Korea and the World Economy
Vol. 25, No. 1 (April 2024) 29-43
http://doi.org.10.46665/kwe.2024.04.25.1.29

Tariff-Growth Association through Tariff Revenue Redistribution and Labor Reallocation*

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This paper examines the impact of unilateral tariffs on the world growth rate through changes in tariff revenue and labor reallocation in a two-country endogenous growth model when firms are internationally mobile. In particular, in contrast to the effects of small deviations from free trade, this paper considers the effects of tariff increases given initial positive tariff rates. This paper finds that the growth effect of a unilateral tariff increase is pro-growth at high barriers levels, such as higher tariffs, but anti-growth at low barriers levels, such as low or zero tariffs.

JEL Classification: E22, F12, F16, F21, F43
Keywords: growth, tariff, location

* The author is grateful to two anonymous referees for many valuable comments and suggestions that improved the article.

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1. INTRODUCTION

Recently, protectionism and trade disputes between the US and China have been discussed in the empirical literature, and it is often argued that the trade war between the US and China leads to both countries being exposed to higher tariffs as a consequence. Indeed, Benguria et al. (2022) and Fajgelbaum and Khandelwal (2022) empirically show the various negative effects of such trade policy uncertainty on the real economy. In a globalized world economy what is the mechanism by which a unilateral tariff increase in one country can have a negative impact on the world growth rate?

In general, an increase in tariff rates has the effect of increasing a country's tax revenue. In addition, an increase in tariff rates leads to a decrease in customs revenue due to a decrease in imports. It can therefore be said that an increase in tariff rates determines the increase or decrease in a country's customs revenue, depending on the magnitude of these two effects. On the other hand, changes in tariff revenues can affect the allocation of resources in the country that raises tariffs. If an increase in household income due to a tariff increase leads to an increase in production in the non-innovation sector, activity in the innovation sector will be constrained. As a result, global economic growth will be negatively affected. Conversely, if a tariff increase reduces household income, it will reduce demand in non-innovation sectors, reallocate more productive resources to innovation sectors, and increase global economic growth.

In this paper, we use a two-country growth model to analyze the impact of an increase in a country's tariff rate on the world growth rate through the redistribution of tariff revenue and the reallocation of labor across sectors when firms are internationally mobile. In this paper, the impact of an increase in a country's tariff rate on that country's tariff revenue is largely determined by the level of the tariff rate before the tariff increase. If the tariff rate before the increase is low, the level of imports is already high due to the low tariffs, so the increase in tariff revenue due to a tariff increase will be greater and will offset the decrease in tariff revenue due to the decrease in imports, resulting in an increase in the country's tariff revenue. On the other hand, if the tariff level is high, the level of imports is already low due to the high tariffs, so the direct increase in tariff revenue due to a tariff increase will be smaller and will not offset the indirect decrease in tariff revenue due to reduced imports, resulting in a decrease in the country's tariff revenue.

In this paper's model, an increase in tariff revenue increases household consumption expenditure in that country. In addition, it will lead to an increase in global consumption expenditure, and the resulting increase in the size of the global market will lead to an increase in expenditure on numeraire goods that are exempt from tariffs. An increase in the production of numeraire goods will itself put pressure on the labor market, leading to a reduction in the level of employment in the R&D sector. A decline in employment in the R&D sector will suppress innovation and, as a result, reduce global growth rates. Therefore, if the pre-raise tariff rate is low, a tariff increase in one country will have a negative impact on the world growth rate

through changes in tariff revenues and a reallocation of labor from the innovation sector to the non-innovation sector. Conversely, if the pre-raise tariff rate is high, the resulting reduction in tariff revenue will increase employment in the R&D sector through the resulting reduction in demand in the non-innovation sector and the resulting reallocation of labor, and stimulate innovation, which in turn will have a positive impact on world growth. In this paper we show the above mechanism using a two-country growth model, which assumes that firms are internationally mobile.

In previous endogenous growth studies, although there are many studies of the growth effects of tariff policy within a small open economy model or a symmetric multi-country economy model, there are few theoretical studies that analyze the world growth effects of a unilateral increase in the tariff rate within a two-country endogenous growth model with international relocation of firms.[1)] Moreover, most recent contributions to the analysis of trade restrictive policies in an endogenous growth framework have focused on how an increase in transport costs affects growth, or how a shift from autarky to free trade (or vice versa) affects growth, or how a global increase in tariffs, for example due to WTO pressure, affects growth. As a result, there are few theoretical studies that analyze the growth effects of a unilateral tariff increase in one country within the open economy endogenous growth model with endogenous determinants of international relocation of firms.

In relation to the theoretical issues raised above, it is important to note that several studies have examined the relationship between a reduction in trade costs, such as iceberg transport costs, and economic growth. The most important studies in this area are Martin (1999), Baldwin (1999), Martin and Ottaviano (1999, 2001), Baldwin and Forslid (2000), Baldwin, Martin, and Ottaviano (2001), Baldwin, Braconier, and Forslid (2005), and Johdo (2013). For example, Martin and Ottaviano (1999) combine the endogenous growth model of Grossman and Helpman (1991b) and the location model of Martin and Rogers (1995) to explain the impact of openness on the world growth rate through its effect on industrial location. However, the above literature does not explicitly explore this adjustment mechanism not only for the direct link between the international distribution of firms' location and tariffs, but also for the relationship between growth and the international income transfer of tariff revenues. This is because all these studies assume that transport costs are barriers to trade. In contrast, this paper examines the impact of a unilateral tariff increase on each economy and the world growth rate by introducing import tariffs into the endogenous growth model of Martin and Ottaviano (1999). This extended model has two countries in which there are global knowledge spillovers. Because of these global knowledge spillovers, the cost of innovation in a given country falls as the total number of firms located in both countries increases.

This analysis shows that with global knowledge spillovers in R&D, a unilateral increase in the

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[1)] In the endogenous growth literature, for the small open economy model, the studies by Osang and Pereira (1996) and Osang and Turnovsky (2000) are well-known theoretical studies on the relationship between tariffs and growth. For the symmetric multi-county model, the studies by Grossman and Helpman (1991a), Rivera-Batiz and Romer (1991a, 1991b), Dinopoulos and Sergerstrom (1999a, 1999b), Peretto (2003), Lee (2005), Blackburn and Hung (2006) and Ourens (2016) are well-known theoretical studies.

home (or foreign) country's tariff rate affects the world growth rate through a change in that country's tariff revenue and a reallocation of labor between innovation and non-innovation sectors.

The main results of this analysis are as follows: a unilateral tariff increase in one country raises or lowers the world growth rate, depending on whether the initial tariff rates are small or large. The key to this result is both how the tariff revenue due to a higher tariff depends on the initial tariff rate of the country that raises the tariff rate, and how the amount of labor resources allocated to the innovation sector is consequently changed by the tariff increases.

The rest of the paper is structured as follows. Section 2 outlines the features of the model. Section 3 describes the equilibrium location and firm size, and section 4 describes the R&D sector. Section 5 examines the impact of a unilateral tariff increase in one country on the world growth rate through changes in tariff revenue in that country and labor reallocation across sectors. Section 6 concludes the paper.

2. MODEL

In the following, we focus mainly on a description of the home country. 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, $Y(t)$ is the numeraire good in period t, and $D(t)$ is the consumption index of differentiated goods defined as follows,

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

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 at home and abroad. In this model, the government in each country imposes an ad valorem import tariff on all imported differentiated goods and redistributes the tariff revenue to households in a lump sum. We also assume iceberg transport costs τ ($\tau \geq 1$) for the transport of differentiated goods between countries. In the following, the time subscript is dropped. The per capita expenditure of a typical household, E, is then

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

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. Then the consumption price indices for the differentiated products are

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

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

where P^D (P^{D*}) is the price index in the home (foreign) country and p_i (p_j^*) is the producer price of a typical variety i in the home (foreign) country. In the differentiated goods sector, a patent is required to start producing each variety of good, so we can interpret this capital requirement as a fixed cost of production. Each firm issues shares 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 choosing p_i gives $p_i = w\beta\sigma/(\sigma - 1)$. The profit flow of each firm in the differentiated goods sector (= π_i) is then

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

where $x(p_i)$ is the quantity of output.

The homogeneous good Y is assumed to be produced by a technology with constant returns to scale that requires labor as the only input, where firms use one unit of labor to produce one unit of Y. We also assume that some production of the homogeneous good occurs in both countries. Thus, we ensure factor price equalization between countries $w = w^*$ at any point in time due to free trade in the homogeneous good. Because the numeraire is the homogeneous good, the wage rate in each location is $w = w^* = 1$. We therefore obtain $p = p^* = \beta\sigma/(\sigma - 1)$.

From the standard utility optimization, given the choice 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:

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

Here we define v as the equity value of a firm and r as the return on a riskless bond. Assuming no arbitrage in the capital markets and considering $w = w^* = 1$ and (6), we obtain:

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

Maximizing (1) subject to the intertemporal budget constraint and the assumption of free capital mobility between countries requires that nominal expenditure grows at an instantaneous rate equal to $r - \rho$:

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

3. FIRM SIZES AND LOCATIONS

Here we define $T_h \equiv (\tau_h + \tau)^{1-\sigma}$ and $T_f \equiv (\tau_f + \tau)^{1-\sigma}$ for convenience. Aggregating the demand in (7) over all households worldwide, we obtain the following market clearing condition for any differentiated product x:

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

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

$$x^* = \frac{\alpha L(\sigma-1)}{\beta\sigma}\left(\frac{E(\tau_h + \tau)^{-\sigma}}{n + n^* T_h} + \frac{E^*}{n^* + nT_f}\right). \tag{11}$$

The model assumes that firms face no relocation costs, so that relocation takes no time. For a firm to be indifferent between the home and the foreign locations following location arbitrage, the operating profits of the two locations must also be equal:

$$\pi = \pi^*. \tag{12}$$

Therefore, from equations (6), (12) and $w = w^* = 1$, we obtain $x = x^*$. Let K and K^* be the stocks of capital at home and abroad respectively. The total stock of capital owned by households determines the total number of firms, so that:

$$n + n^* = K + K^* = N. \tag{13}$$

Solving (10)-(13), we obtain the share of firms in the home country, which we define as:

$$\gamma = \frac{n}{N} = \frac{\left(1-\left(\tau_h+\tau\right)^{-\sigma}\right)E-\left(1-\left(\tau_f+\tau\right)^{-\sigma}\right)T_hE^*}{\left(1-\left(\tau_h+\tau\right)^{-\sigma}\right)\left(1-T_f\right)E+\left(1-\left(\tau_f+\tau\right)^{-\sigma}\right)\left(1-T_h\right)E^*}. \tag{14}$$

Then, from equation (14), for a given level of expenditure (E, E^*) we obtain

$$\left.\frac{\partial\gamma}{\partial\tau_h}\right|_{\tau_h=\tau_f=0,E=E^*} > 0, \qquad \left.\frac{\partial\gamma}{\partial\tau_f}\right|_{\tau_h=\tau_f=0,E=E^*} < 0. \tag{15}$$

Equation (15) implies that a unilateral increase in the home (foreign) tariff rate will increase the share of firms in the home (foreign) country and decrease the equilibrium share of firms in the foreign (home) country. This is because a unilateral increase in the tariff rate of the home country reduces the price of the home country's differentiated goods relative to the imported differentiated goods of the foreign country, causing world consumption demand to shift from the imported differentiated goods of the foreign country to the differentiated goods of the home country. Consequently, this shift in demand increases the relative profits of firms located in the home country, thereby inducing firms located abroad to relocate to the home country.

The output of each firm is

$$x = x^* = \alpha L\frac{\sigma-1}{\beta\sigma}\frac{\overline{E}}{N}\left\{\frac{1-\left(\tau_h+\tau\right)^{-\sigma}\left(\tau_f+\tau\right)^{-\sigma}}{\left(1-\left(\tau_h+\tau\right)^{-\sigma}\right)\left(1-\left(\tau_f+\tau\right)^{-\sigma}\right)\left(1-T_hT_f\right)}\right\}, \tag{16}$$

where $\overline{E} = \left(1-\left(\tau_h+\tau\right)^{-\sigma}\right)\left(1-T_f\right)E+\left(1-\left(\tau_f+\tau\right)^{-\sigma}\right)\left(1-T_h\right)E^*$.

4. R&D SECTOR

Let v denote the value of a designed blueprint developed through R&D. As in Martin and Ottaviano (1999), we assume that a researcher engaged in R&D requires η/N units of labor since R&D costs are the same in both locations due to global knowledge spillovers. 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 constants). If there is a balanced growth path, from $v = \eta/N$, this implies that v decreases at the rate $g = \dot{N}/N = \dot{n}/n$. The world labor market clearing condition is as follows:

$$\eta g + (1-\alpha)L\left(E + E^*\right) + \alpha L\left(\frac{\sigma-1}{\sigma}\right)\bar{E}\bar{T} = 2L, \tag{17}$$

where

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

If g is constant in the steady state, equation (17) implies that expenditure must be constant. This gives $r = \rho$ from (9). Then, substituting equation (16), $v = \eta/N$ and $r = \rho$ into equation (8) and considering (17), the following equilibrium world growth rate of K, K^* and N is obtained:

$$\mathrm{g} = \frac{2L}{\eta\sigma} - \frac{(1-\alpha)L(E+E^*)}{\eta\sigma} - \left(\frac{\sigma-1}{\sigma}\right)\rho. \tag{18}$$

Per capita expenditure for each country is

$$E = 1 + \frac{\rho\eta k}{L} + \frac{\tau_h n^* p_f^* D_f}{L}, \quad E^* = 1 + \frac{\rho\eta(1-k)}{L} + \frac{\tau_f n p_h D_h^*}{L}, \tag{19}$$

where $k \equiv K/N$ ($(1-k) \equiv (1-K/N)$) is the share of firms owned by the home (foreign) country, which is constant in the steady state.

5. THE EFFECTS OF A UNILATERAL TARIFF INCREASE

To examine the impact of a country increasing its tariff rate, we assume that $T_hT_f \approx 0$, where $T_h \equiv (\tau_h + \tau)^{1-\sigma}$ and $T_f \equiv (\tau_f + \tau)^{1-\sigma}$. Intuitively, given τ_h and τ_f, if σ and τ are sufficiently large, then $T_hT_f \approx 0$ holds (i.e. $T_hT_f \approx 0$ is approximately zero). These expressions state that if the elasticity of substitution between any two differentiated goods (σ) is high and the iceberg transport cost of shipping the differentiated goods between countries (τ) is high, then $T_hT_f \approx 0$ will hold. Under these assumptions, we can see the effect of a unilateral tariff increase in each country. Next, we analyze the effect of a unilateral increase in the tariff rate in each country on the world growth rate through the effect on world consumption expenditure. Equation (18) shows that the world growth rate depends negatively on world consumption expenditure. This is because the increase in world consumption expenditure implies that more labor is used to produce the numeraire consumption good, which is determined in proportion to world consumption expenditure, and, from the equilibrium condition for labor markets, less labor is

available for the R&D sector. Consequently, this has a negative effect on the world growth rate due to the decrease in innovation. Here, from $T_hT_f \approx 0$, equation (19) gives the following steady state world consumption expenditure:

$$\left(E+E^*\right)_{T_hT_f\approx 0} = 2+\frac{\rho\eta}{L}+\left[\frac{\alpha\tau_f\left(\tau_f+\tau\right)^{-\sigma}}{\left[1-\left(\tau_f+\tau\right)^{-\sigma}\right]}\right]\left[\frac{L+\rho\eta k}{L^2}\right]+\left[\frac{\alpha\tau_h\left(\tau_h+\tau\right)^{-\sigma}}{\left[1-\left(\tau_h+\tau\right)^{-\sigma}\right]}\right]\left[\frac{L+\rho\eta\left(1-k\right)}{L^2}\right]. \quad (20)$$

Differentiating equation (20) with respect the tariff rate of each location yields

$$\left.\frac{\partial\left(E+E^*\right)}{\partial\tau_h}\right|_{T_hT_f\approx 0} = \left[\frac{\alpha\left(\tau_h+\tau\right)^{-\sigma}\left[1-\left(\tau_h+\tau\right)^{-\sigma}-\sigma\tau_h\left(\tau_h+\tau\right)^{-1}\right]}{\left[1-\left(\tau_h+\tau\right)^{-\sigma}\right]^2}\right]\left[\frac{L+\rho\eta\left(1-k\right)}{L^2}\right], \quad (21)$$

$$\left.\frac{\partial\left(E+E^*\right)}{\partial\tau_f}\right|_{T_hT_f\approx 0} = \left[\frac{\alpha\left(\tau_f+\tau\right)^{-\sigma}\left[1-\left(\tau_f+\tau\right)^{-\sigma}-\sigma\tau_f\left(\tau_f+\tau\right)^{-1}\right]}{\left[1-\left(\tau_f+\tau\right)^{-\sigma}\right]^2}\right]\left[\frac{L+\rho\eta k}{L^2}\right]. \quad (22)$$

From equations (21) and (22) we obtain the following results

$$\left.\frac{\partial\left(E+E^*\right)}{\partial\tau_h}\right|_{T_hT_f\approx 0} > 0, \text{ if } \ 1 > \frac{1}{\left(\tau_h+\tau\right)^{\sigma}}+\sigma\left(\frac{\tau_h}{\tau_h+\tau}\right), \quad (23)$$

$$\left.\frac{\partial\left(E+E^*\right)}{\partial\tau_f}\right|_{T_hT_f\approx 0} > 0, \text{ if } \ 1 > \frac{1}{\left(\tau_f+\tau\right)^{\sigma}}+\sigma\left(\frac{\tau_f}{\tau_f+\tau}\right). \quad (24)$$

Equations (23) and (24) show that when τ_h and τ_f are small, a unilateral increase in the tariff rate of the home and foreign countries will increase world consumption expenditure. Intuitively, this can be explained as follows. If τ_h is small, the scale of imports due to low tariffs is already large, so the scale of tariff revenue is also large. Therefore, the direct increase in tariff revenue due to the initial increase in the tariff rate will be larger, so this will exceed the reduction in the volume of imports due to the increase in the tariff rate, and consequently the country's tariff revenue will increase. From (19), the increase in tariff revenue leads to an increase in the country's expenditure and, consequently, in total global expenditure. This leads to the results in equations (23) and (24). In addition, equations (21) and (22) give the following relationship between total world expenditure and initial tariff rates

$$\left.\frac{\partial\left(E+E^*\right)}{\partial\tau_h}\right|_{T_hT_f\approx 0} < 0, \text{ if } \ 1 < \frac{1}{\left(\tau_h+\tau\right)^{\sigma}}+\sigma\left(\frac{\tau_h}{\tau_h+\tau}\right), \quad (25)$$

$$\left.\frac{\partial\left(E+E^{*}\right)}{\partial\tau_{f}}\right|_{T_{h}T_{f}\approx 0}<0\text{, if }\ 1<\frac{1}{\left(\tau_{f}+\tau\right)^{\sigma}}+\sigma\left(\frac{\tau_{f}}{\tau_{f}+\tau}\right). \tag{26}$$

Equations (25) and (26) show that when τ_h and τ_f are large, a unilateral increase in the home and foreign tariff rate will reduce world consumption expenditure. Intuitively, this can be explained as follows. If τ_i ($i = h, f$) is large, the amount of imports due to low tariffs is already small, so the amount of tariff revenue is also small. Therefore, the direct increase in tariff revenue due to the initial increase in the tariff rate will be smaller, so that it will be outweighed by the reduction in the volume of imports due to the increase in the tariff rate, and consequently the country's tariff revenue will decrease.

Recall our earlier explanation that the world growth rate in equation (18) depends negatively on the world consumption expenditure given by equation (20). Therefore, differentiating equation (18) with respect to each location's tariff rate and considering the results from (23) to (26), we obtain

$$\left.\frac{\partial g}{\partial\tau_{i}}\right|_{T_{h}T_{f}\approx 0}<0\text{, if }\ 1>\frac{1}{\left(\tau_{i}+\tau\right)^{\sigma}}+\sigma\left(\frac{\tau_{i}}{\tau_{i}+\tau}\right),\quad i = h, f, \tag{27}$$

$$\left.\frac{\partial g}{\partial\tau_{i}}\right|_{T_{h}T_{f}\approx 0}>0\text{, if }\ 1<\frac{1}{\left(\tau_{i}+\tau\right)^{\sigma}}+\sigma\left(\frac{\tau_{i}}{\tau_{i}+\tau}\right),\quad i = h, f. \tag{28}$$

Therefore, equation (27) implies that a unilateral increase in the home (or foreign) tariff rate will reduce the world growth rate through the increase in world consumption expenditure. In contrast, equation (28) implies that a unilateral increase in the home (or foreign) tariff rate will increase the world growth rate through the decrease in world consumption expenditure. Thus, a unilateral tariff increase in a country can either increase or decrease the world growth rate, depending on the initial level of tariff rates, as follows:

$$\left.\frac{\partial g}{\partial\tau_{i}}\right|_{T_{h}T_{f}\approx 0}<0\text{, if } \tau_i \text{ } (i = h, f) \text{ is low,} \tag{29}$$

$$\left.\frac{\partial g}{\partial\tau_{i}}\right|_{T_{h}T_{f}\approx 0}>0\text{, if } \tau_i \text{ } (i = h, f) \text{ is high.} \tag{30}$$

As shown above, these results indicate that if the initial tariff rate of the country that raised the tariff is low, then the effect of a unilateral increase in the tariff rate in each country on world

growth will be negative. Conversely, if the initial tariff rate of the country that raised the tariff is high, the effect of a unilateral increase in the tariff rate on world growth will be positive.

Therefore, it follows from (29) and (30) that theoretical predictions about the relationship between a unilateral tariff increase in one country and the world growth rate depend primarily on the size of the initial tariff rate of the country that raised the tariff. In other words, a unilateral tariff increase in one country either raises or lowers the world growth rate, depending on the size of the initial tariff rate of the country that raised it. Recall our earlier explanation that the world growth rate given by equation (18) depends negatively on the world consumption expenditure given by equation (20). Therefore, equations (27) and (29) imply that a unilateral increase in the home (or foreign) tariff rate will reduce the world growth rate through the increase in world consumption expenditure. Conversely, equations (28) and (30) imply that a unilateral increase in the home (or foreign) tariff rate will increase the world growth rate through the decrease in world consumption expenditure.

The intuitive explanation for this is as follows. In our model, a unilateral tariff increase by the home country that affects the world growth rate has been split into two effects: the tariff revenue increasing effect and the import demand decreasing effect. First, a unilateral increase in the home country's tariff rate leads to an increase in the home country's consumption expenditure through an increase in the home country's tariff revenue and, consequently, an increase in world expenditure. Moreover, higher world consumption expenditure implies that more labor is used in the production of the numerical consumption good, which is determined in proportion to world consumption expenditure, and that, from the point of view of labor market equilibrium, less labor is available for the R&D sector. Therefore, this effect has a negative impact on the world growth rate. In our model we call this the "tariff revenue increasing effect". Second, a unilateral tariff increase by the home country raises the price index of differentiated goods in the home country in equation (4), thereby reducing the home country's consumption expenditure on imported differentiated goods and consequently reducing the home country's tariff revenue. A decrease in tariff revenue leads to a decrease in total consumption expenditure in the home country and consequently to a decrease in world consumption expenditure. As a result, less labor is used to produce the numerical consumption good, which is also determined in proportion to world consumption expenditure, and thus, from the equilibrium condition for labor markets, more labor is available for the R&D sector. Therefore, this second effect has a positive impact on the world growth rate. In our model we call this the "import demand decreasing effect".

In summary, in our model, with respect to the effect of a unilateral increase in a country's tariff rate on world growth, there is a negative effect on world growth from the tariff revenue increasing effect and a positive effect on world growth from the import demand decreasing effect. Therefore, the net effect of a unilateral tariff increase in the home country on the world growth rate depends on the relative strength of these opposing effects. However, if the initial tariff rate of the raising country is low, a unilateral increase in a country's tariff rate will lower the world growth rate, as shown in (27) or (29). This is because if the initial tariff rate of the

country that raised the tariff is low, the former negative tariff revenue increasing effect exceeds the latter positive import demand decreasing effect. Therefore, we find that when the initial tariff rate of the country that raised the tariff is low, an increase in a country's tariff rate has a negative effect on the world growth rate through the larger increase in world consumption expenditure. On the other hand, when the initial tariff rate of the country that raised the tariff is high, the latter positive import demand decreasing effect outweighs the former negative tariff revenue increasing effect, so that we obtain the results in equation (28) or (30). In other words, we find that when the initial tariff rate of the country that raised the tariff is high, a unilateral increase in a country's tariff rate will increase the world growth rate because the opposite mechanism is at work.

Below we explain how the size of the parameter τ_i ($i = h, f$) relates to the two opposite results above. Intuitively, if the initial tariff rate of the country that raised the tariff is small, the price index of the differentiated goods in that country from equation (4) will be small, and consequently the demand level for each imported differentiated good (equation (7)) in the home country will be high. Therefore, if the initial tariff rate of the country that raised the tariff is small, the tariff revenue will be larger and the tariff revenue increasing effect will be even stronger. Thus, as noted above, if τ_i ($i = h, f$) is small, the negative tariff revenue increasing effect on world growth will outweigh the positive import demand decreasing effect, and consequently we have the result that a unilateral increase in a country's tariff rate will lower the world growth rate.[2)] By exactly the opposite mechanism, the positive import demand decreasing effect will outweigh the negative tariff revenue increasing effect when τ_i ($i = h, f$) is large, so that we obtain the results in equation (28) or (30). That is, in this case, a unilateral increase in a country's tariff rate of will increase the world growth rate.[3)]

Thus, the above results suggest that the growth effect of a country's unilateral tariff increase is pro-growth for high levels of barriers, such as higher tariffs, but anti-growth for low levels of barriers, such as low or zero tariffs. In the empirical literature on growth and tariffs, Clements and Williamson (2001, 2004) show empirically that changes in the world tariff environment are the main reason for the association between a country's own tariff rate and world growth. In particular, they show that higher tariffs were associated with fast growth before World War II, when tariffs were sufficiently high, but were associated with slow growth in the period of relatively free trade (or the period of relatively low tariffs), such as after World War II. The result in this paper is therefore consistent with the evidence in the literature.

[2)] Studies by Lee (1993), Romalis (2007), and Madsen (2009) are empirical studies showing a negative relationship between tariffs and growth. For an overview of empirical research on the relationship between tariffs and growth, see Rodriguez and Rodrik (2000).

[3)] Studies by O'Rourke (2000), Irwin (2002), Vamvakidis (2002), Yanikkaya (2003), Clemens and Williamson (2004), and Schularick and Solomou (2011) are well-known empirical studies that find a positive relationship between tariffs and economic growth.

6. CONCLUSION

This paper analyzed the growth effects of a unilateral tariff increase in one country, taking into account both changes in tariff revenue and the resulting reallocation of labor resources across sectors. In this paper, we showed that a unilateral tariff increase in one country raises or lowers the world growth rate, depending on whether the initial tariff rate of the country that raised the tariff is low or high. In particular, we found from our model that an increase in a country's tariff rate has two opposite effects on the world growth rate, namely the tariff revenue increasing effect and the import demand decreasing effect. We then found that when the initial tariff rate of the country that raised the tariff is low, the negative tariff revenue increasing effect exceeds the positive import demand decreasing effect, so that a unilateral tariff increase in one country lowers the world growth rate. However, we also find that this result is reversed when the initial tariff rate of the raising country is high. Therefore, the above results suggest the following policy implication: if the aim of tariffs in a country is to increase the world growth rate, the tariff rate should be further reduced if the initial tariff rate of the raising country is low, while the tariff rate should be further increased if the initial tariff rate of the raising country is high.

Finally, this paper has analyzed the growth effects of tariffs using the two-country endogenous growth model of Martin and Ottaviano (1999) as simply as possible without complicating the model. Needless to say, the present model, while very tractable, is quite limited and a number of extensions are possible. First, if the current model were to include asymmetric transport costs, as in Johdo (2013), this paper might yield more interesting results. Second, given that the main purpose of this paper is to analyze the impact of an increase in an exogenously given tariff rate in a country, we do not consider the interaction between the two governments in setting endogenous tariff rates. Therefore, it may be an interesting extension to extend the present model to a non-cooperative game theoretic analysis and to consider the tariff rate as a strategic variable, as in Felbermayr, Jung, and Larch (2013), on the world growth rate. Indeed, in recent years, the trade war between the US and China has led both countries to raise tariffs, and there are growing concerns about the various negative effects of trade policy uncertainty due to such increased protectionism on the global economy (e.g., Benguria et al., 2022; Fajgelbaum and Khandelwal, 2022). In order to better analyze these ongoing issues due to trade wars in theoretical analysis, it is necessary to model tariff rates as a strategic variable rather than an exogenous variable as in our model. Third, in the real world, firm relocation is influenced by factors other than tariffs and transport costs, which are the focus of this study, so it may be important to include other factors affecting firm relocation (e.g., corporate taxes and public infrastructure) in addition to the factors mentioned above.

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