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Economic Geography with Tariff Competition

Chao-cheng Mai* Shin-Kun Peng† Takatoshi Tabuchi‡

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Abstract: A simple two-country model of economic geography is constructed in order to examine the effect of tariff competition on the spatial distribution of manufacturing activities as well as on welfare. We show that when the transport cost is sufficiently small, tariff competition with firm migration leads to a core-periphery economy, where one of the two countries imposes no tariff in Nash equilibrium. We also show that when the transport cost is sufficiently large, tariff competition harms the welfare of the two countries, implying that each country is better off by mutually binding agreement of free trade. (*JEL Classification:* F12, F15, F21, R12)

Keywords: trade liberalization, tariff competition, economic geography, core-periphery, trade costs.

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1 Introduction

Ever since Krugman (1980), trade costs, which include tariffs and transport costs, have been important features of new trade theory and new economic geography (e.g. Fujita, Krugman and Venables, 1999; Baldwin, Forslid, Martin, Ottaviano and Robert-Nicoud, 2003). It has long been believed that trade costs have fallen significantly over time. Baier and Bergstrand (2001) estimate that income growth explains 67%, tariff-rate reductions 25%, transport-cost declines 8% of the average growth of world trade among OECD countries between the late 1950s and the late 1980s. Nevertheless, there still exist large border costs even between Canada and the United States having the Free Trade Agreement (FTA) as shown by McCallum (1995) and his successors.

According to Anderson and van Wincoop (2004), “trade costs are broadly defined to include all costs incurred in getting a good to a final user other than the production cost of the good itself. Among others this includes transportation costs (both freight costs and time costs), policy barriers (tariffs and non-tariff barriers), information costs, contract enforcement costs, costs associated with the use of different currencies, legal and regulatory costs, and local distribution costs (wholesale and retail).” They further proceed to report that an approximate estimate of the tax equivalent of representative trade costs for “industrialized countries” amounts to 170%; transport costs, local retail and wholesale distribution costs, and border-related barriers account for roughly 21%, 55%, and 44% of this estimate, respectively ($2.7 = 1.21 \times 1.55 \times 1.44$).

There is a sharp distinction between transport costs and tariffs. The transport costs are considered to be exogenous and to disappear, whereas tariffs are determined endogenously by national tariff policies and are redistributed to consumers in importing countries.

By incorporating these trade costs, we extend Krugman’s (1980) model of firm migration, wherein each country engages in tariff competition in order to attain a high national welfare level. In particular, it differs from Krugman (1980) in that the tariffs

are strategically determined, whereas the transport costs are exogenously given.

The specific structure of the model yields some interesting results. First, we show that when the transport cost is large enough, each country imposes a positive tariff. Such a tariff is shown to harm each other because it distorts market efficiency. Therefore, if both countries can reach mutually binding agreement of free trade, then it is a Pareto improvement for both countries. On the other hand, when the transport cost is small enough, we show that one of the two countries does not impose a tariff and firms migrate from a zero-tariff country to a positive-tariff country, leading to a core-periphery structure. We therefore conclude that from a welfare perspective, when the transport cost is small, it is more desirable to allow than to prohibit firm migration.

The organization of the paper is as follows. In the next section, we present the model and characterize dispersed and agglomerated equilibria for the given tariffs. In Section 3, we analyze the tariff competition in the case of both a large and small transport cost. In order to substantiate the analytical results, we perform numerical simulations, using the values of Anderson and van Wincoop (2004) in section 4. Section 5 concludes.

2 The model

The global economy comprises two countries, indexed by r and s , and involves two sectors, called the manufacturing sector (\mathbb{M} -sector) and the agricultural sector (\mathbb{A} -sector). Each country is endowed with an identical number of homogenous workers (= consumers) by mass $L_r = L_s = L/2$. Each worker supplies one unit of labor inelastically and is perfectly mobile between sectors but spatially immobile between countries.

Individual preferences are identical and described by the following utility function:

$$U = \left[\int_0^n q(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\mu\sigma}{\sigma-1}} q_A^\alpha \quad (1)$$

where $q(i)$ represents the consumption of a differentiated \mathbb{M} -good of variety $i \in [0, n]$, n is the mass of varieties, q_A is the consumption of the homogenous \mathbb{A} -good, $\sigma > 1$ measures both the elasticity of demand of any variety and the elasticity of substitution between any pair of varieties, μ is the expenditure share of \mathbb{M} -goods, and α is the expenditure share of \mathbb{A} -good, where $0 < \mu < 1$, $0 < \alpha < 1$ and $\mu + \alpha = 1$. Each individual maximizes her utility subject to the income constraint:

$$\int_0^n p(i)q(i)di + q_A = y \quad (2)$$

where $p(i)$ is the price of the \mathbb{M} -good i , y is the income of an individual, and the price of the \mathbb{A} -good is chosen as a numéraire.

Ex-post symmetry between varieties imposes that $q_{rs}(i) = q_{rs}$ for all variety i produced in country r and sold in country s . Thus, the first-order condition to maximize the individual utility yields the demand of each variety in country s for a good produced in region r as

$$q_{rs} = \frac{p_{rs}^{-\sigma}}{P_s^{1-\sigma}} \mu y_s \quad (3)$$

where p_{rs} is the price of any variety produced in country r and sold in country s , y_s is the individual income in country s ,

$$P_s = (n_r p_{rs}^{1-\sigma} + n_s p_{ss}^{1-\sigma})^{\frac{1}{1-\sigma}} \quad (4)$$

is the price index of \mathbb{M} -goods in country s , and n_r is the mass of firms in country r . Product differentiation ensures a one-to-one relation between firms and varieties. Thus, the number of firms and varieties in country r is given by n_r .

On the production side, firms in the \mathbb{A} -sector produce a homogenous good using labor under perfect competition and constant returns to scale. Without loss of generality, units are chosen such that one unit of output requires one unit of labor. Assuming costless transportation of the \mathbb{A} -good, the equilibrium wage of workers is equalized between the countries as $w_r = w_s = 1$.¹

¹We assume $\mu < 1/2$ such that factor price equalization holds for any tariff. See Appendix 1 in Behrens, Lamorgese, Ottaviano and Tabuchi (2004) for more details.

While both the firms in the \mathbb{A} -sector and all the workers are immobile, the firms in the \mathbb{M} -sector are mobile between countries. The production technology for any variety of \mathbb{M} -goods needs the same marginal and fixed labor requirements, labeled c and F respectively, under increasing returns to scale in a monopolistically competitive market. We assume “iceberg” transport costs both between the countries and within each country: a firm in country r has to produce $t_d t q_{rs}$ units to satisfy the final demand q_{rs} in country $s (\neq r)$, and $t_d q_{rr}$ units to satisfy the final demand q_{rr} in country r , where $t_d (\geq 1)$ is the local retail and wholesale distribution costs, and $t (\geq 1)$ denotes the international transport cost. For simplicity, we ignore the domestic transport cost, so that the transport cost means the international transport cost throughout the paper. We also assume that country s imposes the *ad valorem* tariff τ_s on one unit of \mathbb{M} -good imported from country r , while no tariff is imposed on \mathbb{A} -good. The transport costs “melt” during the process of trade, whereas the tariffs do not and are redistributed equally to workers in importing countries. Given the demand (3), each firm (i.e., each owner of capital) in country r maximizes its profits

$$\pi_r = p_{rr} q_{rr} L_r + \frac{1}{1 + \tau_s} p_{rs} q_{rs} L_s - w_r [c (t_d q_{rr} L_r + t_d t q_{rs} L_s) + F] \quad (5)$$

The second term in (5) is discounted by $1 + \tau_s$ owing to the *ad valorem* tariff in country s . This is because the share $\tau_s / (1 + \tau_s)$ of export sales is levied by the government in importing country s , and the share $1 / (1 + \tau_s)$ of export sales is earned by a firm in exporting country r .

The first-order conditions for maximization (5) with respect to p_{rr} and p_{rs} yield the equilibrium prices as

$$\begin{aligned} p_{rr}^* &= \frac{\sigma c}{\sigma - 1} w_r t_d = 1 \\ p_{rs}^* &= \frac{\sigma c}{\sigma - 1} (1 + \tau_s) w_r t_d t = (1 + \tau_s) t \end{aligned} \quad (6)$$

where we normalize $c = t_d (\sigma - 1) / \sigma$ and utilize the factor price equalization $w_r = 1$. Substituting (6) into (4), the price index of manufacturing goods in country y is

rewritten as

$$P_r = [(\lambda_r + \phi(1 + \tau_r)^{1-\sigma} \lambda_s) n]^{\frac{1}{1-\sigma}} \quad (7)$$

where $\lambda_r = n_r/n$ is the share of M-firms in country r with $\lambda_r + \lambda_s = 1$, $\phi = t^{1-\sigma}$ is the freeness of trade, where $0 \leq \phi \leq 1$.

In what follows, we assume that both countries select their tariffs simultaneously, and then after having observed the decisions made, M-firms decide to enter the market, choose their locations and prices of M-goods. Therefore, the tariffs are determined by the Nash duopoly game, while the firms' choice is determined by the monopolistic competition. Following the procedure of backward induction, we first solve the second stage of firm's decision, given the tariffs of both countries in the next two subsections.

2.1 Dispersed configuration

Assuming free entry and exit of M-firms in the market of each country, the profits must be zero in equilibrium. Plugging (6) into (5), we have the zero profit condition in country r as

$$\pi_r^* = \frac{\mu L}{2\sigma n} \left[\frac{y_r}{\lambda_r + \phi(1 + \tau_r)^{1-\sigma} \lambda_s} + \frac{\phi y_s}{\phi(1 + \tau_s) \lambda_r + (1 + \tau_s)^\sigma \lambda_s} \right] - F = 0 \quad (8)$$

Solving $\pi_r^* = \pi_s^* = 0$ and $\lambda_r + \lambda_s = 1$ yields the unique equilibrium distribution of firms $(\hat{\lambda}_r, \hat{\lambda}_s)$ and the unique equilibrium number of firms \hat{n} .

Unlike the transport costs, the tariffs do not disappear during the trading processes. The tariff revenue per worker in country r is given by

$$T_r = \frac{\tau_r}{1 + \tau_r} \frac{p_{sr} q_{sr} L_r n_s}{L_r} \quad (9)$$

where $\tau_s / (1 + \tau_s)$ is the tariff share, $(p_{sr} q_{sr} L_r n_s) / L_r$ is the total import of M-goods divided by the number of individuals in country r . Substituting the prices (6) and the demand (3) into (9), we have the equilibrium per capita tariff revenue in country r as:

$$T_r^* = \frac{\mu \phi y_r \tau_r \lambda_s}{(1 + \tau_r)^\sigma \lambda_r + \phi(1 + \tau_r) \lambda_s} \quad (10)$$

Each worker in country r has two sources of income: wage income w_r and the tariff revenue T_r^* :

$$y_r = w_r + T_r^* = 1 + \frac{\mu\phi y_r \tau_r \lambda_s}{(1 + \tau_r)^\sigma \lambda_r + \phi(1 + \tau_r) \lambda_s} \quad (11)$$

Thus, substituting $\lambda_r = \widehat{\lambda}_r$, $\lambda_s = \widehat{\lambda}_s$, and $n = \widehat{n}$ into (11) for countries r and s , we have a system of two linear equations with respect to y_r and y_s . Solving them and plugging the solution into $\widehat{\lambda}_r$ and \widehat{n} yields a unique interior solution of the spatial distribution of M-firms

$$\lambda_r^{\text{int}} = [(1 + \tau_r)^\sigma (1 + \tau_s)^\sigma - \phi(2 + \alpha\tau_r)(1 + \tau_s)^\sigma + \phi^2(1 + \alpha\tau_r)] A_1(\tau_r, \tau_s)^{-1} \quad (12)$$

where

$$A_1(\tau_r, \tau_s) \equiv 2(1 + \tau_r)^\sigma (1 + \tau_s)^\sigma - \phi[(1 + \tau_r)^\sigma (2 + \alpha\tau_s) + (1 + \tau_s)^\sigma (2 + \alpha\tau_r)] + \phi^2(2 + \alpha\tau_r + \alpha\tau_s)$$

Hence, the equilibrium distribution of M-firms is given by

$$\lambda_r^* = \begin{cases} 0 & \text{if } \lambda_r^{\text{int}} \leq 0 \\ \lambda_r^{\text{int}} & \text{if } 0 < \lambda_r^{\text{int}} < 1 \\ 1 & \text{if } \lambda_r^{\text{int}} \geq 1 \end{cases} \quad (13)$$

When the solution is interior $\lambda_r^* = \lambda_r^{\text{int}}$, we obtain the dispersed equilibrium, where the number of firms is

$$n^* = \frac{\mu L [(1 + \tau_r)^\sigma (1 + \tau_s)^\sigma - \phi^2] A_1(\tau_r, \tau_s)}{2\sigma F A_2(\tau_r, \tau_s)}$$

the individual income is

$$y_r^* = \frac{A_3(\tau_r, \tau_s)}{[(1 + \tau_r)^\sigma - \phi] [(1 + \tau_r)^\sigma (1 + \tau_s)^\sigma - \phi^2(1 + \alpha\tau_r)(1 + \alpha\tau_s)]} \quad (14)$$

and the price index is

$$P_r^* = \left[\frac{\mu L [(1 + \tau_s)^\sigma - \phi^2] A_4(\tau_r, \tau_s)}{2\sigma F A_2(\tau_r, \tau_s)} \right]^{\frac{1}{1-\sigma}} \quad (15)$$

Here,

$$\begin{aligned}
A_2(\tau_r, \tau_s) &\equiv [(1 + \tau_r)^\sigma - \phi] [(1 + \tau_s)^\sigma - \phi] [(1 + \tau_r)^\sigma (1 + \tau_s)^\sigma - \phi^2 (1 + \alpha\tau_r)(1 + \alpha\tau_s)] \\
A_3(\tau_r, \tau_s) &\equiv (1 + \tau_r)^{2\sigma} (1 + \tau_s)^\sigma - \phi (1 + \tau_r)^\sigma (1 + \tau_s)^\sigma [1 - (1 - \alpha)\tau_r] \\
&\quad - \phi^2 (1 + \tau_r)^\sigma (1 + 2\tau_r - \alpha\tau_r + \alpha\tau_s + \alpha\tau_r\tau_s) + \phi^3 (1 + \tau_r) (1 + \alpha\tau_s) \\
A_4(\tau_r, \tau_s) &\equiv (1 + \tau_r)^\sigma (1 + \tau_s)^\sigma - \phi (1 + \tau_s)^\sigma [1 - (1 - \alpha)\tau_r] - \phi^2 (1 + 2\tau_r - \alpha\tau_r + \alpha\tau_s + \alpha\tau_r\tau_s) \\
&\quad + \phi^3 (1 + \tau_r)^{1-\sigma} (1 + \alpha\tau_s)
\end{aligned}$$

The indirect utility in dispersed equilibrium is therefore computed as

$$V_r^* = \frac{y_r^*}{(P_r^*)^\mu} \quad (16)$$

where y_r^* and P_r^* are given by (14) and (15). Hence, the indirect utility (16) is expressed as a function of the two strategic variables τ_r and τ_s together with the parameters σ , ϕ , F , L , and $\alpha (= 1 - \mu)$. The strategic variables (τ_r, τ_s) are determined in the next section.

2.2 Agglomerated configuration

We have analyzed the dispersed configuration $\lambda_r^* \in (0, 1)$ in the previous section. However, λ_r^{int} in (13) is not necessarily in the interval of $(0, 1)$. For example, if the transport cost t is small, τ_r is small, and τ_s is large, then $\lambda_r^{\text{int}} < 0$ holds from (12), which implies a corner solution $(\lambda_r^c, \lambda_s^c) = (0, 1)$. In this case, solving the zero profit condition (8) for country s with $(\lambda_r^c, \lambda_s^c) = (0, 1)$, we have the agglomerated equilibrium, where the number of firms is computed as

$$\hat{n}^c = \frac{L(1 - \alpha)(2 + \alpha\tau_r)}{2\sigma F(1 + \alpha\tau_r)}$$

Solving (11) with $\lambda_r^c = 0$ and $n^c = \hat{n}^c$ yields the incomes

$$y_r^c = \frac{1 + \tau_r}{1 + \alpha\tau_r}, \quad y_s^c = 1$$

and the utilities

$$\begin{aligned}
V_r^c &= \left[\frac{\mu L \phi (2 + \alpha\tau_r)}{2\sigma F (1 + \alpha\tau_r)} \right]^{\frac{\mu}{\sigma-1}} \frac{(1 + \tau_r)^\alpha}{1 + \alpha\tau_r} \\
V_s^c &= \left[\frac{\mu L (2 + \alpha\tau_r)}{2\sigma F (1 + \alpha\tau_r)} \right]^{\frac{\mu}{\sigma-1}}
\end{aligned} \quad (17)$$

Observe that these utilities do not involve τ_s because no firm in country r ($\lambda_r^c = 0$) implies no import in country s .

3 Tariff competition

Thus far, the tariffs are considered to be exogenously given in the location and price competition by M-firms. We now proceed to investigate the first-stage tariff competition, where each country noncooperatively chooses its tariff in order to maximize its national welfare, anticipating the consequences of the competition by M-firms.

Setting a high tariff has two opposing effects on the welfare. On the one hand, a high tariff induces in-migration of firms because firms want to avoid incurring the burden of a high tariff. Attracting firms implies a decrease in the prices of the goods for in-migration firms due to reduction in the transport cost t , which enhances the welfare. On the other hand, a high tariff distorts the market by raising the prices of imported goods, which decreases the welfare. The country's welfare is thus depending on which effects are dominant. It can be analytically verified in the following subsections that the former effect dominates the latter in the case of a large transport cost, but that the reverse is true in the case of a small transport cost.

3.1 When the transport cost is large

Differentiating the interior distribution λ_r^* with respect to τ_r , it is shown that

$$\frac{\partial \lambda_r^*}{\partial \tau_r} > 0 \tag{18}$$

when τ_r is close to τ_s . This implies that a tariff reduction leads to a loss of firms because firms move to a higher-tariff country in order to avoid paying a higher tariff when exporting M-goods. Such tariff-jumping by firms that are a source of foreign direct investments is supported empirically by Blonigen (2002) and theoretically by Konishi, Saggi and Weber (1999).

This is true in our framework when the transport cost between the countries is large (the proof is contained in Appendix 1).

Proposition 1 *When the transport cost is sufficiently large, there exists a Nash equilibrium such that both countries impose the same positive tariff:*

$$\tau_r^* = \tau_s^* = \frac{1}{\sigma - 1} \quad (19)$$

In the presence of a large transport cost between countries, each country attempts to attract firms by raising tariffs in order to increase market access and avoid paying the tariff when exporting \mathbb{M} -goods. This effect is more important for each noncooperative country than is the market distortion effect, which results from the imposition of a high tariff.

A positive tariff adversely affects the other country. In fact, given the same tariff between two countries $\tau_r = \tau_s = \tau$, the welfare level necessarily decreases with the tariff:

$$\frac{\partial V_r^*|_{\tau_r=\tau_s=\tau}}{\partial \tau} < 0$$

where V_r^* is given by (16). We thus obtain the following.

Proposition 2 *In the presence of a large transport cost, tariff competition harms each other.*

Proposition 2 implies that when the transport cost between countries is relatively large, tariff competition distorts the \mathbb{M} -goods market, which leads to a so-called prisoners' dilemma. Therefore, if mutually binding agreement of free trade is possible, the two countries would benefit more from such an arrangement.

3.2 When the transport cost is small

In the previous subsection, we have seen that a tariff reduction triggers out-migration of firms, which decreases the consumer utility. This serves as an incentive for each

government to set a positive tariff, although it ends up with the prisoners' dilemma. However, this is not true when the transport cost t is unimportant.

Reducing the transport cost weakens the market access effect by attracting firms, but it does not affect the market distortion effect. Consequently, the former effect is outweighed by the latter. In fact, it can be shown that setting zero tariff is a dominant strategy when the transport cost is small enough, as demonstrated below. The small transport cost presents the opportunity of attaining a socially efficient outcome with no market-distorting tariffs. In fact, it can be verified that either one of the two countries chooses zero tariff in Nash equilibrium if the transport cost is small enough (the proof is contained in Appendix 2).

Proposition 3 *When the transport cost is sufficiently small, there exist Nash equilibria such that one country imposes a high tariff and another zero tariff:*

$$\tau_s^* \gg \tau_r^* = 0.$$

Proposition 3 suggests that when each country maximizes its welfare by tariff competition, one of the two countries does not impose a tariff for importing goods. Then, all the firms would move out from the zero-tariff country because of the inequality (18). Consequently, no tariff revenue is generated in both countries: no firm in country r implies no imports from country r and no tariff revenue in country s despite imposing a positive tariff; and zero tariff in country r implies no tariff revenue in country r despite importing M-goods. We may therefore conclude that *tariff competition leads to free trade in spite of the fact that the economy exhibits a core-periphery structure*; this is in sharp contrast to Proposition 1.

We have seen in the previous subsection that reducing the tariff leads to loss of firms because they prefer to locate in a higher-tariff country in order to avoid the tariff barriers in exporting M-goods. Moreover, reducing the tariff decreases the tariff revenue for each worker. However, a tariff reduction depreciates the prices of imported goods and, hence, the consumer price index, which in turn increases the consumer

utility. In fact, V_r^c in (17) is decreasing in τ_r , implying that the peripheral country has no incentive to impose a tariff in the case of an agglomerated configuration. Due to the mixed effects of tariff reduction on the welfare, the net effect is generally not clear. However, if the transport cost is small enough, it can be shown that the losses are outweighed by the gains from free trade due to the lower prices of imported goods. Consequently, each country has an incentive to remove the tariff. Stated differently, an international binding agreement for free trade is not required when the transport cost is so small that an agglomerated equilibrium is realized.

When $\tau_s^* \gg \tau_r^* = 0$, the individual utilities in (17) are simplified as

$$V_r^c = \left(\frac{\mu L \phi}{\sigma F} \right)^{\frac{\mu}{\sigma-1}} \quad V_s^c = \left(\frac{\mu L}{\sigma F} \right)^{\frac{\mu}{\sigma-1}}$$

From $\phi < 1$, we have $V_r^c < V_s^c$: workers in peripheral country r attains a lower welfare because they have to incur the entire transport cost. Nevertheless, they benefit from no tariff. That is, country r chooses zero tariff by allowing country s to attract all firms; this is more beneficial than engaging in fierce tariff competition.

Finally, when the transport cost between the countries is negligible, we have the following.

Corollary 1 *In the absence of the transport cost, there exists a continuum of Nash equilibria such that at least one country does not impose a tariff:*

$$\begin{aligned} \tau_r^* &= 0 < \tau_s^* \quad \text{with } \lambda_r^* = 0 \quad \text{or} \\ \tau_r^* &= \tau_s^* = 0 \quad \text{with arbitrary } \lambda_r^*. \end{aligned}$$

In the continuum of Nash equilibria, the individual utilities are given by

$$V_r^c = V_s^c = \left(\frac{\mu L}{\sigma F} \right)^{\frac{\mu}{\sigma-1}}$$

Thus, the first-best outcome is attained without any international coordination under no transport frictions.

4 Simulations

Finally, what happens in the case of an intermediate transport cost? To answer this question, we must perform a numerical analysis by using Newton methods in Mathematica. Given the parameter values, we can calculate Nash equilibrium tariffs numerically. Although we have not proven the uniqueness of the Nash equilibrium, a rough simulation indicates that it is unique.

In order to reproduce Anderson and van Wincoop (2004) presented in the introduction, we set the transport cost at $t = 1.21$, whereas the local distribution cost $t_d = 1.55$ is not needed in the determination of the tariffs due to the normalization. If we assume $\mu = 0.3$ and $\sigma = 2.7$, then the best response tariffs are numerically obtained as $\tau_r^* = \tau_s^* = 0.44$, which is the tariff value (border-related trade barriers) in Anderson and van Wincoop (2004).

Therefore, we set $\mu = 0.3$ and $\sigma = 2.7$, and compute the best response tariffs for different values of the transport cost t , which ranges from 1 to infinity. The results are summarized as follows:²

(i) If $t > \hat{t} = 1.15$, there is a dispersed configuration with a Nash equilibrium $\tau_r^* = \tau_s^* > 0$ (which corresponds to Proposition 1).

(ii) If $1 \leq t < \hat{t}$, there is an agglomerated configuration with a Nash equilibrium $\tau_s^* \gg \tau_r^* = 0$ (which corresponds to Proposition 3)

Accordingly, we may say that *the Nash equilibrium tariffs are positive for large transport costs and zero for small transport costs*. Because the value $t = 1.21$ of Anderson and van Wincoop (2004) exceeds $\hat{t} = 1.15$, we are in a position of case (i). That is, choosing a positive tariff by each country is a Nash equilibrium. What if the transport cost t decreases from 1.21 to 1.15 due to technical progress in the transport

²It is noted in the simulations that we did not find any other configurations other than the fully dispersed and agglomerated configurations, and that we did not find any multiple equilibria which often appear in NEG, such as Krugman (1991).

sector. The above results predicts transition from case (i) to case (ii). That is, the core-periphery structure with free trade may be realized without any international coordination not in the far future.

5 Concluding remarks

Since regions under study belong to the same country in new economic geography, transport costs constitute a significant fraction of the trade costs; hence, the trade costs are considered exogenous. On the other hand, in new trade theory, tariff barriers account for a large proportion of the trade costs; therefore, the trade costs are considered endogenous. We developed a unified model of the new economic geography and new trade theory, where the transport costs melt according to the conventional assumption, but the tariffs do not melt and are redistributed equally to consumers.

On analyzing Nash equilibrium of the tariff competition, we showed that when the transport cost is sufficiently small, one of the two countries does not impose a tariff, in which the core is associated with a positive tariff and the periphery is associated with zero tariff. Therefore, trade is virtually free. We also showed that in the case of a high transport cost, tariff competition harms each country, which suggests the necessity of mutually binding agreement of free trade from a welfare point of view.

It is worth studying several extensions of this model along these lines. First, one may consider both the transport cost and the tariff of the A-good as well as the M-goods in order to examine the North-South trade. Second, it may be interesting to investigate the mobility of workers as well as of capital, which is often assumed in new economic geography (Krugman, 1991). This would lead to a dramatic increase in the geographical concentration of industrial activities *via* self-reinforcing agglomeration processes. Finally, it may also be interesting to consider using the tariff revenues to finance public goods instead of redistributing these revenues equally among workers, and to reexamine the effect on social welfare.

Appendix 1: Proof of Proposition 1

When $\lambda_r^* \in (0, 1)$, the indirect utility can be rewritten as

$$V_r^* = (y_r^*)^{1+\frac{\mu}{\sigma-1}} A_5(\tau_r, \tau_s)^{\frac{\mu}{\sigma-1}}$$

where

$$A_5(\tau_r, \tau_s) \equiv \frac{\mu L [(1 + \tau_s)^\sigma - \phi^2 (1 + \tau_r)^{-\sigma}]}{2\sigma F [(1 + \tau_s)^\sigma - \phi]}$$

Then,

$$\frac{\partial V_r^*}{\partial \tau_r} = \frac{\partial y_r^*}{\partial \tau_r} (y_r^*)^{\frac{\mu}{\sigma-1}} A_5(\tau_r, \tau_s)^{\frac{\mu}{\sigma-1}} + \frac{\partial A_5(\tau_r, \tau_s)}{\partial \tau_r} (y_r^*)^{1+\frac{\mu}{\sigma-1}} A_5(\tau_r, \tau_s)^{\frac{\mu}{\sigma-1}-1} \quad (20)$$

When t is sufficiently large, we get

$$\begin{aligned} \lim_{t \rightarrow \infty} \frac{\partial y_r^*}{\partial \tau_r} &= \mu \phi (1 + \tau_r)^{-\sigma-1} (1 + \tau_r - \sigma \tau_r) \\ \lim_{t \rightarrow \infty} y_r^* &= 1 \\ \lim_{t \rightarrow \infty} \frac{\partial A_5(\tau_r, \tau_s)}{\partial \tau_r} &= \frac{\mu L \phi^2}{2F} (1 + \tau_r)^{-\sigma-1} (1 + \tau_s)^{-\sigma} \\ \lim_{t \rightarrow \infty} A_5(\tau_r, \tau_s) &= \frac{\mu L}{2\sigma F} \end{aligned}$$

Since $t \rightarrow \infty$ implies $\phi \rightarrow 0$, the second term in (20) disappears more quickly than does the first one. Hence,

$$\begin{aligned} \lim_{t \rightarrow \infty} \frac{\partial V_r^*}{\partial \tau_r} &\approx \frac{\partial y_r^*}{\partial \tau_r} (y_r^*)^{\frac{\mu}{\sigma-1}} A_5(\tau_r, \tau_s)^{\frac{\mu}{\sigma-1}} \\ &= \mu \phi (1 + \tau_r)^{-\sigma-1} (1 + \tau_r - \sigma \tau_r) \left(\frac{\mu L}{2\sigma F} \right)^{\frac{\mu}{\sigma-1}} \end{aligned}$$

which implies

$$\frac{\partial V_r^*}{\partial \tau_r} \begin{cases} \geq 0 \\ < 0 \end{cases} \quad \text{when } \tau_r \begin{cases} \leq \\ > \end{cases} \frac{1}{\sigma-1}$$

This means that (19) is a unique Nash equilibrium. \blacksquare

Appendix 2: Proof of Proposition 3

(a) Interior solution. When $\lambda_r^* \in (0, 1)$, we want to show that (20) is positive such that any interior solution of $\lambda_r^* \in (0, 1)$ is not an equilibrium outcome in tariff competition for sufficiently small t and sufficiently large τ_s .

(a1) Since $\lim_{\tau_s \rightarrow \infty} y_r^* > 0$ and $\lim_{\tau_s \rightarrow \infty} A_5(\tau_r, \tau_s) > 0$, we examine the derivatives.

We have

$$\frac{\partial A_5(\tau_r, \tau_s)}{\partial \tau_r} = \frac{\mu L \phi^2 (1 + \tau_r)^{-\sigma-1}}{2F [(1 + \tau_s)^\sigma - \phi]}$$

and hence, $\lim_{\tau_s \rightarrow \infty} \partial A_5(\tau_r, \tau_s) / \partial \tau_r = 0$ for sufficiently large τ_s . Thus, the second term in (20) approaches zero.

(a2) We also have

$$\lim_{\tau_s \rightarrow \infty} \frac{\partial y_r^*}{\partial \tau_r} = \frac{\mu \phi [(1 + \tau_r)^{\sigma-1} (1 + \tau_r - \sigma \tau_r) - \phi]}{[(1 + \tau_r)^\sigma - \phi]^2}$$

Thus, we show below that

$$B_2(\tau_r, \phi) \equiv (1 + \tau_r)^{\sigma-1} (1 + \tau_r - \sigma \tau_r) - \phi > 0$$

when τ_r ensures an interior solution of $\lambda_r^* \in (0, 1)$ for $\phi \rightarrow 1$.

For sufficiently large τ_s , we get

$$\lim_{\tau_s \rightarrow \infty} \lambda_r^* = \frac{(1 + \tau_r)^\sigma - \phi (2 + \alpha \tau_r)}{2(1 + \tau_r)^\sigma - \phi (2 + \alpha \tau_r)}$$

Thus,

$$B_3(\tau_r, \phi) \equiv (1 + \tau_r)^\sigma - \phi (2 + \alpha \tau_r) > 0$$

is necessary for the existence of a dispersed equilibrium when $\phi \rightarrow 1$.

It can be readily shown that B_2 is decreasing from $B_2(0, \phi) = 1 - \phi > 0$ to $B_2(\tau_r, \phi) < 0$ for large τ_r , and that B_3 is increasing from $B_3(0, \phi) = 1 - 2\phi < 0$ to $B_3(\tau_r, \phi) > 0$ for large τ_r . Hence, there exists a unique $\tau_r = \tau_{r1}$ such that $B_2(\tau_r, \phi) \geq 0$ for $\tau_r \leq \tau_{r1}$ and a unique $\tau_r = \tau_{r2}$ such that $B_3(\tau_r, \phi) \geq 0$ for $\tau_r \geq \tau_{r2}$.

We define $\tilde{\tau}_r \equiv \sqrt{2(1 - \phi)} / (\sigma - 1)$. The Taylor series expansion of $B_2(\tilde{\tau}_r, \phi)$ about

$\phi = 1$ is

$$\begin{aligned} B_2(\tilde{\tau}_r, \phi) &= B_2(\tilde{\tau}_r, \phi)|_{\phi=1} + \left. \frac{\partial B_2(\tilde{\tau}_r, \phi)}{\partial \phi} \right|_{\phi=1} (\phi - 1) + R_2 \\ &= 0 + \frac{1}{\sigma - 1} (\phi - 1) + R_2 < 0 \end{aligned}$$

when $\phi \rightarrow 1$ with $\phi < 1$, where R_2 is a remainder of order $(\phi - 1)^2$. Thus, $\tilde{\tau}_r > \tau_{r1}$.

On the other hand, the Taylor series expansion of $B_3(\tilde{\tau}_r, \phi)$ about $\phi = 1$ is

$$\begin{aligned} B_3(\tilde{\tau}_r, \phi) &= B_3(\tilde{\tau}_r, \phi)|_{\phi=1} + R_3 \\ &= -1 + R_3 < 0 \end{aligned}$$

when $\phi \rightarrow 1$ with $\phi < 1$, where R_3 is a remainder of order $(\phi - 1)$. Thus, $\tilde{\tau}_r < \tau_{r2}$. By combining these results, we have $\tau_{r1} < \tau_{r2}$. This implies that whenever there exists a dispersed equilibrium $\lambda_r^* \in (0, 1)$, it must be that $\tau_r > \tau_{r2}$, and hence, $\tau_r > \tau_{r2} > \tau_{r1}$. Consequently, $B_2(\tau_r, \phi) < 0$ and $\lim_{\tau_s \rightarrow \infty} \partial y_r^* / \partial \tau_r < 0$. Thus, the first term in (20) is negative.

Since (20) is always negative for sufficiently small t and sufficiently large τ_s , country r does not choose a tariff that yields an interior solution $\lambda_r^* \in (0, 1)$.

(b) Corner solution. When $\lambda_r^c = 0$, the indirect utility is given by V_r^c in (17). Since this is decreasing in τ_r , the best reply for country r is $\tau_r = 0$. Hence, $\tau_s^* \gg \tau_r^* = 0$ is a Nash equilibrium. Similarly, when $\lambda_r^c = 1$, $\tau_r^* \gg \tau_s^* = 0$ is a Nash equilibrium.

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