good z in order to stay competitive. Notice that if coordination and assembly have no costs (i.e., $\Gamma(z)$ is close to zero), firms will choose a very high level of production specialization (i.e. $n_e(z)$ will approach infinitive) to take advantage of the efficiency gain from the division of labor. This is a very important point that was missed by Adam Smith. Smith only recognized that division of labor is limited by the extent of the market. He failed to realize that division of labor is also intrinsically limited by the technology in production coordination. The latter is important and probably more relevant today.

From (5) it is straightforward to show that (noticing that $\ln K(z) < 0$),

$$
\frac{dn_e}{d\Gamma(z)} < 0 \text{ and } \frac{dn_e}{dK(z)} < 0.
\tag{6}
$$

Therefore, we have the following proposition.

Proposition 1 *A reduction of the coordination cost and/or a rise in the efficiency gain of division of labor increases the efficient level of production specialization (or division of labor).*

Proposition 1 is simple but fundamental. It suggests that a key economic force behind the current phenomenon in international trade and production (e.g., fragmentation,

outsourcing, vertical/horizontal specialization, etc.) could be the recent revolution in communication/information technology.

From (5) notice that with a different $\Gamma'(z)$, we can always find a corresponding $K'(z)$ that gives us the same $n_e(z)$. Thus we can let the parameter of the industrial technology, $K(z)$, to capture the difference in the technology that is sector-specific, and let the technological parameter for production coordination, $\Gamma(z)$, to capture the role of *communication/information* technology that in general affects all sectors. Specifically, for the rest of the analysis I assume $\Gamma(z) = \gamma$ for all z and the corresponding $K'(z) = k(z)$. Therefore, (4) becomes,

$$
\begin{aligned}
a(z, n_e) &= a(z, 1)\frac{(k(z))^{n_e - 1}}{1 - (n_e - 1)\gamma} \\
&= a(z, 1)\phi(z, n_e), \qquad z \in [0, 1]
\end{aligned}
\tag{7}
$$

where $\phi(z, n_e) \equiv \frac{(k(z))^{n_e-1}}{1-(n_e-1)\gamma}$.

Applying the envelope theorem to (7), we obtain the following results.

Proposition 2

$$
\frac{da(z, n_e)}{d\gamma}\frac{\gamma}{a(z, n_e)} = \frac{(n_e(z) - 1)\gamma}{1 - (n_e(z) - 1)\gamma} > 0 \ \textit{and is increasing in } n_e(z).
$$

A progress in information technology that reduces the coordination cost increases production efficiency. The efficiency gain, however, is different across sectors, depending on the level of production specialization. The higher the level of production specialization that a sector has, the greater the gain of its production efficiency. The second point is important for the results of our subsequent analysis.

2.2. Market structure, goods prices, and comparative advantage

Assume that perfect competition prevails. If good z is produced in the home country, then its price becomes

$$
\begin{aligned}
p(z, n_e) & = wa(z, n_e) \\
& = wa(z, 1)\phi(z, n_e) \\
& = wa(z, 1)\frac{(k(z))^{n_e - 1}}{1 - (n_e - 1)\gamma}, \qquad z \in [0, 1]
\end{aligned}
\tag{8}
$$

where w is the wage rate in the home country. To focus on the effects due to the common shock (progress/innovation) in information technology, I assume $\gamma^* = \gamma$. Thus, if good z is produced in the foreign country, its price becomes,

$$
\begin{aligned}
p^*(z, n_e^*) & = w^*a^*(z, n_e^*) \\
& = wa^*(z, 1)\phi(z, n_e^*) \\
& = w^*a^*(z, 1)\frac{(k^*(z))^{n_e^* - 1}}{1 - (n_e^* - 1)\gamma}, \qquad z \in [0, 1]
\end{aligned}
\tag{9}
$$

With perfect competition and zero transport cost, good z will be produced at the home country if and only if

$$
wa(z, n_e) \leq w^*a^*(z, n_e^*), \text{ or } \omega \equiv \frac{w}{w^*} \leq \frac{a^*(z, n_e^*)}{a(z, n_e)} \equiv A(z, n_e, n_e^*)
\tag{10}
$$

where $\omega \equiv w/w^*$ is the relative wage and $A(z, n_e, n_e^*) \equiv a^*(z, n_e^*)/a(z, n_e)$ is the relative unit labor requirement. Furthermore,

$$
\begin{aligned}
A(z, n_e, n_e^*) & \equiv a^*(z, n_e^*)/a(z, n_e) \\
& = \frac{a^*(z, 1)}{a(z, 1)}\frac{\phi^*(z, n_e^*)}{\phi(z, n_e)} \\
& = A(z, 1, 1)\Phi(z, n_e, n_e^*)
\end{aligned}
\tag{11}
$$

where $A(z, 1, 1) \equiv a^*(z, 1)/a(z, 1)$ and $\Phi(z, n_e, n_e^*) \equiv \phi^*(z, n_e^*)/\phi(z, n_e)$. Notice that $A(z, 1, 1)$ is the relative unit labor requirement in the absence of division of labor (as in Dornbusch, et al. 1977).

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Similar to Young (1991), I rank goods hierarchically by their level of technical sophistication. For being analytically tractable, I use the following assumptions.

Assumption 1: $a(z,1)$ *and* $a^*(z,1)$ *are increasing but* $k(z)$ *and* $k^*(z)$ *are decreasing in* z.

Assumption 2: $a^*(z,1)/a(z,1)$ *and* $k^*(z)/k(z)$ *are decreasing in* z.

Assumption 3: $k^*(z)$ *and* $k(z)$ *are crossing, and* $k^*(z_k)/k(z_k) = 1, z_k \in (0,1)$.

These three assumptions are fairly intuitive. First, a more sophisticated good has a higher unit labor requirement when there is no division of labor. But its efficiency gain from the division of labor is also higher (it isn't much the efficiency gain from dividing a simple production process into several subtasks). Using (5), we can also show that the efficient level of division of labor, n_e, is increasing in z. Secondly, the home country's *initial* (i.e. without the division of labor) comparative advantage is diminishing in z, which could be attributed to the difference in human capital between the two countries. Furthermore, the pattern of the initial comparative advantage and the industrial technology (in the division of labor) is positively correlated, although not perfectly so.[9] Thirdly, the home country has an absolute advantage in the division of labor in the less sophisticated goods ($z \in [0, z_k)$), and the foreign country in the more sophisticated goods ($z \in (z_k, 0]$). This difference could simply result from learning-by-doing in production. It will be clear that our analysis will include the special (and relatively simple) case in which one country has an advantage in the division of labor for all goods. The $k^*(z)$ *and* $k(z)$ curves are illustrated 1n **Figure 1.**

From Assumption 2, the $A(z,1,1)$-curve is decreasing in z as depicted in **Figure 2**. To draw the $A(z, n_e, n_e^*)$-curve, we have to find out how the presence of $\Phi(z, n_e, n_e^*)$ in (11) deforms the $A(z,1,1)$-curve. Using the envelope theorem, (7) and (5), we obtain that

$$
\begin{aligned}
\frac{z}{\Phi(z, n_e, n_e^*)} \frac{d\Phi(z, n_e, n_e^*)}{dz} &= \frac{d\phi^*(z, n_e^*)}{dz} \frac{z}{\phi^*(z, n_e^*)} - \frac{d\phi(z, n_e)}{dz} \frac{z}{\phi(z, n_e)} \\
&= (n_e^* - 1)\frac{k^{*\prime}(z)}{k^*(z)} - (n_e - 1)\frac{k'(z)}{k(z)} \quad (12) \\
&= (1/\gamma + 1/\ln k^*(z))\frac{k^{*\prime}(z)}{k^*(z)} - (1/\gamma + 1/\ln k(z))\frac{k'(z)}{k(z)}
\end{aligned}
$$

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[9]This is similar to the assmption in Taylor (1994a, 1994b) that a country's pattern of comparative advantage in goods and R&D production is positively correlated.

Notice that when $z = z_k$ (i.e. $k^*(z) = k(z)$), we have $\Phi(z, n_e, n_e^*) = 1$ and $d\Phi(z, n_e, n_e^*)/dz <$ 0 since $k^{*\prime}(z)/k^*(z) < k'(z)/k(z)$ from Assumption 2. Also, it is not difficult to show that the solution of $\Phi(z, n_e, n_e^*) = 1$ is unique. Thus, $\Phi(z, n_e, n_e^*) > 1$ when $z < z_k$ and $\Phi(z, n_e, n_e^*) < 1$ when $z > z_k$. Therefore, $A(z, n_e, n_e^*)$ is above $A(z, 1, 1)$ when $z < z_k$, and $A(z, n_e, n_e^*)$ is below $A(z, 1, 1)$ when $z > z_k$, as illustrated in **Figure 2**.

From (10), for a given relative wage ω, the home (*resp.* foreign) will produce the goods in the range of $0 \le z \le \widetilde{z}(\omega)$ (*resp.* $\widetilde{z}(\omega) \le z \le 1$). The competitive margin is determined by

$$\widetilde{z} = A^{-1}(\omega) \tag{13}$$

where $A^{-1}(\omega)$ is the inverse function of $A(z, n_e, n_e^*)$.

2.3. Demand, Trading equilibrium, and competitive margin

The two countries are populated with L and L^* consumers, respectively, and each supplies one unit of labor. All consumers have the same Cobb-Douglas utility function,

$$u = \int_0^1 b(z) \ln x(z) dz \tag{14}$$

where $x(z)$ is the consumption of good z, and $b(z)$ is the share of expenditure on good z, with $\int_0^1 b(z) dz = 1$. From (13), suppose the home country produces the goods in the range $[0, \widetilde{z})$. Then, the fraction of income spent on the goods produced by the home country is $\vartheta(\widetilde{z}) \equiv \int_0^{\widetilde{z}} b(z) dz$, in both countries, and that by the foreign country is $\int_{\widetilde{z}}^1 b(z) dz = 1 - \vartheta(\widetilde{z})$. Balance-of-trade requires,

$$(1 - \vartheta(\widetilde{z}))wL = \vartheta(\widetilde{z})w^*L^* \tag{15}$$

Rearranging (15) yields

$$\omega = \frac{\vartheta(\widetilde{z})}{1 - \vartheta(\widetilde{z})}(L/L^*) \equiv B(\widetilde{z}, L^*/L) \tag{16}$$

where $B(z, L^*/L)$ is increasing in z.

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Figure 3 combines both the demand and the supply side, and the equilibrium is determined by the intersection of $B(z, L^*/L)$-curve and $A(z, n_e, n_e^*)$-curve:

$$\overline{\omega} = A(\overline{z}, n_e, n_e^*) = B(\overline{z}, L^*/L) \tag{17}$$

where $\overline{\omega}$ is the relative wage and $\overline{z}$ is the competitive margin in equilibrium.

3. IT PROGRESS, COMPETITIVE MARGIN, AND LABOR SUPPLY

To determine how a progress in information technology affects the equilibrium outcome, we have to find out about the effect of a change in γ on $A(z, n_e, n_e^*)$-curve. Using (5) and Proposition 2, we obtain

$$
\begin{aligned}
\frac{\gamma}{A(z, n_e, n_e^*)} \frac{dA(z, n_e, n_e^*)}{d\gamma} &= \frac{da^*(z, n_e^*)}{d\gamma} \frac{\gamma}{a^*(z, n_e^*)} - \frac{da(z, n_e)}{d\gamma} \frac{\gamma}{a(z, n_e)} \\
&= \frac{(n_e^*(z) - 1)\gamma}{1 - (n_e^*(z) - 1)\gamma} - \frac{(n_e(z) - 1)\gamma}{1 - (n_e(z) - 1)\gamma} \\
&= -(1 + \frac{\ln k^*(z)}{\gamma}) + (1 + \frac{\ln k(z)}{\gamma}) \\
&= (1/\gamma) \ln[k(z)/k^*(z)]
\end{aligned}
\tag{18}
$$

Thus, together with Assumptions 2 and 3 we have the following result.

Proposition 3

(i) $\dfrac{dA(z, n_e, n_e^*)}{d\gamma}|_{z=z_k} = 0$; *(ii)* $\dfrac{\gamma}{A(z, n_e, n_e^*)} \dfrac{dA(z, n_e, n_e^*)}{d\gamma}$ *is increasing in z for all* $z \in [0, 1]$.

At $z = z_k$, a reduction in γ has no effect on the relative unit labor requirement. A reduction in γ, however, will improve a country's comparative advantage for the goods for which it has absolute advantage in the division of labor.[10] That is, $\frac{\gamma}{A(z, n_e, n_e^*)} \frac{dA(z, n_e, n_e^*)}{d\gamma} < 0$ for $z < z_k$, and $\frac{\gamma}{A(z, n_e, n_e^*)} \frac{dA(z, n_e, n_e^*)}{d\gamma} > 0$ for $z > z_k$. Furthermore, the greater the absolute advantage in the division of labor, the larger the improvement of its comparative advantage.

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[10] Suppose that $A(z, 1, 1)$ is horizontal by ignoring the initial difference, then an absolute advantage in the division of labor represents an absolute advantage in production of goods.

The intuition for the second point can be found in Proposition 2. A progress in IT reduces the labor requirement of each subtask (including the initial decomposing and the final assembly), and such cost saving multiplies as the number of subtasks increases. On the other hand, a greater absolute advantage in the division of labor results in a larger number of subtasks in producing the good.

Diagrammatically, the $A(z, n_e, n_e^*)$-curve tilts clockwise at point $A(z_k, n_e, n_e^*)$ when there is a reduction in γ. Since in general z_k does not coincide with $\overline{z}$, the effect on the competitive margin (i.e. $\overline{z}$) depends on whether z_k is larger or smaller than $\overline{z}$. When $\overline{z} < z_k$, a reduction in γ moves $\overline{z}$ to the right, increasing the range of goods produced by the home country (**Figure 4**). When $\overline{z} > z_k$, it moves $\overline{z}$ to the left, increasing the range of goods produced by the foreign country (**Figure 5**). Therefore, we obtain the following proposition.

Proposition 4 *When $\overline{z} < z_k$ (resp. $\overline{z} > z_k$), an IT progress increases the home (resp. foreign) country's competitive margin, i.e. $d\overline{z}/d\gamma < 0$ (resp. $d\overline{z}/d\gamma > 0$).*

So what determines whether $\overline{z} < z_k$ or $\overline{z} > z_k$? One important variable is the relative labor supply, L^*/L. From (16), an increase in L shifts the $B(z, L^*/L)$-curve downward, moving $\overline{z}$ to the right. The intuition is as follows. For instance, when the labor supply in the home country is large relative to the foreign country, its wage becomes relative low, *cetaris paribus*. The lower wage will help the home country increase its competitive margin beyond z_k. For the goods in the range $(z_k, \overline{z})$, however, the foreign country has an absolute advantage in the division of labor. Therefore, a progress in IT will help the foreign country to recover some of its competitive margin lost due to the lower wage (or larger labor supply) in the home country. In summary,

Proposition 5 *An IT progress tends to reduce (resp. increase) the competitive margin of the economy of a larger (resp. smaller) labor supply.*

These results may shed light on the U.S. economy (and some other DCs) that has maintained its competitiveness *vis-a-vis* other low-wage LDCs during the last two decades. In

addition to the fact that DCs usually have better IT, our results show that even if all countries could access the same IT, the recent IT revolution may benefit DCs in gaining back some of its competitive margin lost in trade with low-wage economies.

Finally, from (18), notice that $\frac{\gamma}{A(z,n_e,n_e^*)} \frac{dA(z,n_e,n_e^*)}{d\gamma}$ is decreasing in γ. Therefore, the effects of the results in Propositions 3-5 are greater when γ becomes lower. In particular, following Proposition 5 we conclude

Proposition 6 *Continuing IT progresses will accelerate, rather than slow down, the speed in losing (resp. gaining) its competitive margin of the economy of a larger (resp. smaller) labor supply.*

4. CONCLUDING REMARKS

This paper presents a Smith-Ricardo model that incorporates division of labor into the continuum-good Ricardian model to explain the impact of the recent IT revolution on a country' pattern of production specialization and international trade. Unlike its predecessor (i.e. the Ricardian model of Dornbusch, et al. 1977), this Smith-Ricardo model retains Smith's spirit in that the absolute advantage (in division of labor) plays a crucial role in determining the effects of an IT progress on a country's competitive margin in international trade.

Given the relative simplicity of the model and the useful continuum-good Ricardian approach, this Smith-Ricardo structure could be relatively easily extended to examine other issues. For instance, like Taylor (1994a, 1994b) one can introduce R&D in innovation to make technology progress endogenous. Also, in the model we assume that division of labor takes place within a firm. As long as components are *not* traded in the international market, however, this specification is equivalent to the case in which firms can purchase their intermediate components from competitive domestic suppliers. It would be interesting to investigate an extension that allows international trade in the intermediate components.

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References

Brynjolfsson, E., Malone, T.W., Gurbaxani, V., and Kambil, A., 1994, "Does information technology lead to smaller firms?", *Management Science* v40(12), pp1628-1644.

Campa, J. and Goldberg, L., 1997, "The evolving external orientation of manufacturing industries: evidence from four contries," NBER Working Paper No. 5958.

Hanson, G. H., Mataloni Jr., R. J., and Slaughter, M.J., "Expansion strategies of U.S. multinational firms," NBER Working Paper No. 8433.

Chen, Y., J. Ishikawa and Z. Yu, "Trade Liberalization and Strategic Outsourcing", *Journal of International Economics,* 2003 *(forthcoming).*

Cheng, Leonard K. and Henryk Kierzkowski, 2001, Global Production and Trade in East Asia*, Kluwer Academic Press, London.

Cheng, W. Sachs, J. and Yang, X. 2000, "An inframarginal Analysis of the Ricardian Model", *Review of International Economics* v8(2), pp208-220.

Dornbusch, R., Fishcher, S., and Samuelson, P.A., 1977, "Comparative advantage, trade, and payments in a Ricardian model with a continuum of goods", *American Economic Review,* v67, pp823-839.

Ethier, W., "Decreasing costs in international trade and Frank Graham's argument for protection", *Econometrica,* September 1982, v50 (5), pp-1243-68.

Feenstra, Robert C. and Gordon H. Hanson, 1996b, "Globalization, outsourcing and wage inequality." *American Economic Review* 86, 240-245.

Feenstra, Robert C. 1998, "Integration of trade and disintegration of production in the global economy", *Journal of Economic Literature,* v12(4), pp31-50.

Grossman, Gene and Elhanan Helpman, 1989, "Product development and international trade", *Journal of Political Economy, v97, pp1261-1283.*

Grossman, Gene and Elhanan Helpman, 1990, "Comparative advantage and long-run growth", *American Economic Review, v80, pp796-815.*

Grossman, Gene and Elhanan Helpman, 1991, "Quality ladders in the theory of growth", *Review of Economic Studies,* v58, pp43-61.

Grossman, Gene and Elhanan Helpman, 2002, "Outsourcing in a global economy", *NBER*

Research Paper No. 8728.

Hummels, D., Ishii, J. and Yi, K. 2001, "The nature and growth of vertical specialization" *Journal of International Economics* v54, pp75-96.

Jones, Ronald W., 2000, *Globalization and the Theory of Input Trade*, MIT Press, Cambridge.

Jones, Ronald W. and Henryk Kierzkowski. 2001, "Globalization and the consequences of international fragmentation." in R. Dornbusch, G. Calvo, and M. Obstfeld, eds., *Money, Factor Mobility, and Trade: The Festschrift in Honor of Robert A. Mundell*, MIT Press, Cambridge.

Kambil, A., 1991, "Information technology and vertical integration: evidence from the manufacturing sector" in *Electronic services networks: A business and public policy challenge,* edited by Guerin, C., Margeret, E., and Wildman, S.S., Praeger: London.

McLaren, John, 2000, "Globalization and vertical structure." *American Economic Review* *v*90, 1239-1254.

Romer, P. 1986, "Increasing returns and long run growth" *Journal of Political Economy* v94, pp1002-37.

Romer, P. 1990, "Endogenous technological change" *Journal of Political Economy* v98, S71-S102.

Schmitt, N. and Yu, Z. 2001, "Economies of scale and the volume of intra-industry trade", *Economic Letters,* v74, pp127-132.

Schmitt, N. and Yu, Z. 2002, "Horizontal intra-industry trade and the growth of international trade" Chapter 3 in *Frontiers of Research in Intra-industry Trade,* edited by Lloyd, P. and Lee, H., Palgrave: London.

Stigler, George J. 1951, "The division of labor is limited by the extent of the market", *Journal of Political Economy* v59, pp185-193.

Smith, Adam, 1776, *An Inquiry into the Nature and Causes of the Wealth of Nations,* Reprinted, edited byE. Cannan, Chicago: University of Chicago, 1976.

Taylor, M.S. 1994a, "'Quality ladders' and Ricardian trade", *Journal of International Economics,* v34, pp225-243.

16

Taylor, M.S. 1994b, "'Once-off' and continuing gains from trade", *Review of Economic Studies,* v61, pp589-601.

Yang, X. 1998, "Specialization and division of labor: a survey" Chapter 1 in *Increasing Returns and Economic Analysis,* edited by Arrow, K., Ng, Y., and Yang, X. Macmillan: London.

Young, A. 1991, "Learning by doing and the dynamic effects of international trade", *Quarterly Journal of Economics,* v106, pp-369-405.

Yi, Kei-Mu, 2003, "Can vertical specialization explain the growth of world trade?", *Journal of Political Economy,* v111(1), pp-52-102.

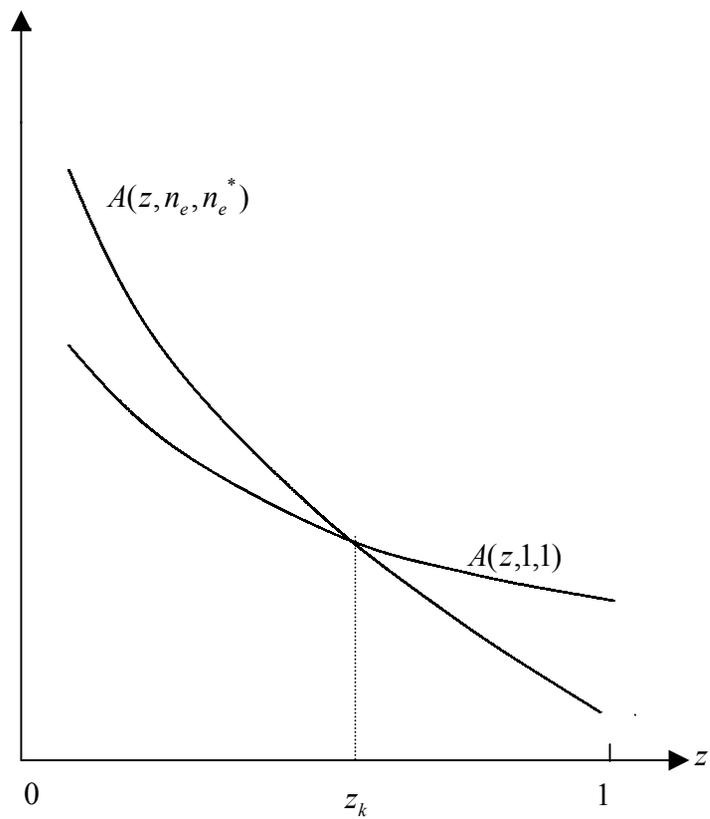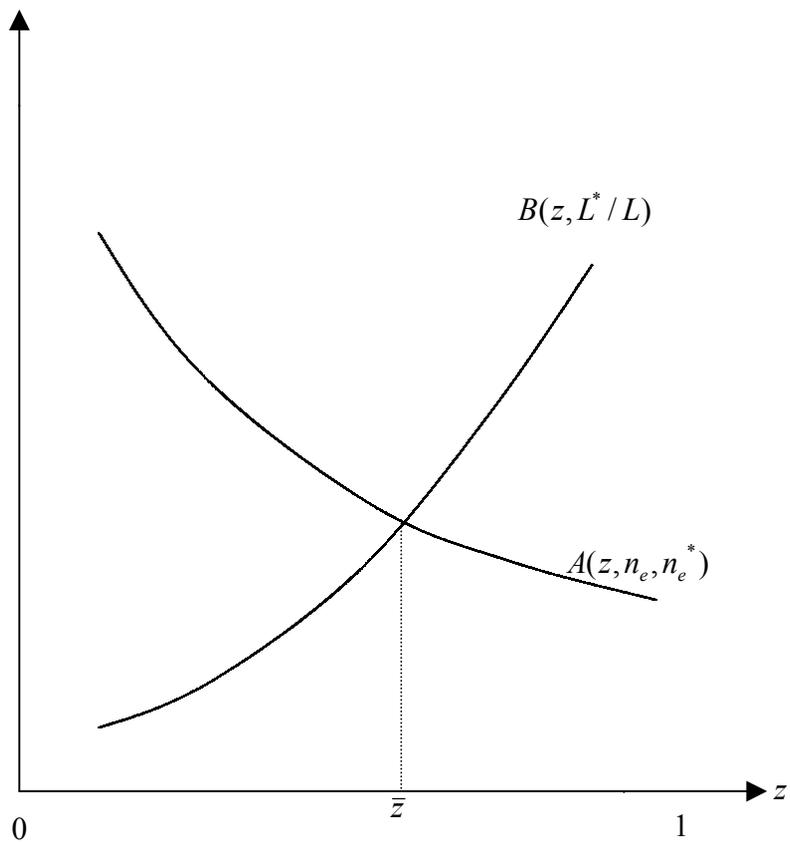Zhao, Laixun, 2001, "Unionization, vertical markets, and outsourcing." Journal of International Economics 55*, 187-202.*
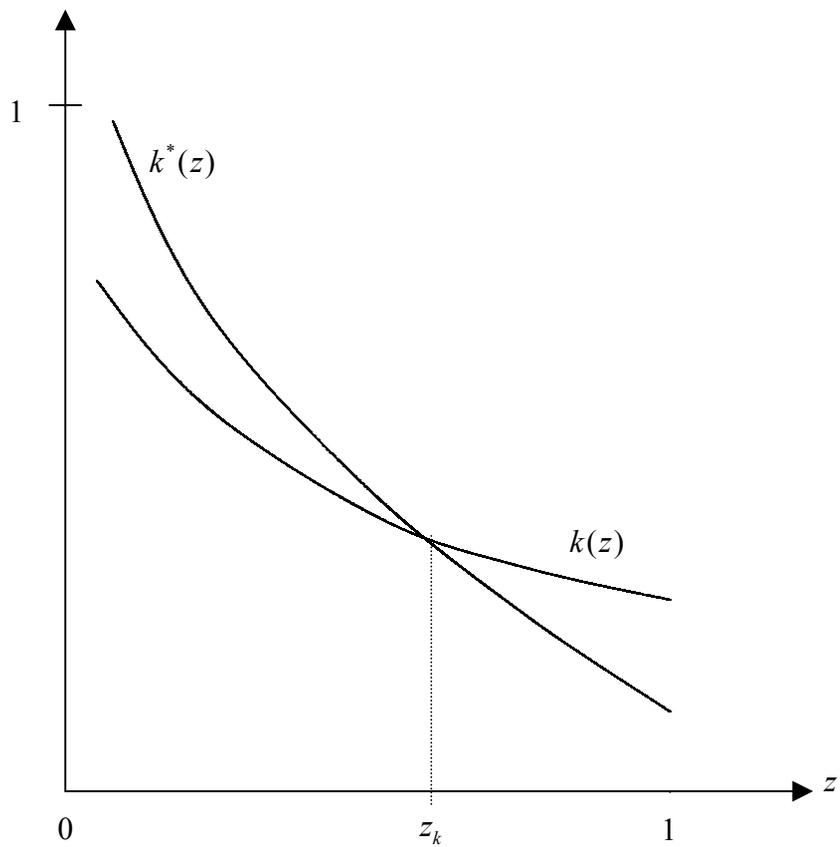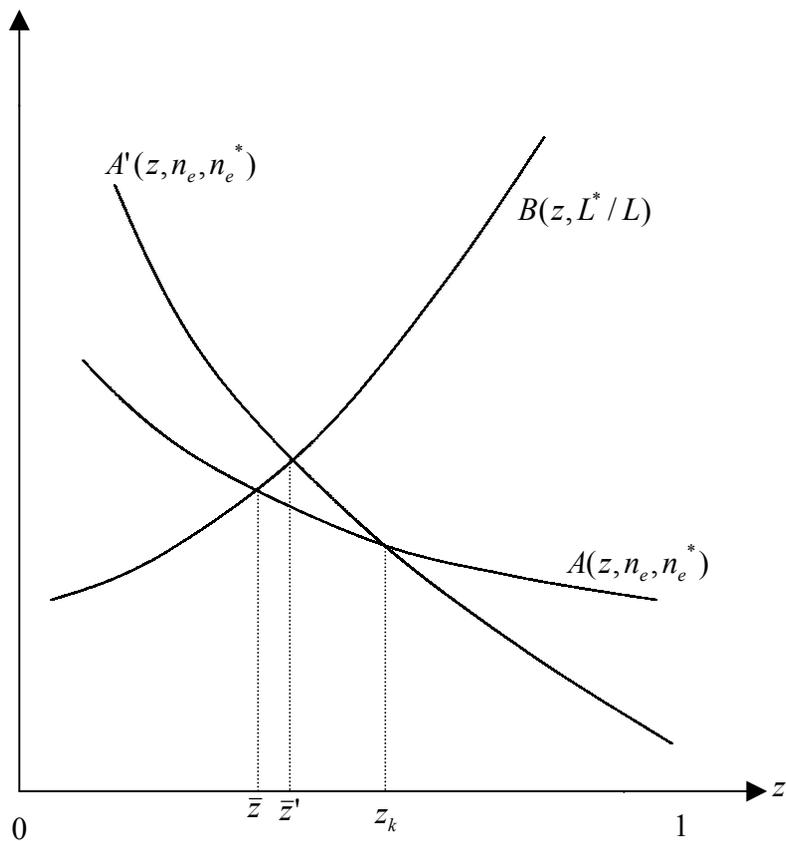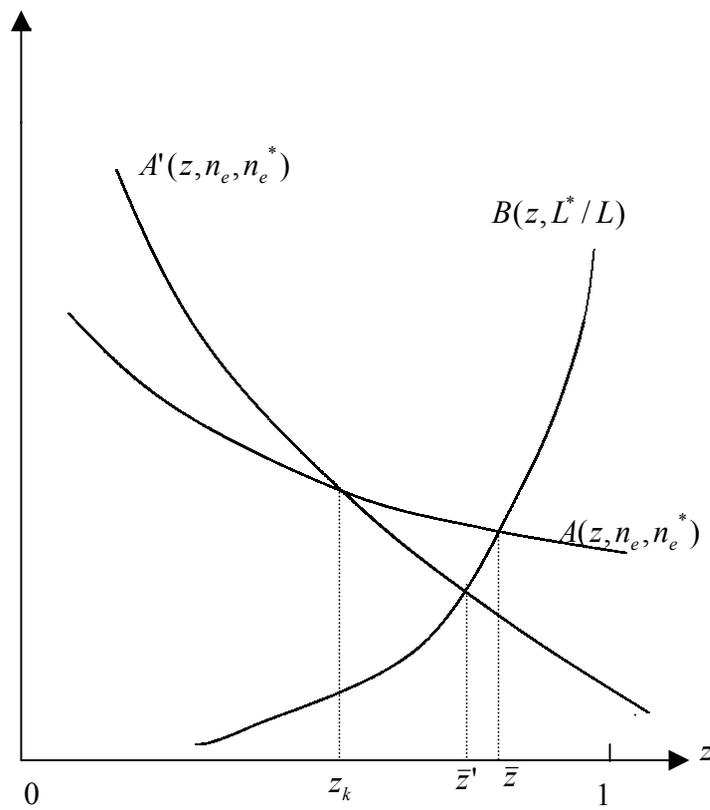
Figure 1

Figure 2

Figure 3

Figure 4

Figure 5