

**TARIFF VS. EXPORT SUBSIDY:
AN ENDOGENOUS GROWTH PERSPECTIVE***

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This paper presents an endogenous growth model of an open economy in an intra-industry trade framework. The model is a revised version of the influential work by Rivera-Batiz and Romer (1991a, 1991b) with two distinguishing features: i) an assumption of asymmetry between the two countries engaged in trade, and ii) the long run growth effects of trade policy interaction, particularly tariff protection and export subsidy. With this model, the following three novel features can be derived: 1) the long run growth rate of a country is correlated positively with the factor endowment of its trade partner 2) export subsidy can enhance the long run growth rate; 3) the net effect of export subsidy can even surpass the counter-effect of foreign import tariffs.

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I. INTRODUCTION

Recent development of the endogenous growth theory has revitalized international trade theory. This endogenous growth theory can be divided into two categories: learning by doing models and invention models driven by R&D activities. Both exhibit: economies of scale due to external economies or spill over effects. It is true that specialization driven by economies of scale is just as important as comparative advantage due to differences in resource endowment and exogenous differences in technology. Along this line of research, often qualified as new international

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trade theory, it is often recommended that protection or promotion is better than free trade. But, if one wishes to measure correctly the efficiencies of protectionism, one needs to consider the reactions of trading partners. This is even more necessary when seeking the long run efficiencies of protectionism. This paper investigates this possibility: trade policy aimed to gain unilateral benefit is reconsidered when there is retaliation by a trade partner. To incorporate this idea, we examine the effects of policy interactions on long run growth within the framework of an intra-industry trade model. This model is a revised version of the international technology transfer model of Rivera-Batiz and Romer (1991a and 1991b, hereafter RBR). One distinguishing feature is the assumption of asymmetry in terms of factor endowment between the two countries engaged in trade. Allowing for asymmetry in the RBR model, we show how the effects of export subsidy on the long run growth rate vary when there is foreign tariff protection.

The introduction of an export subsidy is based on the fact that even though it is sanctioned by international organizations such as the WTO, the export subsidy is common practice in the real world (but not easily detected, especially when it takes on, for instance, the form of a preferential bank loan).

With respect to international technology transfer, much literature relies on the theory of product life cycle (Vernon, 1966), in which many products are initially discovered and produced in developed countries (the North), exported to less developed countries (the South) and then, eventually produced there as the techniques of production become more standardized. Krugman (1979) first incorporated this idea in an innovation-imitation process in a North-South trade model. But he assumed that innovation and imitation rates are exogenous parameters. In some literature (e.g. Jensen and Thursby (1987); Segerstorm, Anant, and Dinopoulos (1990); Grossman and Helpman (1990)), these parameters are endogenized in dynamic general equilibrium models of North-South trade. Innovation in these models is defined as new product development which can be accomplished only by the North. Thus, these authors could not yield informative insight for what happens in the case of 'intra-industry trade', which is increasing in importance and can be easily observed in trade among developed countries, such as member countries of the European Union. RBR (1991b) presents an exceptional model which conforms (albeit quite loosely) to this question.

Using their celebrated "Knowledge Driven Specification (henceforth KDS)" of innovation, RBR (1991b) have shown that trade between similar countries can boost worldwide growth. However, at least two drawbacks could be pointed out in their KDS model: assumptions of symmetry and functional specification in the R&D sector. The first assumption, an identical factor endowment between two countries engaged in trade, is a serious limitation. The second concerns what is called "(intertemporel) scale effects", shown in the functional specification in the R&D sector. Knowledge capital or technology A , according to KDS in RBR(1991a, 1991b), is created by engaging human capital H in research and applying the existing technology A as follows: $\dot{A} = \delta HA$. Knowledge capital A is a nonrival good in

the sense that its use by one firm does not limit its use by others. So this nonrivalry feature of technology implies complete knowledge spillovers. There are a number of counterfactual aspects to this specification. First, knowledge can not be gratuitous, as we know well from educational expenses.¹ Furthermore, in an open economy, the notion that knowledge flows freely worldwide is not true. According to Lichtenberg's empirical study (1992), international knowledge spillovers are neither complete nor instantaneous. Secondly, following the functional forms in the R&D sector of KDS, *i.e.* $\dot{A} = \delta H A$, the long run growth rate is determined exclusively by the stock of human capital H . This scale effect implies that an increase in the level of resources devoted to R&D should increase the growth rate of the economy.² However, such a prediction is clearly at odds with empirical evidence. Even though the number of scientists engaged in R&D in advanced countries has grown dramatically over the last 40 years, growth rates have either exhibited a constant mean or have even declined on average (Jones, 1995). Therefore, virtually all of the R&D based growth models in the literature are inconsistent with this simple observation. Presumably, however, this inconsistency is not detrimental to the spirit of R&D based growth literature. A plausible model could be constructed that eliminates the prediction of scale effects and the assumption that knowledge flows freely worldwide, while maintaining the other features. This is the reason why we adopt "Lab Equipment Specification (hereafter LES)" of RBR (1991a), in which knowledge *per se* has no productive value, hence international flows of knowledge have no economic effect. (We can, therefore, deliberately exclude the assumption of free flow of knowledge). The only way to transfer technology (knowledge) is to trade intermediate goods. Our modified version is different from the original LES in that it: 1) abandoned symmetry assumption between the two countries, and 2) examines impacts of export subsidies on the growth rate, in the presence of foreign tariff protection. The contributions and differences in the results from previous studies will be discussed throughout the analysis.

This paper is organized as follows. Section II describes LES embedded with trade of intermediate inputs. Section III extends the model to a case when two countries engaged in trade have different factor endowments. Section IV analyzes the growth effects of export subsidies, especially in the presence of foreign tariff protection. Section V offers conclusions.

II. THE BASIC MODEL

This section first discusses the model of a closed economy in which capital

¹ Schmookler (1966) pointed out that when one distinguishes knowledge creating activity and knowledge transmission activity, a society engages in more efforts to transmit knowledge as one confirms in education activity.

² The R&D based models in the endogenous growth literature by Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992), and others share this counterfactual prediction of scale effect.

goods are not traded. Then, the model is extended to an open economy where an imported foreign capital good is an important input to the production of a domestic good.

2.1. Production

2.1.1 Manufacturing Sector

Consider a country that is assumed to have the same features of the endogenous growth model as that of Romer(1990). The fundamental assumptions are: many types of capital goods are used in production, these are not perfect substitutes, and technological progress arises from the invention of new types of capital goods. The economy has two types of manufacturing activities: production of consumption goods and production of the physical units of the types of capital goods that have already been invented. Both manufacturing activities are assumed to use the same production function. Let $x(i)$ denote the stock of capital good of type i that is used in production, and let A be the index of the most recently invented good. By the definition of A , $x(i) = 0$ for all $i > A$. Output Y is assumed to take the form,

$$Y = H^{\alpha} L^{\beta} \int_0^A x(i)^{1-\alpha-\beta} di, \quad (1)$$

where H is human capital, L is non-qualified labor, and a set of capital goods indexed by the variable i . Note that the index i is modeled as a continuous variable to avoid complications arising from integer constraints.

Since the production function for manufacturing consumption goods is the same as that for manufacturing units of any type of existing capital, the relative prices of consumption goods and all types of existing capital goods are fixed by technology. For simplicity, we assume that one unit of forgone consumption generates one unit of any capital good. Let K denote the total amount of capital goods existing in the economy. Fixed prices imply that the aggregate capital stock $K = \int_0^A x(i) di$ is well defined, as is aggregate output Y . Because all of the different $x(i)$ goods are produced according to the same production technology, this sum across different types of goods makes sense. It represents the cost of the total quantity of capital goods in units of forgone consumption goods, and is close to the usual national income account measure of total physical capital. As the production technology for consumption goods and for each different capital good is the same, total output in the manufacturing sector is the sum $Y = C + K$.

Given A , it follows by an assumption of symmetry that $x(i)$ will take on a common value $\bar{x} = K/A$ for $\forall i \in [0, A]$. Substituting the expression for x into equation (1) then yields

$$Y = H^{\alpha} L^{\beta} K^{1-\alpha-\beta} A^{\alpha+\beta} \quad (2)$$

Even though the production function for manufacturing goods described in equation (1) is homogenous of degree 1, this reduced form expression is homogenous of degree $1 + \alpha + \beta$ in L , H , A , and K . It is impossible, according to Euler's theorem, for this sector to be decentralized using perfect competition; paying each of the inputs L , H , K , A its marginal product would more than exhaust total output. The increasing returns to scale are decentralized in this model through imperfect competition. The producer of good i is the only supplier of this good. It therefore charges the monopoly price for it. Because of competition between different firms to produce good i , the present discounted value of the stream of the monopoly profits will be equal to the price that is paid for the design for good i . This is how compensation is generated for the research sector.

2.1.2. R&D Sector

The technology for producing designs for new capital goods is assumed to be the same as that for the manufacturing sector, i.e., R&D uses the same inputs as technology manufacturing, in the same proportions. Output of designs can be represented as

$$\dot{A} = BH^{\alpha} L^{\beta} \int_0^A x(i)^{1-\alpha-\beta} di, \quad (3)$$

where B denotes a constant scale factor.

In this setting, output of design, which is homogeneous of degree one, is the same as in the manufacturing sector. There is free entry into the R&D sector, as in the manufacturing sector. The only restriction is that no one can manufacture good i without the patent on good i . R&D activity is undertaken by separate firms that hire inputs, produce patentable designs, and sell them for a price P_A . Once the manufacturer purchases the patent (of design on good i) for this price, he can produce good i as much as he wants.

Since the production functions of the manufacturing sector (remember that since capital goods and consumption goods have the same technology, we integrated them into a single manufacturing sector in the last section) and the R&D sector are the same, the production possibility frontier is a straight line, as shown in the traditional one sector growth model. If the output of goods is reduced by one unit and the inputs released are transferred to the R&D sector, they yield B patents. Thus, the price P_A of a patent in terms of goods is determined on the technology side as $P_A = 1/B$.

As both the manufacturing and R&D sectors use the same technology, we can easily aggregate them into a single sector. Let L , H , and $x(i)$ denote the entire stock of inputs available in the economy at date t . Then we can express the value

of total output in terms of the total stock of inputs as follows,³

$$Y + \dot{A}/B = H^\alpha L^\beta \int_0^A x(i)^{1-\alpha-\beta} di. \quad (4)$$

2.2. Preference

The consumption side of this model assumes that the representative household maximizes an isoelastic utility function:

$$U = \int_0^\infty \{C^{1-\sigma}/(1-\sigma)\} e^{-\rho t} dt, \quad \sigma \in [0, \infty) \quad (5)$$

where σ is the elasticity of marginal utility, and ρ is the constant rate of time preference. In the steady state, the representative household chooses the optimal consumption growth path at the rate (see Appendix):

$$g = (r - \rho)/\sigma \quad (6)$$

where r is the interest rate denominated in terms of the consumption good.

2.3. Open economy under symmetry

This section describes the equilibrium in a world with two perfectly symmetric countries (in terms of their factor endowments) that impose the same tariff on all imported goods used in production.

More notation is needed to describe a model with trade in goods explicitly. Without trade, the quantity of an intermediate input i that is used in a country is identical to the amount that is produced, and both usage and domestically produced stock can be denoted by variable $x(i)$.⁴ With trade, however, production and usage in a country will differ. In what follows, $x(i)$ still denotes the stock of intermediate input i that has been produced by firms in the home country whereas $x^*(i^*)$ denotes the production of intermediate input i^* produced in the foreign coun-

³ It could be argued that one needs to add a coefficient 2 on the right hand side in eq. (4) taking into account eqs. (1) and (3). However, the right hand side represents, by definition, the total stock of inputs available in the economy, which is equal to the value of national income represented in the left hand side, i.e., the value of total production in manufacturing and research depends only on the aggregate stocks of inputs, not on their allocation between the two sectors. This is one of the main differences with respect to "Knowledge Driven Specification". In this regard, see RBR (1991b).

⁴ In an open economy, capital goods are assumed to be called intermediate inputs. This is in order to emphasize the function of capital goods as production factors, i.e., trade can give rise to access to a wider range of intermediate inputs available.

try.⁵ The goods indexed by i and i^* are completely different goods by assumption. Input 5 on the i list could be a hard disk made in Germany; input 5 in the i^* list could be an oscilloscope made in France. Particular intermediate inputs are placed on the i and i^* lists as they are introduced, according to the country in which they are discovered.

For a clear description of the use of intermediate inputs by a final output firm in the domestic country, it is useful to have a separate notation for domestically produced and imported inputs. Let $d(i)$ (*resp.* $m^*(i)$) denote domestic (*resp.* foreign) usage of intermediate inputs produced in the home country, and let $m(i^*)$ (*resp.* $d^*(i^*)$) denote home (*resp.* foreign) usage of intermediate inputs produced in the foreign country. Total domestic utilization of intermediate goods can then be expressed as $d(i) + m(i^*)$. By substituting into eq. (4), the total output in the home country, in the symmetric two-country environment, can be rewritten by

$$Y + A/B = H^\alpha L^\beta \left[\int_0^A d(i)^{1-\alpha-\beta} di + \int_0^{A^*} m(i^*)^{1-\alpha-\beta} di^* \right]. \quad (7)$$

Symmetrically, the total output for the foreign country is

$$Y^* + A^*/B^* = H^{\alpha^*} L^{\beta^*} \left[\int_0^{A^*} d^*(i^*)^{1-\alpha-\beta} di^* + \int_0^A m^*(i)^{1-\alpha-\beta} di \right] \quad (8)$$

The home country imports i^* goods while the foreign country imports i goods. Some portion of these goods are used at home, the rest are exported. A domestic producer of an i -type good buys a design from someone who has developed it in the research sector. Then, he maximizes profit, choosing a level of output $d(i)$ to supply the domestic market and a separate level of $m^*(i)$ to supply the foreign market.

The domestic government imposes a tariff τ on the imports m , so the price paid by domestic purchasers is $(1+\tau)$ times the price received by the foreign seller. The foreign government imposes a tariff τ^* . By the symmetry assumption, τ and τ^* are assumed to be the same, as are L and L^* and H and H^* . This symmetric assumption including the same tariff rates imposed by the two countries was first adapted by RBR (1991b) in their extended KDS model. Even though it seems to be a restrictive assumption, I still use this assumption in this modified LES version in order to show striking differences between the two specifications. Under this symmetric case, the trade balance equation is always satisfied automatically. To simplify the subsequent analysis, we set $L = L^* = 1$ hereafter.⁶

⁵ Foreign variables are given an asterisk.

⁶ One anonymous referee had pointed out that holding equal non-qualified labors and allowing differences in human capital stocks between two countries could be interpreted as differences in technology rather than differences in resource endowment, and that the same qualitative results would be obtained if we set $H = H^* = 1$.

The common interest rate in this case is given by (see Appendix),

$$r = B^{a+\beta} (a + \beta)^{a+\beta} (1 - \alpha - \beta)^{2-a-\beta} \left\{ 1 + (1 + \tau)^{\frac{-1}{a+\beta}} \right\}^{a+\beta} H^a. \quad (9)$$

Combining this with eq. (6), the common rate of growth, in the steady state, in the two countries is given by

$$g(\tau) = (1/\sigma) \left[B^{a+\beta} (a + \beta)^{a+\beta} (1 - \alpha - \beta)^{2-a-\beta} \left\{ 1 + (1 + \tau)^{\frac{-1}{a+\beta}} \right\}^{a+\beta} H^a - \rho \right] \quad (10)$$

The LES curves in Fig. 1 demonstrate the effects on the common growth rate, $g(\tau)$, of an increase in the common tariff rate based on Table 1 in the Appendix.⁷ For any $\tau > 0$, the growth rate is strictly less than the growth rate $g(0)$ with no tariffs. An other curve denoted "KDS" stemmed from RBR (1991b) represents the variations of the common growth rate with respect to the common tariff rate imposed by the two identical countries. In the latter, the growth rate $g(\tau)$ first falls with τ , reaches a minimum, and then begins to increase. In the limit as τ goes to ∞ , $g(\tau)$ approaches the free trade growth rate $g(0)$.⁸

However, the growth rate in our modified LES model is a monotonic decreasing function of the common tariff rate. Knowledge $A(A^*)$ per se has no direct productive value in manufacturing and research as shown in eqs. (1) and (3). As knowledge is always embedded in intermediate goods, its free movement beyond a country's boundary, which is the most unrealistic assumption in KDS of RBR (1991a), is easily abandoned. Consequently, the trade of intermediate goods is the only way to transfer technology, *i.e.*, trade provides access to a wider range of intermediates inputs, which in turn contributes to an increase in final outputs. Therefore, an increase in $\tau(\tau^*)$ reduces the quantity of imported intermediate inputs m used by domestic manufacturers of final outputs. This reduces the range of intermediate inputs available in the economy. As a result, the growth rate falls once and for all. This

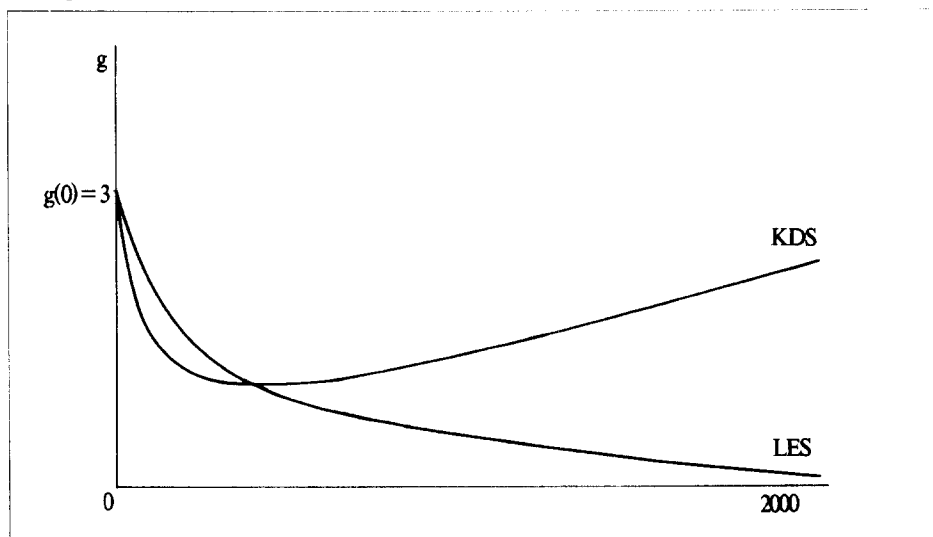
I entirely agree with his opinion. What is important, however, is that the economies considered in the model are sufficiently advanced to invent new intermediate inputs. Then, as mentioned in the introduction, the focus is laid on the growth effects of intra-industry trade between two advanced countries which differ in their size measured by the factor endowments. If we had only one fixed factor in the model, for example L or H the analytical results would not change. I use nonetheless the same model as "Lab. Equipment Specification" in RBR (1991a) in order to show clear differences with "Knowledge Driven Specification" of RBR (1991b) in an open economy.

⁷ The specific parameter values used to generate this graph are as follows: $B = 0.0015$, $\alpha = \beta = 1/3$, $\rho = 0.05$, $\sigma = 1$ and $H = 10000$.

⁸ This nonmonotonicity of the growth rate in the tariff rate, as shown in KDS, arises because two offsetting forces influence the allocation of human capital. *i.e.*, symmetric increases in the common tariff rate have effect on the return to human capital in both research and manufacturing. As τ approaches ∞ , the net effect on the allocation of human capital is more and more favorable to the R&D sector. This is, of course, due to the fact that the functional forms in the R&D sector are defined as $\dot{A} = \delta H A$. See RBR (1991b, pp. 984-985) for a more detailed explanation about this allocation effect.

shows a striking difference between the two specifications. Unlike the KDS curves stemmed from RBR (1991b), our modified LES has no allocation effect on human capital between the two sectors, *e.g.*, both manufacturing and R&D sectors use exactly the same factor intensities.

[Figure 1] The Growth Effects of Common Tariff Rate



III. EXTENSION OF THE MODEL

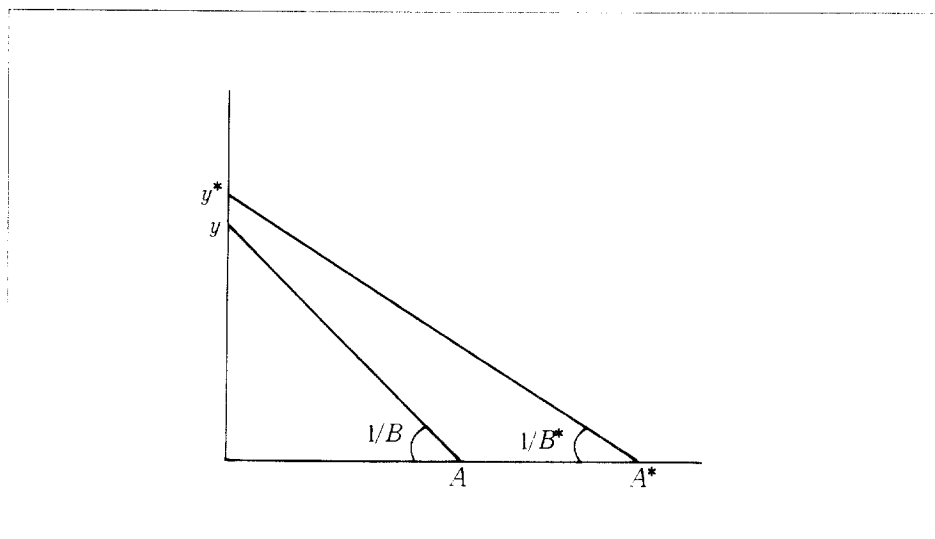
In this section the model is extended to the case when two countries with different factor endowments engage in trade only with the intermediate goods. By introducing an assumption of asymmetry, the restriction of two symmetric environments can be avoided and more general results can be obtained. To keep the analysis tractable, some assumptions need to be modified.

3.1. Different Interest Rate Regime

The final goods are no longer assumed to be traded and the international capital market is so highly segmented that the interest rates differ in the two countries. This seems to be a restrictive assumption. Without it, however, a different interest rate regime cannot be guaranteed.⁹ Gelb (1989) has shown that the real interest rate

⁹ Grossman and Helpman (1991, ch. 11) and Helpman (1992) also allow the interest rates to be different in the North and the South in their Innovation-Imitation models. However, our model differs from theirs in that the two countries engaged in trade are both developed enough to invent new intermediate inputs, which constitute the only object of trade.

[Figure 2] Production Possibility Curves



correlates significantly with the growth rate. The real interest rate in our model is determined by the market, therefore it is different from the nominal interest rate. However, if there is no control on the nominal interest rate, then the market interest rate is the same as the real interest rate. To avoid unnecessary ambiguity in the subsequent analysis, the interest rate indicates the real interest rate, and the foreign interest rate is assumed to be higher than the domestic interest rate: $r < r^*$. In this situation, the price of the patent is inevitably different in the two countries. As shown in eq. (3), the price of a patent $P_A = 1/B$ is determined by technology. A higher interest rate reduces the demand for intermediate goods, thereby lowering the profit earned by the monopolist at each date. As noted in subsection 2.1.2., the price of the patent is nothing but the current value of monopoly profit. Therefore, the following result arises: if $r < r^*$, then $P_A > P_A^*$.

Observing eq. (3), the latter inequality leads to another inequality: $B^* > B$. Therefore we can draw the production possibility curves for the two countries as shown in Figure 2 where the straight line standing for the foreign country (Y^*A^*) is flatter than that of the home country (YA).

3.2. Relative Factor Endowment Effect

The long run growth rate under asymmetry in the factor endowments is solved by (see Appendix):

$$g = (1/\sigma) \left[B^{\alpha+\beta} (\alpha + \beta)^{\alpha+\beta} (1 - \alpha - \beta)^{2-\alpha-\beta} \left\{ 1 + (H/H^*)^{\frac{-1}{\alpha+\beta}} (1 + \tau^*)^{\frac{-1}{\alpha+\beta}} \right\}^{\alpha+\beta} H^{\alpha} - \rho \right] \quad (11)$$

Comparing this with eq. (10), the only difference is shown in the term $(H/H^*)^{-\frac{1}{\alpha+\beta}}$, which implies that the long run growth rate for the home country is as higher as the stock of foreign human capital is greater. This interesting result, qualified as "the relative factor endowment effect" is based on good reasons.¹⁰ The model considered here is an intra-industry trade model in which two countries are assumed to be developed enough to invent new intermediate goods. Thereby, this trade provides a wider range of intermediate inputs, which in turn contributes to the production of more consumption goods and designs of R&D. On the other hand, if the two countries had identical factor endowments, i.e. $H=H^*$, the common growth rate would be exactly the same as shown in equation (10).

3.3. Calibration

[Figure 3] The Relative Factor Endowment Effect

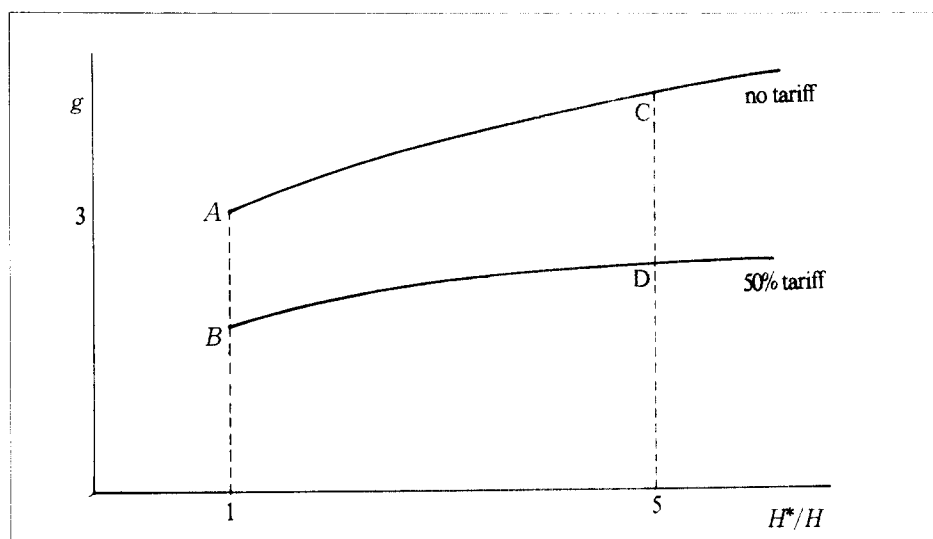


Table 2 in the Appendix reports the calibration results where the estimations of parameters are the same as those we retained in section 2.3. In the absence of tariffs, the long run growth rate varies from 1% to 8%. Figure 3 is drawn based on the numerical results in Table 2. The long run growth rate in the home country varies heavily with respect to the size of the foreign country measured by the stock of human capital in the foreign country. However, notice that this neither means that the long run growth rate in the home country depends directly on the stock of foreign human capital, nor that it increases when it comes to a brain drain. For a pre-

¹⁰ As mentioned earlier (note 6), the result would be the same if we set $H=H^*=1$ and $L \neq L^*$. This is why we call it "relative factor endowment effect" and not "relative effect of human capital stock".

cise comprehension of these seemingly paradoxical curves shown in Figure. 3, one needs to keep in mind that the variables H and H^* are exogenous and that every point in these curves represents the long run growth rates in the steady state equilibrium after a period of transitional dynamics. So, it would be helpful to understand each point on the curves in the following manner. First of all, we choose a trade partner for which the size is measured by its human capital stock. Then, if we are engaged in trade with this partner, our long run growth rate finally reaches a certain point on the curves in steady state equilibrium. With this in mind, we can not conclude that the long run growth rate depends directly on the existence of brain drain or on the accumulation of foreign human capital.

The curves AC represent the variations of growth rate under a free trade regime (no tariff imposed by the foreign country), and the curve BD corresponds to the case where the foreign country imposes a 50% tariff rate. What is interesting to observe is that the larger the foreign factor endowments, the further the gap between growth rates in the absence of tariffs (imposed by foreign country) and in the presence of tariffs, that is, $AB < CD$. This implies that tariffs imposed by big countries have a great influence vis-à-vis small countries.¹¹

IV. INTRODUCTION OF EXPORT SUBSIDY

4.1. Tariff protection and Export promotion

As international trade is a field of interactions between trade partners, import protection aimed at unilateral gain can damage cooperation efforts and make the trade partner resort to retaliation. To incorporate this idea, an export subsidy is introduced to circumvent the foreign tariff protection.

Let $s(t)$ denote the specific rate of export subsidy imposed in the home country at time t . It would be useful to consider an endogenization of s into the model, but doing so here would require several additional equations. This modification contributes little to the analysis of growth effect and would greatly increase the complexity of the arguments. On the other hand, an entire exogenization of $s(t)$ is meaningless; financing export subsidy can not be gratuitous. One of the easiest ways to treat this complexity is to assume that all firms are 100% debt-financed, and that the consumer's financial asset is a debt instrument. Under no uncertainty, debt is equivalent to equity. Then, the export subsidy is assumed to be financed by a tax levied on consumers. Even though this reduces the consumer's financial asset, it only has a price effect and no redistribution effect between the consumer and the producer because of the debt-instrument assumption. The same can be applied to the case of tariff revenues assigned to the consumer through rebates (see Appendix), that is,

¹¹ This fits well in the real world; when it comes to trade wars between big and small countries, small countries often concedes unilaterally (McMillan 1992, p. 86).

the consumer's financial assets accrued from tariff revenues have no redistribution effect.

Assume that the home country imposes an export subsidy at rate s on export quantity $m^*(i)$. Then, the long run growth rate in the home country is solved by (see Appendix)

$$g = (1/\sigma) \left[\Psi \left\{ 1 + \left(\frac{H}{L^*} \right)^{\frac{-\alpha}{\alpha+\beta}} (1 + \tau^*)^{\frac{-1}{\alpha+\beta}} (1 - s)^{\frac{-1}{\alpha+\beta}} \right\}^{\alpha+\beta} H^\alpha - \rho \right] , \quad (12)$$

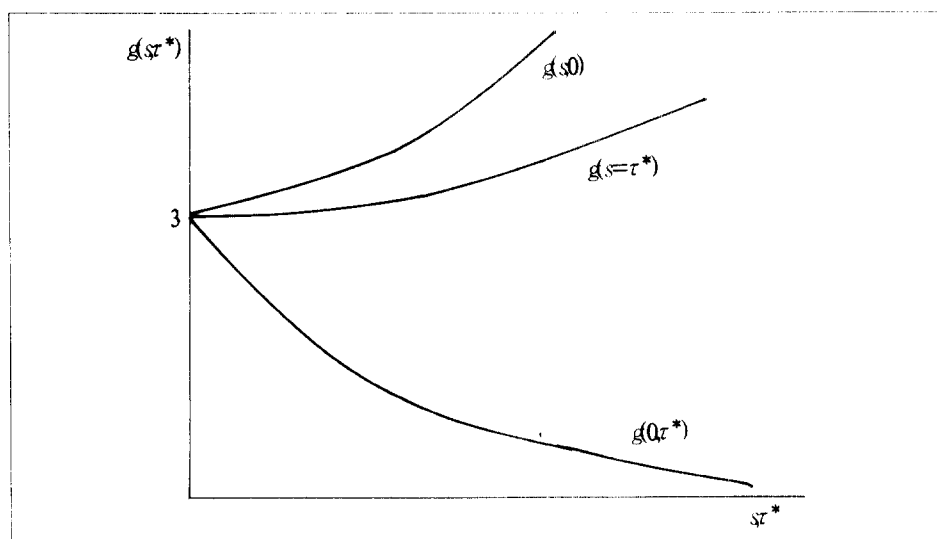
where $\Psi = B^{\alpha+\beta} (\alpha + \beta)^{\alpha+\beta} (1 - \alpha - \beta)^{2 - \alpha - \beta}$.

As $(\partial g / \partial s) > 0$ in eq. (12), the export subsidy increases the long run growth rate, whereas the foreign tariff decreases the long run growth rate, as shown by $(\partial g / \partial \tau^*) < 0$.

4.2. Net effect of export subsidy

What is interesting is to observe that $(\partial^2 g / \partial s^2) > 0$, $(\partial g / \partial \tau^*) < 0$ and $(\partial^2 g / \partial s^2 \tau^{*2}) < 0$. This implies that when the home country imposes an export subsidy at the rate s which is equal to the foreign tariff rate τ^* , the effects of export subsidy on the

[Figure 4] Net Effect of Export Subsidy



growth rate surpass the counter-effect of foreign tariff protection. Let's define the case where the home country imposes the same rate of export subsidy as the foreign tariff rate as 'net effect of export subsidy'. Then, this net effect enhances the growth rate. The following figure is constructed based on the numerical results in Table 3 in the Appendix, and the signs of partial derivatives.

In Figure 4, curve $g(s, 0)$ denotes the variations of the growth rate in the absence of foreign import tariffs, which correspond to the values in the first column in Table 3. Curve $g(0, \tau^*)$ represents those values, corresponding to the values in the first row, when $s=0$ and curve $g(s=\tau^*)$ the diagonal values in the table. As mentioned earlier, the latter indicates that the export subsidy imposed at the same rate as the foreign tariff rate can boost the growth rate in the home country. This interesting result emphasizes implicitly the necessity of cooperation, especially in an intra-industry trade relationship.

Note also that equation. (12) states that if the foreign factor endowments are bigger than the home country's ($H^* > H$), the three curves shift up at the same proportion. Consequently, the relative factor endowment effect is an effective proposition even in the case of export subsidy.

V. CONCLUSION

This paper has argued that tariff protection aimed at unilateral gain is not an effective policy when there is retaliation by the foreign country. By extending RBR's (1991a). LES model, technology transfer is embedded only in the exchange of intermediate goods in a framework of intra-industry trade. Thus, trade limitations decrease the long run growth rate once and for all. Then, allowing asymmetry in an extended LES version, we examined the growth effects of trade policy interactions, especially import tariff and export subsidy. This paper contributes to the following novel analytical results :

- i) the long run growth rate of a country correlates positively with the factor endowment of her trade partner (relative factor endowment effect);
- ii) export subsidy can boost the long run growth rate;
- iii) the net effect of export subsidy can overwhelm the counter-effect of foreign import tariff.

Combining these above results leads us to conclude that free trade is always better than restricted trade, especially when it comes to potential retaliation of a trade partner. Consequently, reciprocal and mutual arrangements to reduce tariffs and other non-tariff barriers in the WTO system can be easily understood.

If one searches for policy implications, the relative factor endowment effect provides an informative insight. However, recall that the model considered here is for intra-industry trade among developed countries. A developed country, here, means that it can invent a new type of capital good. Therefore, a country merely abundant in unskilled labor is hardly qualified.

APPENDIX

A. Derivation of equation. (6)

Let $T(t)$ denote the redistribution of tariff revenues through rebates, let $S(t)$ denote the lump sum tax to finance export subsidy, let $D(t)$ denote the consumer's holdings of debt instruments, and assume that all firms are 100% debt-financed. This device is used to avoid the analytical complexity which arises from the relation between $T(t)$, $S(t)$ and $D(t)$; that is, $T(t)$ and $S(t)$ either increase or decrease $D(t)$, thus the consumption level. However, there is no redistribution effect between the consumer and the producer, only a price effect. The utility maximization problem of a representative household is to maximize eq.(5) in the text subject to

$$\dot{D} = rD + w(t)L + w_H(t)H + T(t) - S(t) - C(t), \quad (\text{A.1})$$

where r , $w(t)$, and $w_H(t)$ represent respectively the interest rate (constant in steady state), the wage for labor, and the wage for human capital. The Hamiltonian for this problem is

$$H = \frac{C(t)^{1-\sigma}}{1-\sigma} e^{-\rho t} [tH + T(t) - S(t) - C(t)]. \quad (\text{A.2})$$

The first order conditions are

$$H_C = e^{-\rho t} C^{-\sigma} = \lambda \quad (\text{A.3})$$

$$H_D = -\dot{\lambda} = r\lambda \quad (\text{A.4})$$

The transversality condition is written by

$$\lim_{t \rightarrow \infty} D(t)\lambda(t) = 0 \quad (\text{A.5})$$

Differentiating (A.3) with respect to time and then using (A.4), we obtain equation. (6) in the text. We show below that this interest rate in equation. (6) is consistent with the equilibrium conditions on the production side as well.

B. Derivation of equations. (9) and (11)

The production function in manufacturing and research sectors in an open economy setting is given in eq. (7). Taking its supply of H and L as given, each representative firm in the manufacturing sector chooses levels of $d(i)$ and $m(i^*)$ to maximize profits. Consequently, the first order-condition for the problem of maximizing $Y + \dot{A}/B$ minus total input cost with respect to domestic input i and imported input i^* yields the economywide inverse demand curve for goods i and i^* . The maximization problem can be represented as:

$$\max_{d, m} \left\{ (Y + \dot{A}/B) - \int_1^{\dot{A}} P_d(i) d(i) di - \int_{i^*}^{\dot{A}^*} (1 + \tau) P_m^*(i^*) m(i^*) di^* \right\}, \quad (\text{B.1})$$

where P_d refers to the home price of domestic inputs and P_m^* is the price received by foreign producers for their exports. The price $(1 + \tau)P_m^*(i^*)$ is paid by domestic users of foreign inputs. The first order necessary conditions for the choice of $d(i)$ and $m(i^*)$ in the domestic manufacturing and research sectors are:

$$(1 - \alpha - \beta) H^\alpha d(i)^{-\alpha-\beta} - P_d(i) = 0, \quad (\text{B.2})$$

$$(1 - \alpha - \beta) H^\alpha m(i^*)^{-\alpha-\beta} - (1 + \tau) P_m^*(i^*) = 0, \quad (\text{B.3})$$

The implied derived demands for domestic and imported inputs are:

$$d(i) = (1 - \alpha - \beta)^{1/(\alpha+\beta)} H^{\alpha/(\alpha+\beta)} P_d(i)^{-1/(\alpha+\beta)} \quad (\text{B.4})$$

$$m(i^*) = (1 - \alpha - \beta)^{1/(\alpha+\beta)} H^{\alpha/(\alpha+\beta)} (1 + \tau)^{-1/(\alpha+\beta)} P_m^*(i^*)^{-1/(\alpha+\beta)}. \quad (\text{B.5})$$

An analogous procedure yields the first order necessary conditions for the foreign country's choice of $d^*(i^*)$ and $m^*(i)$ in the symmetric tariff case ($\tau = \tau^*$):

$$(1 - \alpha - \beta) H^{\alpha^*} d^*(i^*)^{-\alpha-\beta} - P_d^*(i^*) = 0, \quad (\text{B.6})$$

$$(1 - \alpha - \beta) H^{\alpha^*} m^*(i)^{-\alpha-\beta} - (1 + \tau^*) P_m^*(i) = 0. \quad (\text{B.7})$$

The implied derived demands for locally produced and imported inputs abroad are:

$$d^*(i^*) = (1 - \alpha - \beta)^{1/(\alpha+\beta)} H^{\alpha/(\alpha+\beta)} P_{i^*}^* (i^*)^{-1/(\alpha+\beta)} \quad (\text{B.8})$$

$$m^*(i) = (1 - \alpha - \beta)^{1/(\alpha+\beta)} H^{\alpha/(\alpha+\beta)} (1 + \tau)^{-1/(\alpha+\beta)} P_{m^*}(i)^{-1/(\alpha+\beta)} \quad (\text{B.9})$$

$P_{i^*}^*(i^*)$ is the price of foreign input i^* set by foreign firms. $P_{m^*}(i)$ is the price of input i set by home firms on goods imported by foreigners. $(1 + \tau)P_{m^*}(i)$ is the price paid by the foreign users of good i .

In equilibrium, the total domestic production of good i is equal to the sum of domestic usage $d(i)$ and exports $m^*(i)$. By equations (B.4) and (B.9), the input demand function for good i has the same elasticity, i.e., $-1/(\alpha + \beta)$. This constant elasticity demand curves apply to all intermediate inputs in the interval $(0, A)$, which means that all domestic producers face the same demand and have identical cost functions. We can ignore the index i and total production of an intermediate input in the home country can then be expressed as $d(P_d) + m^*(P_{m^*})$. Total revenue is then equal to $d(P_d)d + m^*(P_{m^*})m^*$.

Because it costs one unit of forgone output to produce one unit of an intermediate good, the flow opportunity cost of these units is $r(d + m^*)$. The instantaneous rate of monopoly (the holder of the patent) profit is therefore written by

$$\pi = \max_{d, m^*} P_d(d)d + P_{m^*}(m^*)m^* - r(d + m^*) \quad (\text{B.10})$$

Considering eqs. (B.4) and (B.9), the mark-up pricing for the monopoly is easily obtained:

$$p = p^* = r/(1 - \alpha - \beta) \quad (\text{B.11})$$

As this mark-up price (chosen by the monopoly) which ensures the profit maximizing price is the same in the two countries, (B.10) can be rewritten by,

$$\pi = (p - r)(d + m^*) \quad (\text{B.12})$$

On the other hand, free entry into the R&D sector implies that the value of a design at time t is equal to the current discounted value of infinite profit stream that the monopoly producer (purchaser of a design) can earn:

$$P_A(t) = \int_t^{\infty} e^{-\int_t^s \alpha(s) ds} \pi(s) ds. \quad (\text{B.13})$$

Differentiating with respect to time yields an arbitrage condition relating the interest rate to current profits per dollar invested plus the percentage change in the value of designs over time,

$$r = \pi(t)/P_A + \dot{P}_A/P_A. \quad (\text{B.14})$$

In a steady state equilibrium, the value for P_A is constant. Combining eqs. (B.11) and (B.12), we can rewrite them as

$$P_A = \pi(t)/r = (\alpha + \beta)(d + m^*)/(1 - \alpha - \beta). \quad (\text{B.15})$$

The first order conditions in (B.10) can be obtained by using eqs.(B.4) and (B.9):

$$(1 - \alpha - \beta)^2 H^\alpha d^{-\alpha-\beta} = r, \quad (\text{B.16})$$

$$(1 - \alpha - \beta)^2 H^\alpha m^{*\alpha-\beta} = (1 + \tau)^{-1} = r. \quad (\text{B.17})$$

Combining these two equations, we can obtain

$$m^* = (1 - \tau)^{-1/(\alpha+\beta)} d. \quad (\text{B.18})$$

Since $P_A = 1/B$ using equations. (B.18) and (B.15), the domestic demand d is solved by,

$$d = \left[\frac{(1 - \alpha - \beta)}{B(\alpha - \beta)\{1 + (1 + \tau)^{-1/(\alpha+\beta)}\}} \right] \quad (\text{B.19})$$

Substituting this expression into equation. (B.16) yields equation. (9) in the text. The same procedure in the regime of asymmetrical factor endowments yields:

$$m^* = (H/H^*)^{-1/(\alpha+\beta)} (1 + \tau^*)^{-1/(\alpha+\beta)} d. \quad (\text{B.20})$$

The domestic demand in this case can be solved by,

$$d = \left[\frac{(1 - \alpha - \beta)}{B(\alpha + \beta) \{1 + (H/H^*)^{-\alpha/(\alpha+\beta)}\} (1 + \tau)^{-1/(\alpha+\beta)}} \right] \quad (\text{B.21})$$

Substituting this expression into equation. (B.16) yields equation. (11) in the text.

C. Derivation of equation. (12)

The export subsidy at the specific rate s reduces the marginal cost of intermediate input to be exported. This modification yields only a slight change in equation. (B.17) as follows:

$$(1 - \alpha - \beta)^2 H^* m^* \cdot^{-\alpha-\beta} (1 + \tau^*)^{-1} = r(1 - s). \quad (\text{C.1})$$

Combining this and equation. (B.16), we can obtain:

$$m^* = (H/H^*)^{-\alpha/(\alpha+\beta)} (1 + \tau^*)^{-1/(\alpha+\beta)} (1 - s)^{-1/(\alpha+\beta)} d. \quad (\text{C.2})$$

Substituting this expression into equation. (B.16) yields:

$$d = \left[\frac{(1 - \alpha - \beta)}{B(\alpha + \beta) \{1 + (H/H^*)^{-\alpha/(\alpha+\beta)}\} (1 + \tau)^{-1/(\alpha+\beta)} (1 - s)^{-1/(\alpha+\beta)}} \right] \quad (\text{C.3})$$

Putting this expression back to equation. (B.16) yields equation. (12) in the text.

D. Calibration Results

Table 1. Variations of growth rate with respect to common tariff rate

τ (%)	0	10	20	30	40	50	60	100	200	300	500	1000	2000
g (%)	29	25	25	20	18	17	15	11	06	04	02	006	001

Table 2. Variations of growth rate with respect to relative factor endowments

τ (%) \ H^*/H	1	1.2	1.4	1.6	1.8	2.0	3.0	4.0	5.0	10.0
0	29	3.15	3.38	3.59	3.78	3.96	4.73	5.36	5.89	7.88
10	2.55	2.77	2.97	3.16	3.23	3.49	4.18	4.73	5.21	7.0
50	1.65	1.8	1.94	2.06	2.18	2.29	2.75	3.13	3.47	4.71

Table 3. Net effects on growth rate of export subsidy

$s(\%) \backslash \tau^*(\%)$	0	10	20	30
0	29	255	226	202
10	335	294	261	234
20	392	345	307	275
30	467	412	367	33

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