Tariffs, Endogenous Growth, and the Direction of Capital Flows

Wataru Johdo

This paper incorporates tariffs into a two-country endogenous growth model to analyze the growth effects of a unilateral increase in a tariff rate in each country given global knowledge spillovers in research and development. This paper shows that a unilateral increase in the tariff rate of one country lowers the world rate of growth under certain conditions. In addition, this paper shows that if the home country's initial capital stock is smaller (larger) than the foreign country's initial capital stock, then net capital flows occur from the foreign (home) country to the home (foreign) country.

Keywords: Tariff, Knowledge spillover, Industrial location, Growth, R&D investment

JEL Classification: E2; F1; F2; F43

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I. Introduction

In the endogenous growth literature, many studies explore how the rate of growth is influenced by trade restrictions (or trade liberalizations), including tariffs, within an open economy. The literature can be classified into three approaches according to different theoretical frameworks. The first approach uses the endogenous growth model of a symmetric two-country world and finds that a global increase in tariffs or a move from autarky to free trade can have either beneficial or harmful growth effects, thus presenting ambiguous results in general (*e.g.*, Grossman and Helpman, 1991a; Rivera-Batiz and Romer, 1991a, 1991b; Dinopoulos and Segerstrom, 1999a, 1999b; Peretto, 2003). The second approach uses the endogenous growth model in a small open economy and shows that a tariff increase in the small country generally lowers the country's growth rate (*e.g.*, Grossman and Helpman, 1991b; Osang and Pereira, 1996; Osang and Turnovsky, 2000).[1] The third approach combines the endogenous growth model of Grossman and Helpman (1991a) and the location model of Martin and Rogers (1995) to account for the impact of transportation costs (as trade costs) on the world growth rate through the effect on industrial location. Generally, studies within this approach conclude that the rate of growth is negatively related to transportation costs (*e.g.*, Martin and Ottaviano, 1999; Hirose and Yamamoto 2007; Johdo, 2013).

Although many studies utilize endogenous growth models to examine the growth effects of trade restrictions, few theoretical studies analyze the world growth effects of a unilateral increase in the tariff rate within an asymmetric two-country model with international relocation of firms. One exception is Johdo (2013), who develops an endogenous growth model that incorporates the international relocation of firms and examines the growth effect of an iceberg-type trade cost levied on home firms within an asymmetric two-country model. However, the model focuses on the growth effects that result from differences in transportation costs across countries. Therefore, Johdo (2013) does not explore the relationship between tariffs and the geographic space in which a firm operates. Another related study that uses a similar

[1] In fact, most empirical studies confirm that tariffs lower economic growth (*e.g.*, Ahmed and O' Donoghue, 2010).

framework is by Hirose and Yamamoto (2007), who use the Martin and Ottaviano (1999) model to investigate how the growth effects of iceberg-type trade costs depend on both innovation costs and market sizes. Again, however, their study does not discuss the effects of a unilateral tariff increase on the world growth rate, focusing instead on the effects of a global decrease in symmetric transportation costs on the world growth rate.

Utilizing the abovementioned theoretical background of endogenous growth theory, this paper shows the impacts of a unilateral tariff increase on the home and foreign national economies as well as the rate of world growth by introducing import tariffs into the two-country endogenous growth model of Martin and Ottaviano (1999). Their two-country endogenous growth model offers a rigorous analytical framework for the relocation of firms in an open economy with sound micro-foundations. By adopting the Martin and Ottaviano (1999) model, which allows us to include tariffs, we can consider additional channels of trade restrictions unlike the studies by Johdo (2013) and Hirose and Yamamoto (2007), which focus on the growth effects of the relocation of firms by decreasing transportation costs. In particular, our framework enables us to analyze the relationship between tariffs and the international relocation of firms, and that between the world growth rate and tariff revenues, which is an aspect that is overlooked by endogenous growth studies.

Our main findings are as follows: i) a unilateral increase in the tariff rate of one country lowers the world growth rate through a decrease in labor in the research and development (R&D) sector under certain conditions; and ii) if the home country's initial capital stock is smaller (larger) than the foreign country's initial capital stock, then net capital flows occur from the foreign (home) country to the home (foreign) country.

Here, we explain the main differences between the model in this paper and the model used in previous studies, and how these differences affect the above results. Previous studies assumed the existence of iceberg-type trade costs, which result in losses being incurred only in transit across the border. That is, the previous studies assumed that these are the only trade costs affecting the world growth rate. Conversely, in this study, as a novel feature, we consider the relationship between import tariffs and the world growth rate within the two-country endogenous growth model of Martin and Ottaviano (1999). On this basis, we can show that a unilateral increase in the home country's tariff increases the tariff revenue, thereby raising the consumption expenditure in the home country, which then increases global consumption spending. Moreover, the increase in the global consumption spending implies that more labor is used for the production of global consumption goods and services, and, from the equilibrium condition for labor markets, less labor is available for the R&D sector. Consequently, this situation has a negative effect on the world growth rate through the decline in innovation. This effect, which we refer to as the "tariff revenue effect," has a negative influence on the world growth rate. The tariff revenue effect is an additional effect caused by including import tariffs in the original model developed by Martin and Ottaviano (1999) with iceberg-type trade costs. Another important point is how import tariffs affect the direction of net capital flows between countries in our model compared with those in the previous studies, which assumed only trade costs. Although our results for net capital flows are similar to those from the original model by Martin and Ottaviano, our model has an additional mechanism that arises from the changes in tariff revenues. Nevertheless, we obtain similar results to those of Martin and Ottaviano because, in our model, the impact of the import tariff becomes small if the R&D cost and the equilibrium rate of return of capital are assumed to be small, as in the previous studies.

The remainder of this paper is structured as follows. Section II outlines the features of the model. Section III describes the equilibrium location and firm size, and Section IV details the R&D sector. Section V examines the impact of a unilateral tariff increase in each country on the world growth rate. The final section concludes the paper.

II. Model Structure

We develop a two-country model that comprises home and foreign locations. The models for the home and foreign countries are identical, apart from their initial stock of capital and tariffs. We use an asterisk to denote the variables for the foreign country. Henceforth, we focus mainly on a description of the home country, given its equivalence with the foreign country. Unlike owners (households/workers), firms in this model are internationally mobile. In our model, each country has three sectors: the numeraire good sector, the differentiated goods sector, and the R&D sector. Furthermore, following Martin and Ottaviano (1999), we assume that each researchers' knowledge creation is a side product of R&D activities and, therefore, as in the existing literature, knowledge of new products is an international public good that any other country's researchers can access and utilize without restrictions or costs.

The intertemporal objective of a representative household in the home country is to maximize the following lifetime utility function:

$$U = \int_0^\infty \log(D(t)^\alpha Y(t)^{1-\alpha})e^{-\rho t}dt, \tag{1}$$

where ρ is the subjective discount rate, which is also identical in both countries; $Y(t)$ is the numeraire good in period t; and $D(t)$ is the consumption index of differentiated goods, which is defined as follows:

$$D(t) = (\int_{i=0}^{N(t)} D_i(t)^{1-\frac{1}{\sigma}} di)^{\frac{1}{1-\frac{1}{\sigma}}}, \quad \sigma > 1, \tag{2}$$

where σ is the elasticity of substitution between any two differentiated goods, $D_i(t)$ is the consumption of differentiated good i in period t, and $N(t)$ is the total number of differentiated goods produced in both the home and foreign countries. In this model, the government in each country levies import tariffs on all imported differentiated goods and redistributes the tariff revenue to households in a lump-sum manner. For simplicity, no tariff is imposed on the numeraire good. Furthermore, following the conventional setup in the new economic geography literature, we assume symmetric iceberg transport costs in shipping the differentiated goods between countries. Specifically, τ ($\tau \geq 1$) units of a differentiated good are shipped from the foreign country to the home country (or from the home country to the foreign country) for one unit to arrive at its destination. Henceforth, we omit the time subscript. Then, the per capita expenditure of a typical home household, E, is

$$\int_{i\in n} p_i D_i di + \int_{j\in n^*} (1+\tau_h)\, \tau p_j^* D_j dj + Y = E\,, \tag{3}$$

where τ_h (τ_f) is the tariff rate of the home (foreign) country. In this model, as shown in (3), the home country consists of n firms and the remaining n^* firms are in the foreign country, where n and n^* are endogenous and $n + n^* = N$ holds at each point in time. p_i is the producer price of a typical variety i in the home country, and p_j^* is its price in the foreign country. Then, the consumption price indices for the differentiated products are

$$P^D = \left(\int_{i\in n} p_i^{1-\sigma} di + \int_{j\in n^*} ((1+\tau_h)\tau p_j^*)^{1-\sigma} dj\right)^{\frac{1}{1-\sigma}}, \tag{4}$$

$$P^{D^*} = \left(\int_{i\in n} ((1+\tau_f)\tau p_i)^{1-\sigma} di\right) + \int_{j\in n^*} p_j^{*1-\sigma} dj)^{\frac{1}{1-\sigma}}, \tag{5}$$

where P^D (P^{D^*}) is the price index in the home (foreign) country. In the differentiated goods sector, a patent is required to begin producing each variety of good, and therefore, we can interpret this capital requirement as a fixed production cost. Each firm issues equities to finance the fixed cost of the patent and distributes all profits to shareholders as dividends. In addition, each good requires β units of labor. Standard profit optimization by the choice of p_i yields $p_i = w\beta\sigma/(\sigma-1)$. The profit flow of each firm in the differentiated goods sector (= π) is then

$$\pi = p_i x_i(p_i) - w\beta x_i(p_i) = \frac{w\beta x(p_i)}{(\sigma-1)}, \tag{6}$$

where x is the amount of output.

The homogeneous good Y is assumed to be produced using some constant returns to scale technology that requires labor as the only input where firms devote one unit of labor to produce one unit of Y. In addition, we assume that some production of the homogeneous good occurs in both countries. Hence, we ensure factor-price equalization across countries $w = w^*$ at each instant because of free trade in the homogeneous good. The numeraire is the homogeneous good; thus, the wage rate in each location is $w = w^* = 1$. Therefore, we obtain $p = p^* = \beta\sigma/(\sigma-1)$. Here, we define $\delta \equiv \tau^{1-\sigma} \in (0,1)$ for convenience, in line with the new economic geography literature.

From standard utility optimization, given the choices of D_i, D_j, and Y, each household spends a constant fraction α of its consumption expenditure E on the differentiated goods and the remaining $(1-\alpha)$ of E on good Y

$$D_i = \frac{\sigma-1}{\beta\sigma}\left(\frac{\alpha E}{n + n^*(1+\tau_h)^{1-\sigma}\delta}\right), D_j = \frac{\sigma-1}{\beta\sigma}\left(\frac{\alpha E(1+\tau_h)^{-\sigma}}{n + n^*(1+\tau_h)^{1-\sigma}\delta}\right), Y = (1-\alpha)E. \tag{7}$$

Next, we consider the stock market valuation of profit-making firms. We define v as the equity value of a firm and r as the return on a riskless bond. A no-arbitrage condition in capital markets relates the expected return on equity to the return on an equally sized investment in the riskless bond. Therefore, by considering (6), we obtain

$$\frac{\beta x}{\sigma - 1} + \dot{v} = rv. \tag{8}$$

Next, we solve the intertemporal optimization problem. The maximization of (1) subject to the intertemporal budget constraint and the assumption of free capital mobility between countries require that nominal expenditures grow at an instantaneous rate equal to $r - \rho$

$$\frac{\dot{E}}{E} = \frac{\dot{E}^*}{E^*} = r - \rho. \tag{9}$$

III. Firm Sizes and Locations

We determine firm sizes (x, x^*) and locations (n, n^*) for a given level of expenditure (E, E^*). Aggregating the demands in (7) across all households worldwide yields the following market-clearing condition for any differentiated product x

$$x = \frac{\alpha L(\sigma - 1)}{\beta\sigma}\left(\frac{E}{n + n^*(1+\tau_h)^{1-\sigma}\delta} + \frac{E^*(1+\tau_f)^{-\sigma}\delta}{n^* + n(1+\tau_f)^{1-\sigma}\delta}\right), \tag{10a}$$

where L is the amount of labor endowment, which is equal in both countries. Similarly, for any product x^*, we obtain

$$x^* = \frac{\alpha L(\sigma - 1)}{\beta\sigma}\left(\frac{E(1+\tau_h)^{-\sigma}\delta}{n + n^*(1+\tau_h)^{1-\sigma}\delta} + \frac{E^*}{n^* + n(1+\tau_f)^{1-\sigma}\delta}\right). \tag{10b}$$

The model assumes that firms do not face any relocation costs, so relocating does not take any time. For a firm to be indifferent between the home and the foreign locations following location arbitrage, the operating profits from the two locations must also be equal

$$\pi = \pi^*. \tag{10c}$$

Therefore, from Equations (6) and (10c), and $w = w^* = 1$, we obtain $x = x^*$. Here, we set K and K^* as the capital stocks in the home and the foreign countries, respectively. The total stock of capital owned by agents determines the total number of firms such that

$$n + n^* = K + K^* = N. \tag{10d}$$

Solving (10a)–(10d), we obtain the share of firms in the home country, which we define as

$$\gamma = \frac{n}{N} = \frac{\left((1+\tau_f)^{-\sigma}\delta - 1\right)(1+\tau_h)^{1-\sigma}\delta E^* - \left((1+\tau_h)^{-\sigma}\delta - 1\right)E}{\left((1+\tau_h)^{-\sigma}\delta - 1\right)\left((1+\tau_f)^{1-\sigma}\delta - 1\right)E + \left((1+\tau_f)^{-\sigma}\delta - 1\right)\left((1+\tau_h)^{1-\sigma}\delta - 1\right)E^*}. \tag{11}$$

Then, from Equation (11), for a given level of expenditure (E, E^*), we obtain

$$\frac{\partial\gamma}{\partial\tau_h} > 0, \quad \frac{\partial\gamma}{\partial\tau_f} < 0. \tag{12}$$

Equation (12) implies that a unilateral increase in the tariff rate of the home (foreign) country will raise the equilibrium share of firms in the home (foreign) country and lower the share of firms in the foreign (home) country.

The level of output of each firm is

$$x = x^* = \alpha L\left(\frac{\sigma - 1}{\beta\sigma}\right)\frac{\bar{E}}{N}\left\{\frac{(1+\tau_f)^{-\sigma}\delta(1+\tau_h)^{-\sigma}\delta - 1}{\left((1+\tau_h)^{1-\sigma}\delta(1+\tau_f)^{1-\sigma}\delta - 1\right)\left((1+\tau_h)^{-\sigma}\delta - 1\right)\left((1+\tau_f)^{-\sigma}\delta - 1\right)}\right\}. \tag{13}$$

where $\bar{E} = \left((1+\tau_h)^{-\sigma}\delta - 1\right)\left((1+\tau_f)^{-\sigma}\delta - 1\right)E + \left((1+\tau_f)^{-\sigma}\delta - 1\right)\left((1+\tau_h)^{-\sigma}\delta - 1\right)E$.

IV. R&D Sector

Next, we turn to the R&D sector. We assume that forward-looking researchers decide on the amount of R&D investment and that the R&D technology is linear, whereby the invention of a new good is directly proportional to the labor devoted to the activity. To consider the incentive for researchers to engage in innovative R&D, let v denote the value of a blueprint developed through innovative R&D. As in Martin and Ottaviano (1999), we assume that a researcher who undertakes R&D activities requires η/N units of labor because the R&D cost is the same in both locations owing to global spillovers. In the endogenous growth literature, it is often assumed that the technological knowledge contributed by local R&D is a global public good and the knowledge spillovers augment R&D productivity worldwide. Therefore, free entry into the R&D sector leads to $v = \eta/N$.

In this section, we derive the solution for a steady state in which the share of firms in the home country and the growth rate of N do not change (i.e., $\gamma = n/N$ and g $(=\dot{N}/N)$ are both constants). The equity value of each firm is equal to the value of the blueprint that it owns. Thus, the equity value of any firm v is determined by the free-entry condition in the R&D sector: $v = \eta/N$. If a balanced growth path exists, then this situation implies that v decreases at rate $g = \dot{N}/N = \dot{n}/n$. The world labor market-clearing condition is as follows:

$$\eta g + (1-\alpha) L \left(E + E^*\right) + \alpha L \left(\frac{\sigma - 1}{\sigma}\right) \bar{E}\bar{T} = 2L, \tag{14}$$

where

$$\bar{T} = \frac{(1+\tau_h)^{-\sigma} \delta (1+\tau_f)^{-\sigma} \delta - 1}{\left((1+\tau_h)^{1-\sigma} \delta (1+\tau_f)^{1-\sigma} \delta - 1\right)\left((1+\tau_h)^{-\sigma} \delta - 1\right)\left((1+\tau_f)^{-\sigma} \delta - 1\right)}.$$

If g is constant in the steady state, then Equation (14) implies that expenditures must be constant. This condition leads to $r = \rho$ from (9). Then, substituting Equation (13), $v = \eta/N$, and $r = \rho$ into Equation (8) and considering (14) yield the following equilibrium growth rate:

$$g = \frac{2L}{\eta\sigma} - \frac{(1-\alpha)L(E+E^*)}{\eta\sigma} - \left(\frac{\sigma-1}{\sigma}\right)\rho. \tag{15}$$

The respective steady-state levels of per capita expenditure for each country are

$$E = 1 + \frac{\rho\eta k}{L} + \frac{\tau_h \tau n^* p_f^* D_f}{L},\ E^* = 1 + \frac{\rho\eta(1-k)}{L} + \frac{\tau_f \tau n p_h D_h^*}{L}, \tag{16}$$

where $k \equiv K/N$. The first term in the abovementioned equations denotes per capita labor income, the second denotes rent income per capita, and the third denotes the per capita transfer of tariff revenues from the government.

Then, substituting (16) into the equilibrium share of firms in the home country given by Equation (11) yields:

$$\gamma = \frac{n}{N} = \frac{\alpha\tau_h(1+\tau_h)^{-\sigma}\delta[L+\rho\eta(1-k)] - L(L+\rho\eta k)[(1+\tau_h)^{-\sigma}\delta - 1]}{L(L+\rho\eta k)[(1+\tau_h)^{-\sigma}\delta - 1][(1+\tau_f)^{1-\sigma}\delta - 1] + \alpha\tau_h(1+\tau_h)^{-\sigma}\delta[L+\rho\eta(1-k)]}$$
$$+ \frac{L(L+\rho\eta(1-k))[(1+\tau_f)^{-\sigma}\delta - 1](1+\tau_h)^{1-\sigma}\delta}{L(L+\rho\eta(1-k))[(1+\tau_f)^{-\sigma}\delta - 1][(1+\tau_h)^{1-\sigma}\delta - 1] + \alpha\tau_f(1+\tau_f)^{-\sigma}\delta[L+\rho\eta k]}. \tag{17}$$

Similarly, from (17) and (10d), the equilibrium share of firms in the foreign country is given by:

$$1-\gamma = \frac{n^*}{N} = \frac{\alpha\tau_f(1+\tau_f)^{-\sigma}\delta[L+\rho\eta k] - L(L+\rho\eta(1-k))[(1+\tau_f)^{-\sigma}\delta - 1]}{L(L+\rho\eta k)[(1+\tau_h)^{-\sigma}\delta - 1][(1+\tau_f)^{1-\sigma}\delta - 1] + \alpha\tau_h(1+\tau_h)^{-\sigma}\delta[L+\rho\eta(1-k)]}$$
$$+ \frac{L(L+\rho\eta k))[(1+\tau_h)^{-\sigma}\delta - 1](1+\tau_f)^{1-\sigma}\delta}{L(L+\rho\eta(1-k))[(1+\tau_f)^{-\sigma}\delta - 1][(1+\tau_h)^{1-\sigma}\delta - 1] + \alpha\tau_f(1+\tau_f)^{-\sigma}\delta[L+\rho\eta k]}. \tag{18}$$

V. Effects of a Unilateral Tariff Increase

To examine the effects of one country increasing its tariff rate, we assume that $\chi_h \equiv \alpha\tau_h(1+\tau_h)^{-\sigma}(1+\tau_f)^{1-\sigma}\ \delta^2 \approx 0$ and $\chi_f \equiv \alpha\tau_f(1+\tau_f)^{-\sigma}(1+\tau_h)^{1-\sigma}\ \delta^2 \approx 0$. Intuitively, if σ is sufficiently large, and δ, α, τ_h, and τ_f are sufficiently small, then $\chi_h \equiv \alpha\tau_h(1+\tau_h)^{-\sigma}(1+\tau_f)^{1-\sigma}\ \delta^2 \approx 0$ and $\chi_f \equiv \alpha\tau_f(1+\tau_f)^{-\sigma}(1+\tau_h)^{1-\sigma}\ \delta^2 \approx 0$ hold (that is, χ_h and χ_f are approximately zero). Under these assumptions, we can show the effects of a unilateral increase in the tariff rate in each country clearly.

First, we analyze the effects of a unilateral increase in the tariff rate in each country on the world growth rate through the effect on the world consumption expenditure. From Equation (15), the rate of world growth is negatively dependent on the world consumption expenditure. Therefore, from Equation (16), we obtain the following steady-state world consumption expenditure:

$$(E+E^*)|_{\chi_h\approx 0,\,\chi_f\approx 0}=2+\frac{\rho\eta}{L}+\left[\frac{\alpha\tau_f(1+\tau_f)^{-\sigma}\delta}{[(1+\tau_h)^{1-\sigma}\delta(1+\tau_f)^{1-\sigma}\delta-1][(1+\tau_f)^{-\sigma}\delta-1]}\right]\left[\frac{L+\rho\eta k}{L^2}\right]$$
$$+\left[\frac{\alpha\tau_h(1+\tau_h)^{-\sigma}\delta}{[(1+\tau_h)^{1-\sigma}\delta(1+\tau_f)^{1-\sigma}\delta-1][(1+\tau_h)^{-\sigma}\delta-1]}\right]\left[\frac{L+\rho\eta(1-k)}{L^2}\right]. \quad (19)$$

Differentiating Equation (19) with respect to each location's tariff rate and evaluated at $\tau_h = \tau_f = 0$ yields:

$$\left.\frac{\partial(E+E^*)}{\partial\tau_h}\right|_{\chi_h\approx 0,\,\chi_f\approx 0,\,\tau_h=\tau_f=0}>0,\quad \left.\frac{\partial(E+E^*)}{\partial\tau_f}\right|_{\chi_h\approx 0,\,\chi_f\approx 0,\,\tau_h=\tau_f=0}>0. \quad (20)$$

Equation (20) implies that a unilateral increase in the tariff rate of the home and foreign countries will raise the world consumption expenditure. Differentiating Equation (15) with respect to each location's tariff rate and considering Equation (20) and evaluated at $\tau_h=\tau_f=0$ yield:

$$\left.\frac{\partial g}{\partial\tau_h}\right|_{\chi_h\approx 0,\,\chi_f\approx 0,\,\tau_h=\tau_f=0}<0,\quad \left.\frac{\partial g}{\partial\tau_f}\right|_{\chi_h\approx 0,\,\chi_f\approx 0,\,\tau_h=\tau_f=0}<0. \quad (21)$$

Recall our earlier explanation that the world growth rate in Equation (15) depends negatively on the world consumption expenditure given by Equation (19). Therefore, Equation (21) implies that a unilateral increase in the tariff rate of the home (foreign) country will lower the world growth rate through the increase in the world consumption expenditure.

Why does a unilateral increase in the tariff rate in the home (or foreign) country decrease the world growth rate? In our model, a unilateral tariff increase by the home country has three effects that influence growth: relative price, price index, and tariff revenue effects. First, a unilateral tariff increase by the home country raises the price index of the composite industrial goods in the home country (P_D), as shown in Equation (4) in the main text, thereby decreasing both the home country's consumption expenditure on differentiated goods and global consumption spending. When global consumption spending is lower, less labor is used to produce global consumption goods, and thus, from the equilibrium condition for labor markets, more labor is available for the R&D sector. Therefore, this effect of the tariff increase, which we refer to as the "relative price effect," has a positive effect on the world growth rate.

Second, a unilateral tariff increase by the home country raises the home consumption price index, thereby increasing the total cost of consumption expenditure in the home country and consequently increasing global consumption spending. Import tariffs are a type of indirect tax; thus, a rise in the tariff rate leads to a proportional increase in the home consumption price index. Therefore, in contrast to the relative price effect, in this case, more labor is used in the production of global consumption goods and, from the equilibrium condition for labor market, less labor is available for the R&D sector. Therefore, this second effect, which we refer to as the "price index effect," has a negative effect on the world growth rate.

Third, a unilateral increase in the home country's tariff leads to an increase in the home country's tariff revenue, thereby raising the consumption expenditure in the home country and thus increasing global spending. As for the price index effect, greater global consumption spending implies that more labor is used in the production of goods and services to satisfy global consumption spending and, from the equilibrium condition for labor market, less labor is available for the R&D sector. Therefore, this third effect, which we refer to as the "tariff revenue effect," has a negative effect on the world growth rate. In summary, in response to a unilateral increase in the home tariff, a positive effect on the rate of world growth is obtained from the relative price effect, and a negative effect equal to the sum of the price index and tariff revenue effects exists. Therefore, the net growth effect of a unilateral tariff rise in the home country depends on the relative strength of the conflicting effects. However, the latter two (negative) effects always dominate the (positive) relative price effect under $\chi_h \approx 0$ and $\chi_f \approx 0$. We obtain the results in Equation (21). More explicitly, when $\chi_h \approx 0$ and $\chi_f \approx 0$ hold, that is, when the elasticity of substitution between any two differentiated goods is high, the iceberg transport cost in shipping the differentiated goods between the countries is high, the fraction of consumption expenditure devoted to the differentiated goods is small, and the tariff rate of the home (foreign) location is small, a unilateral increase in the tariff rate of the home (foreign) country will lower the world growth rate.

From the above, we find that when $\chi_h \approx 0$ and $\chi_f \approx 0$ hold, that is, when σ is large, α is small, δ is small, and the tariff rate τ_h (τ_f) is small, an increase in the tariff rate has a negative effect on the world growth rate through the greater increase in world consumption expenditure. Now, we explain how the magnitudes of each parameter value within $\chi_h \approx 0$ and $\chi_f \approx 0$ are related to the above result.

Intuitively, first, when the fraction of consumption expenditure on the differentiated goods, α, is small (and therefore when $\chi_h \approx 0$ and $\chi_f \approx 0$ hold), the magnitude of the decline in the home country's consumption of differentiated goods (and therefore the decline in global consumption spending) in response to the rise in the relative price of the differentiated goods through the tariff increase becomes smaller. This condition occurs because the consumption level of differentiated goods before the tariff increase is already small. Therefore, when the fraction of consumption expenditure on the differentiated goods, α, is small (and therefore when $\chi_h \approx 0$ and $\chi_f \approx 0$ hold), the positive impact on the rate of world growth owing to the relative price effect is small. Second, when the level of transport costs is sufficiently high (and therefore $\chi_h \approx 0$ and $\chi_f \approx 0$ hold), the price index effect becomes large from Equation (3) because, when the level of transport costs is high, the price level of the imported goods before the tariff increase is already high. Therefore, the tariff increase involves a greater price index effect. Thus, when the level of transport costs is sufficiently high (and thus $\chi_h \approx 0$ and $\chi_f \approx 0$ hold), the negative impact on the rate of world growth owing to the price index effect is large. Third, if the elasticity of substitution between any two differentiated goods, σ, is large and the fraction of consumption expenditure on the differentiated goods, α, is small, then not only the mark-up prices ($p = p^* = \beta\sigma / (\sigma - 1)$) but also the demand level for each imported differentiated good (Equation (7)) is low. This condition reduces the tariff revenues and thus weakens the magnitude of the tariff revenue effect. In addition, high transport costs (or a low level of δ) lead to a low tariff revenue effect because the demand for imported goods is lower than otherwise because, when the level of transport costs is high, the demand for imported goods before the tariff increase is already low. Therefore, the tariff revenue effect of the tariff increase is low. Furthermore, a small value of the tariff rate, τ_h (τ_f), corresponds to a low tariff revenue effect of a tariff increase. This condition occurs because, when tariff rates are low, the tariff revenues before the tariff increase are already small. Therefore, the tariff revenue effect of a small tariff increase is low.[2] As stated above, when $\chi_h \approx 0$ and $\chi_f \approx 0$ hold, the negative impact on the rate of world growth of the tariff revenue effect becomes small.

Thus, for the abovementioned reasons, when $\chi_h \approx 0$ and $\chi_f \approx 0$ hold, the negative price index and tariff revenue effects on world growth will exceed the positive relative price effect. Therefore, when $\chi_h \approx 0$ and $\chi_f \approx 0$ hold, the result of the present model is that a unilateral increase in the tariff rate of the home (foreign) country will lower the world growth rate.

Next, following Martin and Ottaviano (1999), we define the scale of net capital flows as $I \equiv (dn/dt) - (dK/dt)$, where the former is the change in the number of firms operating in the home location and the latter is the change in the number of firms owned by households in the same location. Therefore, $I >$ ($<$) 0 implies that net capital flows will occur from the foreign (home) country to the home (foreign) country. To examine the direction of net capital flows between countries analytically, we focus on symmetric tariff rates ($\tau_h = \tau_f = \tau'$). Then, from Equations (10d) and (16), the scale of net capital flows is:

$$\begin{aligned} I &\equiv \frac{dn}{dt} - \frac{dK}{dt} = g(n-K) \\ &= g\left[\frac{L(1-(1+\tau')^{-\sigma}\delta)(T\delta(L+\rho\eta)-L) - \alpha\tau'(1+\tau')^{-\sigma}\delta(L+\rho\eta)}{(2L+\rho\eta)[L(1-(1+\tau')^{-\sigma}\delta)(1-T\delta)+\alpha\tau'(1+\tau')^{-\sigma}\delta]}\right](K-K^*), \end{aligned} \tag{22}$$

where $(1+\tau_h)^{1-\sigma} = (1+\tau_f)^{1-\sigma} = (1+\tau')^{1-\sigma} \equiv T$.

Equation (22) indicates that the direction of net capital flows, I, is

[2] Concerning whether the parameter values assumed above are realistic, Fontagné, Guimbard, and Orefice (2022) indicate that high-income developed countries impose lower average import tariffs than low- and middle-income countries, thus indicating that global tariff rates tend to be lower as the economy grows. This finding supports the realism of the parameters for tariff rates assumed in this paper. In addition, Fontagné, Guimbard, and Orefice (2022) show that import tariffs for countries in all income groups (high, upper-middle, lower-middle, and low) trended downward from 2001 to 2016.

ambiguous. To determine whether the direction of net capital flows is positive or negative, we assume that the sizes of ρ and η are sufficiently small, which implies that the rate of time preference is small and the productivity in the R&D sector is high. This assumption implies that the sign of the equation within the square brackets in Equation (22) is negative. This assumption contributes to developing an intuitive explanation of the direction of net capital flows because, under this assumption, Equation (22) indicates that the sign of $(K - K^*)$ plays an important role in determining the direction of net capital flows. From Equation (22), we obtain the following relationship between the direction of net capital flows and the sign of $(K - K^*)$:

$$I > 0, \ \mathit{if}\ K < K^*, \tag{23a}$$

$$I = 0, \ \mathit{if}\ K = K^*, \tag{23b}$$

$$I < 0, \ \mathit{if}\ K > K^*. \tag{23c}$$

Equation (23a) implies that net capital flows will occur from the foreign country to the home country over time if $K < K^*$ holds. Conversely, from (23c), net capital flows will occur from the home to the foreign if $K > K^*$ holds. Equation (23b) shows that when $K = K^*$, no capital flow takes place between the home and foreign locations. In sum, the above-mentioned results indicate that if the capital stock of the home country is smaller (larger) than the capital stock of the foreign country, then net capital flows occur from the foreign (home) country to the home (foreign) country. The above result is similar to the result obtained by Martin and Ottaviano (1999) on what the direction of net capital flows negatively depends on $(K - K^*)$ when the sizes of ρ and η are sufficiently small.

Let us now explain why our results regarding the relationship between the direction of net capital flows between countries and the differences between the countries' capital stock levels are qualitatively the same as those obtained by Martin and Ottaviano (1999), who exclude import tariffs, when we include import tariffs in their model. To begin, the difference between the home and foreign country's capital stock levels has three opposing effects on the direction of net capital flows between the two countries. Specifically, first, under $K < K^*$, as Martin and Ottaviano (1999) argue, the home country with a lower level of capital can attract more firms because locating there is advantageous for firms to avoid competitive pressure rather in the foreign country, which has a greater number of rival firms than in the home country. Martin and Ottaviano (1999) refer to this as the "competition effect." Therefore, under $K < K^*$, this competition effect causes net capital flows from the foreign country to the home country. Second, in the model in our paper, a country's income is sourced from wage incomes, capital incomes, and tariff revenues. The labor endowment of both countries is identical; thus, the wage rate in each country becomes $w = w^* = 1$ in equilibrium. Hence, wage incomes do not contribute to differences in the total income levels of the two countries. However, under $K < K^*$, the foreign country has a higher capital income level than the home country because the equilibrium rate of return of capital (= $r = \rho$) is the same in the two countries, but the capital stock is larger in the foreign country.[3] Thus, under $K < K^*$, the steady-state consumption expenditures are larger in the foreign country than in the home country, and locating in the foreign country is more advantageous for the owners of firms because they can take advantage of the economies of scale in the differentiated goods sector. Martin and Ottaviano (1999) refer to this as the "capital income effect." Therefore, under $K < K^*$, contrary to the competition effect, net capital flows from the home to the foreign country can occur through this capital income effect. Third, the capital income effect increases the home country's demand for the foreign country's differentiated goods. This increase takes place because net capital flows occur from the home to the foreign country through the capital income effect, which results in many differentiated goods firms locating in the foreign country, which in turn increases the home country's demand for foreign differentiated goods. This condition then increases tariff revenues in the home country and thereby leads to an increase in its total income. This increase in total income in turn leads to an immediate increase in home-country consumption, which makes the home country a more favorable location for the owners of firms than the foreign country. We refer to this as the "international redistribution effect." Therefore, even under $K < K^*$, because of this international redistribution effect, net capital flows tend to occur from the foreign

[3] In our model, for the household budget constraint equations, home and foreign capital incomes are $rvK = \rho\eta K/N$ and $rvK^* = \rho\eta K^*/N$, respectively.

country to the home country. This finding implies that the international redistribution effect has the opposite effect to the capital income effect and that it thereby weakens the magnitude of the capital income effect on the direction of capital flows.

Accordingly, under $K < K^*$, the direction of net capital flows between the two countries is determined by the relative strength of the competition effect, the capital income effect, and the international redistribution effect. Thus, the direction of net capital flows between the two countries is ambiguous in general. However, in the model in our paper, as in Martin and Ottaviano (1999), when ρ and η are sufficiently small, the impacts of the difference in capital incomes between the two countries become small. Consequently, the capital income effect becomes small. This situation occurs because, given that the home and foreign capital incomes are $rvK = \rho\eta K/N$ and $rvK^* = \rho\eta K^*/N$, respectively, small values of ρ and η correspond to a small capital income effect. Furthermore, as stated above, because the international redistribution effect is a side effect of the capital income effect in our model, small values of ρ and η correspond to a low international redistribution effect. This result occurs because, as stated above, when ρ and η are small, the capital income effect is also small. Thus, if ρ and η are sufficiently small, then, of the three possible effects, the competition effect becomes significantly larger than the other two effects (the international redistribution and capital income effects). Therefore, the sum of the competition effect and the international redistribution effect always exceeds that of the capital income effect. Consequently, as in Martin and Ottaviano (1999), foreign direct investment flows from the foreign country to the home country even under $K < K^*$. Conversely, in the case where $K > K^*$, if ρ and η are sufficiently small, then the opposite results occur: net capital flows take place from the home country to the foreign country.

The important point of the present model is how the international redistribution effect (or tariff revenue) affects the direction of net capital flows between the countries, particularly compared with the previous studies based on Martin and Ottaviano (1999), which assumed only trade costs (without tariff changes). In the previous studies, under the assumption of trade costs only, the competition and capital income effects are the main influence on the direction of net capital flows between countries. Conversely, the novel feature of the present study is that we include import tariffs, which generates the international redistribution effect, which was not considered in the previous studies. This finding implies that the international redistribution effect is key to understanding the negative relationship between the two countries' capital stock differential and the direction of net capital flows. However, as mentioned above, the present model leads to qualitatively similar results for net capital flow as Martin and Ottaviano (1999) despite the additional mechanism in our model, namely, the changes in tariff revenues. This finding suggests that tariff revenues are not necessary for the results on net capital flow, particularly if the sizes of ρ and η are sufficiently small.

Finally, we can observe the impact of excluding the import tariffs (and consequently, removing the international redistribution effect) from the model on the direction of net capital flows, as a special case of the general model here. Substituting $\tau_h = \tau_f = \tau' = 0$ into (22), we obtain

$$I \equiv \frac{dn}{dt} - \frac{dK}{dt} = g(n - K) = g\left[\frac{\eta\rho\delta - L(1-\delta)}{(2L + \rho\eta)(1-\delta)}\right](K - K^*). \qquad (24)$$

Equation (24) shows that even when no tariff revenues exist, under $K < K^*$, net capital flows will take place from the foreign to the home country, as in our model, when ρ and η are sufficiently small. Indeed, Equation (24) is the same as the model of Martin and Ottaviano (1999) with only trade costs.

VI. Conclusion

This paper incorporated tariff rates into a two-country endogenous growth model to analyze the growth effects of a unilateral increase in a tariff rate in one country, given global knowledge spillovers in R&D and international relocation of firms. We showed that a unilateral increase in the tariff rate of one country (irrespective of which country) lowers the world growth rate through a decrease in labor in the R&D sector. In addition, we analyzed the relationship between the international distribution of capital and the direction of international capital flows between the two countries. As in the previous studies, we showed that if the home country's initial capital stock is smaller (larger) than the foreign country's initial capital stock, then net capital flows occur from the foreign (home) country to the home (foreign) country even under import tariffs.

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