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Backfiring with backhaul problems

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Abstract

Trade barriers due to transport costs are as large as those due to tariffs. This paper explicitly incorporates the transport sector into the framework of international oligopoly and studies the effects of trade and industrial policies. Transport firms need to commit to a shipping capacity sufficient for a round trip, with a possible imbalance of shipping volumes in two directions. Because of this "backhaul problem", trade restrictions may backfire: domestic import restrictions may also decrease domestic exports, possibly harming domestic firms and benefiting foreign firms. In addition, trade policy in one sector may affect other independent sectors.

JEL Codes: F12, F13, R40

Key words: Transport firm; transport cost; trade policy; industrial policy; international oligopoly

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1 Introduction

The recent literature on international trade documents the important role of transport costs in terms of both magnitude and economic significance (Estevadeordal et al., 2003; Anderson and van Wincoop, 2004; Hummels, 2007). According to Hummels (2007), studies examining customs data consistently find that transport costs pose a barrier to trade at least as large as, and frequently larger than, tariffs.[1] Hummels (2007) also argues that, "[as] tariffs become a less important barrier to trade, the contribution of transportation to total trade costs—shipping plus tariffs—is rising." Despite such clear presence in international trade, few attempts have been made to incorporate endogenous transport costs, along with underlying transport sectors, into trade theory in an explicit manner.

Although trade theory has incorporated transport costs for a long time, its treatment of these costs tends to be ad hoc. The standard way to incorporate transport costs is to apply the iceberg specification (Samuelson, 1952): the cost of transporting a good is a fraction of the good, where the fraction is given exogenously. Thus this specification implicitly assumes that transport costs are exogenous and symmetric across countries. However, several trade facts indicate that such assumptions are not ideal when studying the impacts of transport costs on international trade. In particular, market power in the transport sector and the asymmetry of trade costs are key characteristics of international transport, as detailed below.

Among the various modes of transport, maritime (sea) transport is the most dominant.[2] Liner shipping, which accounts for about two-thirds of U.S. waterborne foreign trade by value (Fink et al., 2002), is oligopolistic. The top five firms account for more than 45% of the global liner fleet capacity.[3] Liner shipping firms form "conferences," where they agree on the freight rates to be charged on any given route.[4] An empirical investigation by Hummels et al. (2009) find that ocean cargo carriers charge higher prices when transporting goods with higher product prices, lower import demand elasticities, and higher tariffs, and when facing fewer competitors on a trade route—all indicating market power in the shipping industry.[5] Air cargo, whose share in the value of global trade has been increasing, is also oligopolistic

[1]Anderson and van Wincoop (2004) estimate that the ad-valorem tax equivalent of freight costs for industrialized countries is 10.7 percent while that of tariffs and nontariffs is 7.7 percent.

[2]For example, waterborne transport accounted for more than 75% in volume (46% in value) of U.S. international merchandise trade in 2011 (U.S. Department of Transportation, 2013, Figure 3-4). Globally, maritime transport handles over 80% (70%) of the total volume (value) of global trade (United Nations, 2012, p.44).

[3]Based on the Alphaliner Top 100, `www.alphaliner.com/top100/`.

[4]De Palma et al. (2011) provide evidence of market power in various transportation sectors.

[5]Regulations may also be responsible for enhancing transport firms' market power. Under the Merchant Marine Act (also known as the Jones Act) of 1920 in the United States, for example, vessels that transport cargo or passengers between two U.S. ports must be U.S. flagged, U.S. crewed, U.S. owned and U.S. built. Debates exist over the impact of the Act on the U.S. ocean shipping costs.

with two major alliances (SkyTeam Cargo and WOW Alliance) exerting market power in the air shipping markets (Weiher et al., 2002). The prediction of standard trade theory without a transport sector, with exogenously fixed transport costs, may be altered once we consider the markets for transportation explicitly by taking into account the market power of transport firms in influencing shipping costs.[6]

Trade costs exhibit asymmetry in several dimensions. First, developing countries pay substantially higher transport costs than developed nations (Hummels et al., 2009). Second, depending on the direction of shipments, freight charges differ on the same route. For example, the market average freight rates for shipping from Asia to the United States was about 1.5 times the rates for shipping from the United States to Asia in 2009 (United Nations Conference on Trade and Development, 2010).[7] This fact is also at odds with the assumption of iceberg transport costs in the standard trade theory.

Such asymmetry of transport costs may have substantial economic consequences. For example, Waugh's (2010) empirical analysis suggests that "[t]he systematic asymmetry in trade costs is so punitive that removing it takes the economy from basically autarky to over 50 percent of the way relative to frictionless trade" (p.2095). Asymmetric transport costs are associated with the "backhaul problem," a widely known issue regarding transportation: shipping is constrained by the capacity (e.g., the number of ships) of each transport firm, and hence firms need to commit to the maximum capacity required for a round-trip. This implies an opportunity cost associated with a trip (the backhaul trip) with cargo that is under-capacity.[8] This paper studies how trade policies perform given endogenous, and possibly asymmetric, transport costs in the presence of the backhaul problems.

Attempts to incorporate transportation in general equilibrium trade models show the challenges associated with defining simultaneous market clearing for the goods to be traded and the transport services to be required (Kemp, 1964; Wegge, 1993; Woodland, 1968). They assume a competitive transport sector without explicit attentions to shipping capacity constraints. Several recent studies have developed trade models that incorporate an explicit transport sector in a tractable manner. Behrens and Picard (2011) apply a new economic geography model with monopolistic competition in the output sector in order to study how the spatial distribution of economic activities is altered when the freight rates for shipping goods across two regions are determined endogenously, subject to backhaul problems. They

[6]Deardorff (2014) demonstrates that, even without an explicit transport sector, considering transport costs may alter the pattern of trade.

[7]Takahashi (2011) and Behrens and Picard (2011) provide several examples where freight costs exhibit asymmetry.

[8]Dejax and Crainic (1987) provide an early survey of the research on backhaul problems in transportation studies.

find that concentration of production in one region raises the freight rates for shipping from that region to the other. Therefore, consideration of the backhaul transport problem tends to weaken the specialization and agglomeration of firms: the more unequal are the exports of two countries are, the greater the idle capacity in transport, which tends to limit agglomeration.

A few other studies also address the implication of endogenous transport costs on economic geography (i.e., on agglomeration and dispersion forces). Behrens et al. (2009) apply a linear new economic geography model with monopolistic competition in the output sector and imperfectly competitive shipping firms, while Takahashi (2011) applies a Dixit-Stiglitz-Krugman model with income effects (with the transport firms conducting Bertrand competition). Both these studies find that imbalance of transport costs between two regions tends to induce dispersion of economic activities across regions. The pattern of geographical sorting of heterogeneous firms might differ if transportation exhibits scale economies (Forslid and Okubo, 2015). In the framework of international duopoly, Abe et al. (2014) focus on pollution from the international transport sector. They find that the optimal pollution regulation and the optimal tariff depend on the distance of transportation as well as the number of transport firms. Takauchi (2015) examines the relationship between freight rates and R&D efficiency in the presence of a monopolistic carrier in an international duopoly model.

Existing studies have not investigated the impacts of trade policies in the presence of a transport sector with backhaul problems (or with its capacity constraint). Our point of departure is an investigation of how the effects of trade policies change once the transport sector and its decision making are explicitly considered. Specifically, we address the following questions: how does a trade policy influence the volume of trade, the prices of traded goods, and economies and how do such effects depend on the nature of the transport sector? In the presence of the transport sector, how does a trade policy affect domestic and foreign oligopolistic firms?

To investigate these questions, we explicitly incorporate the transport sector into a standard framework of international oligopoly. In the basic model, we assume a monopolistic transport firm to capture market power in a simple manner.[9] We investigate the effects of various trade policies on trade and the performance of trade-exposed firms. We do so by taking into account how each policy influences the volume of trade and the freight rates

[9]As Demirel et al. (2010) argue, most studies that consider the backhaul problem assume that the transportation sector is competitive and hence predict that the equilibrium backhaul price is zero when there is imbalance in shipping volume in both directions over a given route. This is the case for Behrens and Picard (2011). Demirel et al. (2010) offer a matching model to generate equilibrium transport prices that may differ but are positive for both directions. Our model, with the transportation firms having market power, also supports positive equilibrium transport prices.

endogenously, with the backhaul problem being considered explicitly.

Our model with imperfect competition and bilateral trade illustrates how transport costs are determined endogenously, with possible asymmetry between domestic and foreign countries. In particular, when a gap in the demand size exists between the two countries, the country with the lower demand faces higher freight costs on shipping. This theoretical prediction is consistent with Waugh's (2010) finding that countries with lower income tend to face higher export costs.

Our analysis demonstrates that an explicit consideration of a transport sector changes the prediction of the effects of trade policies based on standard trade models. In particular, a country's trade policy may backfire: domestic import restrictions may also decrease domestic exports and could harm domestic manufacturing firms while benefiting foreign manufacturing firms. These results are due to transport firm's endogenous response to trade policy. A transport firm with market power makes decisions on two margins: the freight rate to be charged for each direction, and the capacity for transport. With changes in trade restrictions, the transport firm makes adjustments only in the freight rates, or in the freight rates and the capacity, depending on the stringency of the trade policy. When shipping capacity is binding for transportation in both directions, a policy that affects one trip may influence the return trip through a linkage due to endogenous transport. Thus an increase in a country's import tariff can reduce its exports, thereby generating the backfiring effect described above. We also demonstrate such policy linkages in the case of import quotas and production subsidies.

The impacts of trade policy differ substantially once we consider foreign direct investment (FDI). The option of FDI works as a threat against transport firms because it provides manufacturing firms with an opportunity to avoid shipping their outputs. Because high trade costs induce firms to choose FDI, a transport firm has an incentive to lower freight rates when trade restrictions increase trade costs. However, the decrease in the freight rates has different effects under tariffs and import quotas.

In our basic model, the transport firm is a monopolistic carrier and two manufacturing firms produce a homogeneous good. We then consider extensions and check the robustness of our results. In one extension, we investigate a case with multiple goods. In another extension, we consider multiple transport firms. In these extensions, besides the backfiring effects, we obtain a few additional results. In the case of multiple goods, for example, a tariff in one sector may affect other independent sectors. In particular, a domestic tariff in one sector could hurt domestic firms and benefit foreign firms in other independent sectors. In the case of multiple transport firms, the degree of the backhaul problem can be different for different transport firms. These extensions confirm that the backfiring effect of trade policies is robust under specifications with multiple goods or multiple transport firms.

In what follows, Section 2 describes our trade model with an endogenous transport sector. Section 3 studies the impacts of tariffs, import quotas, and production subsidies on trading firms' profits and the equilibrium transport costs. We provide extensions of our analysis when exporting firms have an option to conduct foreign direct investment (Section 4), when multiple goods are traded (Section 5) and when there are multiple carriers (Section 6). Section 7 concludes the paper with a discussion on further research.

2 A trade model with a transport sector

There are two countries A and B. There is a single manufacturing firm in each country (firm $i; i = A, B$) and a single transport firm: firm T.[10] Both firms A and B produce a homogeneous good and serve both countries. To serve the foreign country, transport services are required. The marginal cost (MC) of producing the good, c_i ($i = A, B$), is constant.

The inverse demand for the good in country A and B are given by

$$P_A = A - aX_A, P_B = B - bX_B.$$

where P_i and X_i are, respectively, the price of the good and the quantity of the good demanded in country i. Parameters A, B, a, and b are positive scalars. It is assumed that the two markets are segmented and that the two firms engage in Cournot competition.

The profits of firm i ($i = A, B$), Π_i, are

$$\Pi_A = (P_A - c_A)x_{AA} + (P_B - c_A - T_{AB})x_{AB}, \Pi_B = (P_B - c_B)x_{BB} + (P_A - c_B - T_{BA})x_{BA}.$$

where x_{ij} is firm i's supply to country j and T_{ij} is the freight rate when shipping the good from country i to country j. We assume that the freight rate is linear and additive by following the empirical findings supporting this specification.[11]

In our setting, firm T first sets freight rates and makes a take-it-or-leave-it offer to manufacturing firms A and B.[12] Then firms A and B decide whether to accept the offer. If they accept the offer, then the firms engage in Cournot competition in each country. We

[10] Firm T may be located in country A or country B or in a third country. The location becomes crucial when analyzing welfare.

[11] Using multi-country bilateral trade data at the 6-digit HS classification, Hummels and Skiba (2004) find that shipping technology for a single homogeneous shipment more closely resembles per unit, rather than ad-valorem, transport costs. Using Norwegian data on quantities and prices for exports at the firm/product/destination level, Irarrazabal et al. (2015) find the presence of additive (as opposed to iceberg) trade costs for a large majority of product-destination pairs.

[12] In Behrens et al. (2009) and Behrens and Picard (2011), for example, the manufacturing firms determine their supplies by taking the freight rate as given.

solve the model with backward induction.

Given the freight rates, we obtain firm i's supply to country j (i,$j = A, B$) under Cournot competition as follows:

$$
\begin{aligned}
x_{AA} &= \frac{A - 2c_A + c_B + T_{BA}}{3a}, x_{BA} = \frac{A + c_A - 2(c_B + T_{BA})}{3a}, && (1)\\
x_{BB} &= \frac{B - 2c_B + c_A + T_{AB}}{3b}, x_{AB} = \frac{B + c_B - 2(c_A + T_{AB})}{3b}, && (2)\\
\Pi_A &= ax_{AA}^2 + bx_{AB}^2, \Pi_B = bx_{BB}^2 + ax_{BA}^2.
\end{aligned}
$$

We assume that x_{AA}, x_{BB}, x_{AB}, and x_{BA} are positive. We will use the expressions $x_{BA}(T_{BA})$ and $x_{AB}(T_{AB})$ when we emphasize the trade volume's dependence on the freight rates.

The costs of firm T, C_T, are given by

$$C_T = f_T + r_T k_T,$$

where f_T, r_T, and k_T are, respectively, the fixed cost, the marginal cost (MC) of operating a means of transport such as vessels, and the capacity, i.e., $\max\{x_{AB}, x_{BA}\} = k_T$. The profits of firm T are:

$$\Pi_T = T_{AB}x_{AB} + T_{BA}x_{BA} - (f_T + r_T k_T).$$

In the following analysis, we assume $x_{AB} \geq x_{BA}$ under free trade without loss of generality. Then we have

$$
\begin{aligned}
\Pi_T &= T_{AB}x_{AB} + T_{BA}x_{BA} - (f_T + r_T x_{AB})\\
&= T_{AB}\frac{B + c_B - 2(c_A + T_{AB})}{3b} + T_{BA}\frac{A + c_A - 2(c_B + T_{BA})}{3a}\\
&\quad -(f_T + r_T\frac{B + c_B - 2(c_A + T_{AB})}{3b}).
\end{aligned}
$$

To maximize its profits, firm T sets[13]

$$\widetilde{T}_{AB}^F = \frac{1}{4}B - \frac{1}{2}c_A + \frac{1}{4}c_B + \frac{1}{2}r_T, \widetilde{T}_{BA}^F = \frac{1}{4}A + \frac{1}{4}c_A - \frac{1}{2}c_B.$$

There are two cases. In Case 1, $x_{AB}(\widetilde{T}_{AB}^F) = \frac{1}{6b}(B - 2c_A + c_B - 2r_T) > x_{BA}(\widetilde{T}_{BA}^F) = \frac{1}{6a}(A + c_A - 2c_B)$ holds. This case is consistent with the assumption: $x_{AB} \geq x_{BA}$. In this

[13]Tilde represents equilibrium values.

case, therefore, the equilibrium is given by

$$
\begin{aligned}
T_{AB}^{F1} &= \frac{1}{4}B - \frac{1}{2}c_A + \frac{1}{4}c_B + \frac{1}{2}r_T, T_{BA}^{F1} = \frac{1}{4}A + \frac{1}{4}c_A - \frac{1}{2}c_B, \\
x_{AA}^{F1} &= \frac{1}{12a}\left(5A - 7c_A + 2c_B\right), x_{BA}^{F1} = \frac{1}{6a}\left(A + c_A - 2c_B\right), \\
x_{BB}^{F1} &= \frac{1}{12b}\left(5B + 2c_A - 7c_B + 2r_T\right), x_{AB}^{F1} = \frac{1}{6b}\left(B - 2c_A + c_B - 2r_T\right).
\end{aligned}
$$

In Case 2, $x_{AB}(\widetilde{T}_{AB}^F) = \frac{1}{6b}\left(B - 2c_A + c_B - 2r_T\right) \leq x_{BA}(\widetilde{T}_{BA}^F) = \frac{1}{6a}\left(A + c_A - 2c_B\right)$ holds. The case with $x_{AB}(\widetilde{T}_{AB}^F) < x_{BA}(\widetilde{T}_{BA}^F)$ is inconsistent with the assumption: $x_{AB} \geq x_{BA}$. With $x_{AB}(\widetilde{T}_{AB}^F) \leq x_{BA}(\widetilde{T}_{BA}^F)$, therefore, firm T maximizes its profits subject to $x_{AB} = x_{BA}$, i.e.,

$$
\begin{aligned}
\max \Pi_T &= \max\{T_{AB}\frac{B + c_B - 2(c_A + T_{AB})}{3b} + T_{BA}\frac{A + c_A - 2(c_B + T_{BA})}{3a} \\
&\quad -(f_T + r_T k_T)\} \\
s.t. T_{AB} &= \frac{1}{2a}\left(ac_B - 2ac_A - bc_A + 2bc_B + 2bT_{BA} - Ab + Ba\right) \Leftrightarrow x_{AB} = x_{BA}.
\end{aligned}
$$

Then we obtain the following equilibrium:

$$
\begin{aligned}
T_{AB}^{F2} &= \frac{1}{4\left(a+b\right)}\left(2ac_B - 4ac_A - 3bc_A + 3bc_B + 2br_T - Ab + 2Ba + Bb\right) \\
T_{BA}^{F2} &= \frac{1}{4\left(a+b\right)}\left(3ac_A - 3ac_B + 2bc_A - 4bc_B + 2ar_T + Aa + 2Ab - Ba\right) \\
x_{AB}^{F2} &= x_{BA}^{F2} = \frac{1}{6\left(a+b\right)}\left(A + B - 2r_T - c_A - c_B\right).
\end{aligned}
$$

We thus obtain the following proposition.[14]

Proposition 1 *Suppose $x_{AB} \geq x_{BA}$ holds under free trade (that is, $\frac{1}{6b}\left(B - 2c_A + c_B\right) \geq \frac{1}{6a}\left(A + c_A - 2c_B - 2r_T\right)$). If $\frac{1}{6b}\left(B - 2c_A + c_B - 2r_T\right) > \frac{1}{6a}\left(A + c_A - 2c_B\right)$, then T_{BA} is independent of r_T. A change in r_T does not affect the supply of either firm in country A. If $\frac{1}{6b}\left(B - 2c_A + c_B - 2r_T\right) \leq \frac{1}{6a}\left(A + c_A - 2c_B\right)$, both T_{AB} and T_{BA} depend on r_T and $x_{AB} = x_{BA}$ holds.*

There are two types of equilibrium with $x_{AB} \geq x_{BA}$. Whereas $x_{AB} > x_{BA}$ holds in type-1 equilibrium, $x_{AB} = x_{BA}$ holds in type-2 equilibrium. In type 1, there is a large demand gap between the two countries, implying that there is an excess shipping capacity from country B to country A. That is, a full load is not realized for shipping from country B to country A. In type 2, the demand gap is small. Thus, firm T adjusts its freight rates so that it does

[14] $x_{AB} < x_{BA}$ holds if and only if $\frac{1}{6b}\left(B - 2c_A + c_B\right) < \frac{1}{6a}\left(A + c_A - 2c_B - 2r_T\right)$.

not have an excess shipping capacity, or, it realizes a full load in both directions. Obviously, type-2 equilibrium arises if the two markets as well as the two manufacturing firms are identical. It should be noted that $T_{AB}^{F1} + T_{BA}^{F1} = T_{AB}^{F2} + T_{BA}^{F2} = \frac{1}{4}(A + B - c_A - c_B + 2r_T)$ holds.

3 Trade Policies

In this section, we explore the effects of import tariffs, import quotas and production subsidies and obtain some unconventional results. We still keep the assumption that $x_{AB} \geq x_{BA}$ holds under free trade. We also assume $c_i = 0$ $(i = A, B)$ for simplicity in the following analysis.

3.1 Tariffs

We begin with tariffs. When a specific tariff, the rate of which is τ_i $(i = A, B)$, is imposed by country i, the profits of firm i $(i = A, B)$, Π_i, are

$$\Pi_A = P_A x_{AA} + (P_B - \tau_B - T_{AB})x_{AB}, \Pi_B = P_B x_{BB} + (P_A - \tau_A - T_{BA})x_{BA}.$$

Then (1) and (2) are modified as follows with $c_i = 0$ $(i = A, B)$.

$$\begin{aligned} x_{AA} &= \frac{A + T_{BA} + \tau_A}{3a}, x_{BA} = \frac{A - 2(T_{BA} + \tau_A)}{3a}, \\ x_{BB} &= \frac{B + T_{AB} + \tau_B}{3b}, x_{AB} = \frac{B - 2(T_{AB} + \tau_B)}{3b}. \end{aligned}$$

We should note that even if $x_{AB} \geq x_{BA}$ holds with free trade, it may not hold with tariffs.

First, suppose $x_{AB} \geq x_{BA}$ with tariffs. Firm T's profits are then given by

$$\Pi_T = T_{AB}\frac{B - 2(T_{AB} + \tau_B)}{3b} + T_{BA}\frac{A - 2(T_{BA} + \tau_A)}{3a} - (f_T + r_T\frac{B - 2(T_{AB} + \tau_B)}{3b}).$$

Thus, we have

$$\widetilde{T}_{AB}^{\tau} = \frac{1}{4}B - \frac{1}{2}\tau_B + \frac{1}{2}r_T, \widetilde{T}_{BA}^{\tau} = \frac{1}{4}A - \frac{1}{2}\tau_A.$$

Just as the free trade case, we have two cases. If $x_{AB}(\widetilde{T}_{AB}^{\tau}) > x_{BA}(\widetilde{T}_{BA}^{\tau})$ holds, the equilibrium is given by

$$\begin{aligned}
T_{AB}^{\tau 1} &= \frac{1}{4}B - \frac{1}{2}\tau_B + \frac{1}{2}r_T, T_{BA}^{\tau 1} = \frac{1}{4}A - \frac{1}{2}\tau_A, \\
x_{AA}^{\tau 1} &= \frac{1}{12a}\left(5A + 2\tau_A\right), x_{BA}^{\tau 1} = \frac{1}{6a}\left(A - 2\tau_A\right), \\
x_{BB}^{\tau 1} &= \frac{1}{12b}\left(5B + 2\tau_B + 2r_T\right), x_{AB}^{\tau 1} = \frac{1}{6b}\left(B - 2\tau_B - 2r_T\right).
\end{aligned}$$

This is type-1 equilibrium with tariffs, which corresponds to type-1 equilibrium under free trade. An increase in τ_i decreases x_{ji} and increases x_{ii} $(i, j = A, B, i \neq j)$ and affects neither x_{ij} nor x_{jj}. This is the conventional effects of tariffs with market segmentation.

If $x_{AB}(\widetilde{T}_{AB}^{\tau}) \leq x_{BA}(\widetilde{T}_{BA}^{\tau})$ holds, firm T maximizes its profits subject to $x_{AB} = x_{BA}$, i.e.,

$$\begin{aligned}
\max \Pi_T &= \max\{T_{AB}\frac{B - 2(T_{AB} + \tau_B)}{3b} + T_{BA}\frac{A - 2(T_{BA} + \tau_A)}{3a} - (f_T + r_T k_T)\} \\
s.t. T_{AB} &= \frac{1}{2a}\left(2b\tau_A - 2a\tau_B + 2bT_{BA} - Ab + Ba\right) \Leftrightarrow x_{AB} = x_{BA}
\end{aligned}$$

Then we obtain the following equilibrium:

$$\begin{aligned}
T_{AB}^{\tau 2} &= \frac{1}{4\left(a+b\right)}\left(2b\tau_A - 4a\tau_B - 2b\tau_B + 2br_T - Ab + 2Ba + Bb\right), \\
T_{BA}^{\tau 2} &= \frac{1}{4\left(a+b\right)}\left(-2a\tau_A + 2a\tau_B - 4b\tau_A + 2ar_T + Aa + 2Ab - Ba\right), \\
x_{AB}^{\tau 2} &= x_{BA}^{\tau 2} = \frac{1}{6\left(a+b\right)}\left(A + B - 2\tau_A - 2\tau_B - 2r_T\right), \\
x_{AA}^{\tau 2} &= \frac{1}{12a\left(a+b\right)}\left(2a\tau_A + 2a\tau_B + 2ar_T + 5Aa + 6Ab - Ba\right), \\
x_{BB}^{\tau 2} &= \frac{1}{12b\left(a+b\right)}\left(2b\tau_A + 2b\tau_B + 2br_T - Ab + 6Ba + 5Bb\right).
\end{aligned}$$

This is type-2 equilibrium with tariffs, which corresponds to type-2 equilibrium under free trade. In this equilibrium, the shipping capacity is binding in both directions. An increase in τ_i decreases both x_{ji} and x_{ij} and increases both x_{ii} and x_{jj} $(i, j = A, B, i \neq j)$. This is in contrast with type-1 equilibrium, in which an increase in τ_i affects the supplies only in country i, that is, an increase in τ_i decreases x_{ji} and increases x_{ii}. An increase in τ_i decreases x_{ji} in both types of equilibrium. In type-2 equilibrium, however, the shipping capacity is reduced to be equal to x_{ji} and hence x_{ij} also decreases. Since x_{ji} (x_{ij}) and x_{ii} (x_{jj}) are strategic substitutes, a decrease in x_{ji} (x_{ij}) increases x_{ii} (x_{jj}).

Next suppose $x_{AB} < x_{BA}$ with tariffs. The profits of firm T become

$$\Pi_T = T_{AB}\frac{B-2(T_{AB}+\tau_B)}{3b} + T_{BA}\frac{A-2(T_{BA}+\tau_A)}{3a} - (f_T + r_T\frac{A-2(T_{BA}+\tau_A)}{3a}).$$

Thus, we have

$$\widehat{T}^{\tau}_{AB} = \frac{1}{4}B - \frac{1}{2}\tau_B, \widehat{T}^{\tau}_{BA} = \frac{1}{4}A - \frac{1}{2}\tau_A + \frac{1}{2}r_T.$$

If $x_{AB}(\widehat{T}^{\tau}_{AB}) < x_{BA}(\widehat{T}^{\tau}_{BA})$ holds,[15] the equilibrium is given by

$$\begin{aligned}
T^{\tau 3}_{AB} &= \frac{1}{4}B - \frac{1}{2}\tau_B, T^{\tau 3}_{BA} = \frac{1}{4}A - \frac{1}{2}\tau_A + \frac{1}{2}r_T,\\
x^{\tau 3}_{AA} &= \frac{1}{12a}\left(5A + 2\tau_A + 2r_T\right), x^{\tau 3}_{BA} = \frac{1}{6a}\left(A - 2\tau_A - 2r_T\right),\\
x^{\tau 3}_{BB} &= \frac{1}{12b}\left(5B + 2\tau_B\right), x^{\tau 3}_{AB} = \frac{1}{6b}\left(B - 2\tau_B\right).
\end{aligned}$$

This is type-3 equilibrium with tariffs. Just as in type-1 equilibrium, an increase in τ_i decreases x_{ji}, increases x_{ii} $(i, j = A, B, i \neq j)$ and affects neither x_{ij} nor x_{jj}.

Figure 1 here

Figure 2 here

The above cases are illustrated in Figures 1 and 2. Figure 1 (Figure 2) shows the relationship between τ_B (τ_A) and the volumes of trade (i.e. x_{AB} and x_{BA}) with $\tau_A = 0$ ($\tau_B = 0$). The free trade equilibrium is given by F_A and F_B in Figure 1 (a) and Figure 2 (a) and by F in Figure 1 (b) and Figure 2 (b). In Figure 1 (a), as τ_B increases, x_{AB} decreases with $0 \leq \tau_A < \frac{B}{2}$. Both with $0 \leq \tau_B < \frac{1}{2a}\left(Ba - Ab - 2ar_T\right)$ and with $\frac{1}{2a}\left(Ba - Ab + 2br_T\right) < \tau_B < \frac{B}{2}$, x_{BA} is independent of τ_B. With $\frac{1}{2a}\left(Ba - Ab - 2ar_T\right) \leq \tau_B \leq \frac{1}{2a}\left(Ba - Ab + 2br_T\right)$, $x_{AB} = x_{BA}$ holds and an increase in τ_B decreases both x_{AB} and x_{BA}. In Figure 1 (b), with $0 \leq \tau_B \leq \frac{1}{2a}\left(Ba - Ab + 2br_T\right)$, both x_{AB} and x_{BA} decrease together as τ_B increases. With $\frac{1}{2a}\left(Ba - Ab + 2br_T\right) < \tau_B < \frac{B}{2}$, when τ_B rises, x_{AB} falls but x_{BA} is constant. In Figure 1, type-1 equilibrium arises if $0 < \tau_B < \frac{1}{2a}\left(Ba - Ab - 2ar_T\right)$, type-2 equilibrium arises if $\max\{0, \frac{1}{2a}\left(Ba - Ab - 2ar_T\right)\} \leq \tau_B \leq \frac{1}{2a}\left(Ba - Ab + 2br_T\right)$, and type-3 equilibrium arises if $\frac{1}{2a}\left(Ba - Ab + 2br_T\right) < \tau_B < \frac{B}{2}$.

In Figure 2 (a), an increase in τ_A decreases x_{BA} with $0 \leq \tau_A < \frac{A}{2}$ but does not affect x_{AB}. In Figure 2 (b), with $0 \leq \tau_A \leq \frac{1}{2b}\left(Ab - Ba + 2ar_T\right)$, both x_{AB} and x_{BA} decrease together as τ_A increases. With $\frac{1}{2b}\left(Ab - Ba + 2ar_T\right) < \tau_A < \frac{A}{2}$, when τ_A rises, x_{BA} falls but x_{AB} is

[15] If $x_{AB}(\widehat{T}^{\tau}_{AB}) \geq x_{BA}(\widehat{T}^{\tau}_{BA})$ holds, firm T maximizes its profits subject to $x_{AB} = x_{BA}$. We have already obtained this case.

constant. In Figure 2, type-1 equilibrium arises if $\max\{0, \frac{1}{2b}(Ab - Ba + 2ar_T)\} < \tau_A < \frac{A}{2}$ and type-2 equilibrium arises if $0 < \tau_A \leq \frac{1}{2b}(Ab - Ba + 2ar_T)$.

The above results are summarized in the following proposition.

Proposition 2 *If country i imposes a tariff, τ_i, firm T lowers the freight rate from country j to country i, T_{ji} $(i, j = A, B, i \neq j)$. That is, firm T mitigates the effects of tariffs. Suppose $x_{AB} \geq x_{BA}$ under the free-trade equilibrium. If $\max\{0, \frac{1}{2a}(Ba - Ab - 2ar_T)\} < \tau_B \leq \frac{B}{2}$, then a tariff in country B increases the freight rate from country B to country A and decreases not only country B's imports but also country B's exports. If $0 < \frac{1}{2b}(Ab - Ba + 2ar_T)$, then a tariff in country A increases T_{AB} and decreases country A's exports as well as country A's imports.*

The impact of trade policy on the transport firm with market power in our model has some resemblance to the impact of the exporting country's trade policy when the importer has market power (Deardorff and Rajaraman, 2009; Oladi and Gilbert, 2012). Deardorff and Rajaraman (2009) explain that "[t]he export tax allows the exporting country to extract a portion of the foreign monopsonist's monopsony rent, albeit at the cost of further worsening the economic distortion caused by monopsony pricing" (p. 193).

It should be pointed out that the effects of a tax on firm T are somewhat similar to the effects of tariffs. Suppose that a specific tax, t, is imposed on the capacity k_T. Then the effective MC of firm T becomes $r_T + t$. In type-1 equilibrium, only T_{AB} increases and hence only x_{AB} decreases. In type-2 equilibrium, both T_{AB} and T_{BA} increase and hence both x_{AB} and x_{BA} decrease. In type-1 and type-2 equilibria, if country B can impose the tax on firm T, country B can substitute the tax for a tariff.

Next we analyze the effects of tariffs on the profits of firms A and B. It is obvious in our model that firm B gains and firm A loses from an increase in country B's tariff under both type-1 and type-3 equilibria as well as from the introduction of a small tariff by country B under type-1 free-trade equilibrium.[16] However, this may not be true under type-2 equilibrium. In the following, we specifically show that there exist parameter values under which a tariff set by country B (country A) harms firm B (firm A) and/or benefits firm A (firm B) in type-2 free-trade equilibrium.

We first examine the case in which country B introduces a small tariff in type-2 free-trade equilibrium.[17] The profits of firm B in type-2 equilibrium with $\tau_A = 0$ are

$$\Pi_B^{\tau 2} = \frac{1}{144b(a+b)^2}(2b\tau_B + 2br_T - Ab + 6Ba + 5Bb)^2 + \frac{a}{36(a+b)^2}(A + B - 2\tau_B - 2r_T)^2, \quad (3)$$

[16] A small tariff is unlikely to lead to type-3 equilibrium with $x_{AB} \geq x_{BA}$ under free trade.

[17] This implies $\tau_A = 0$. The following argument is valid even with $\tau_A > 0$.

where the first and the second terms are the profits from country B and the profits from country A, respectively. It is obvious form (3) that a tariff in country B increases the profits from country B but decreases the profits from country A.

To examine the effect of a small tariff set by country B on the profits of firm B, we differentiate (3) with respect to τ_B and check the sign at $\tau_B = 0$:

$$\frac{d\Pi_B^{\tau 2}}{d\tau_B}|_{\tau_B=0} = \frac{1}{36\,(a+b)^2}\,(8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb)\,.$$

If the sign is negative, then a small tariff imposed by country B decreases the profits of firm B. Suppose $a = 2b$. Then we check if $\frac{d\Pi_B^{\tau 2}}{d\tau_B}|_{\tau_B=0} = -\frac{1}{36b}\,(A - B - 2r_T) < 0$ holds. Moreover, we have to check if the case with $a = 2b$ is consistent with type-2 equilibrium. In view of Figure 1, type-2 equilibrium arises under free trade if $\frac{1}{6a}\,(A - 2r_T) < \frac{1}{6(a+b)}\,(A + B - 2r_T) < \frac{A}{6a}$. We can verify that these constraints are satisfied with, for example, $A = 2B$. Thus, firm B actually loses from a tariff set by country B under some parameterization.

We next examine if firm A gains from a small tariff imposed by country B with $\tau_A = 0$. The profits of firm A in type-2 equilibrium are

$$\Pi_A^{\tau 2} = \frac{1}{144a\,(a+b)^2}(2a\tau_B + 2ar_T + 5Aa + 6Ab - Ba)^2 + \frac{b}{36\,(a+b)^2}(A + B - 2\tau_B - 2r_T)^2, \quad (4)$$

where the first and the second terms are the profits from country A and those from country B, respectively. Country B's tariff increases the profits from country A but decreases the profits from country B. We differentiate (4) with respect to τ_B and check if the following holds:

$$\frac{d\Pi_A^{\tau 2}}{d\tau_B}|_{\tau_B=0} = \frac{1}{36\,(a+b)^2}\,(2ar_T + 8br_T + 5Aa + 2Ab - Ba - 4Bb) > 0.$$

Again, supposing $a = 2b$, we check if $\frac{d\Pi_A^{\tau 2}}{d\tau_B}|_{\tau_B=0} = \frac{1}{54b}\,(2A - B + 2r_T) > 0$ holds. If $A = 2B$, this inequality holds and type-2 equilibrium is realized.[18] This implies that firm A actually gains from a tariff set by country B under some parameterization.

Therefore, with $a = 2b$ and $A = 2B$, for example, a small tariff set by country B harms firm B and benefits firm A. The economic intuition behind the result is as follows. The direct effect of a tariff in country B is a decrease in firm A's exports. The direct effect is harmful for firm A and beneficial for firm B. However, the tariff also restricts firm B's exports to country A under type-2 equilibrium. This indirect effect benefits firm A and hurts firm B. When country A's market is larger than country B's, the indirect effect could dominate the

[18] If $\frac{d\Pi_A^{\tau 2}}{d\tau_B}|_{\tau_B=0} > 0$, then $\frac{d\Pi_A^{\tau 2}}{d\tau_B} > 0$ holds for $\tau_B \geq 0$ and hence an increase in τ_B also increases the profits of firm A.

direct effect.[19]

We can similarly show that a small tariff introduced by country A could harm firm A and benefit firm B in type-2 equilibrium. Moreover, if the two markets are identical (i.e., $A = B$ and $a = b$), both $\frac{d\Pi_B^{\tau 2}}{d\tau_i} > 0$ and $\frac{d\Pi_A^{\tau 2}}{d\tau_i} > 0$ hold for $\tau_i \geq 0$ $(i = A, B)$. Thus, both firms gain not only from the imposition of a small tariff by either country but also from an increase in the tariff.

Thus, we obtain the following proposition.

Proposition 3 *When country i introduces a small import tariff in type-2 equilibrium, firm i may not gain and firm j may not lose. Depending on the parameter values, the following situations could arise: i) both firms gain; or ii) firm i loses while firm j gains.*

Next we explore the welfare effects of tariffs. In our welfare analysis, we consider the introduction of a small tariff under free trade. Since type-3 equilibrium is unlikely to arise in this situation, we focus on type-1 and type-2 equilibria. Obviously, a tariff harms firm T. Although the effects of a tariff on consumers are mitigated by the change in the freight rate(s), consumers still lose. Country A's (B's) tariff harms consumers in country A (country B) in type-1 equilibrium and consumers in both countries in type-2 equilibrium. In type-1 equilibrium, the effects of tariffs are the same as the well-known effects in a standard international oligopoly model.[20] That is, when country B introduces a small tariff, firm B gains, consumers in country B and firm A lose, and the government obtains the tariff revenue. Thus, if the profits of firm T are not included in the welfare measurement, country B as a whole gains.

In the following, therefore, we first investigate the welfare effects of a tariff in country B in type-1 equilibrium when the profits of firm T are included in the welfare.[21] In this case, country B's welfare is

$$W_B^\tau = CS_B^\tau + \Pi_B^\tau + TR_B^\tau + \Pi_T^\tau.$$

The profits of firm T in type-1 equilibrium are

$$\Pi_T^{\tau 1} = \frac{1}{24}\frac{(B - 2\tau_B - 2r_T)^2}{b} + \frac{1}{24}\frac{(A - 2\tau_A)^2}{a} - f_T.$$

Then we obtain

$$\frac{d\Pi_T^{\tau 1}}{d\tau_B} = -\frac{1}{6}\frac{(B - 2\tau_B - 2r_T)}{b} < 0,$$

[19] If the market of country A is much larger than that of country B, then type 2 equilibrium would not arise.

[20] See Brander and Spencer (1984) and Furusawa et al. (2003) among others.

[21] In our welfare analysis, we consider the introduction of a small tariff under free trade. Type-3 equilibrium is unlikely to arise in this situation. Thus, we focus on type-1 and type-2 equilibria here.

from which we can confirm that firm T loses from the tariff.

The welfare effects are given by[22]

$$\frac{dW_B^{\tau 1}}{d\tau_B} = \frac{1}{24}\frac{B - 6\tau_B + 2r_T}{b};\ \frac{dW_B^{\tau 1}}{d\tau_B}\mid_{\tau_B=0} = \frac{1}{24}\frac{B + 2r_T}{b} > 0.$$

Thus, even if the profits of firm T are included in the welfare measurement, country B as a whole gains from a small tariff.

In type-1 equilibrium with a tariff in country B tariff, firm A's trade costs consist of the tariff rate τ_B and the freight rate T_{AB} which is decomposed into the MC r_T and the markup, m. When the tariff is introduced, firm T lowers its markup. However, from the viewpoint of country B as a whole, $m + \tau_B$ can be regarded as the country's "markup" and the effects of the small increase are essentially the same as the effects of a small increase in the tariff in a standard international oligopoly model without the transport sector.

In type-2 equilibrium, firm B may lose from a tariff in country B. If the profits of firm T are not included in the welfare measurement, then the welfare effects evaluated at $\tau_A = \tau_B = 0$ are given by

$$\frac{dW_B^{\tau 2}}{d\tau_B}\mid_{\tau_A=\tau_B=0} = \frac{-8ar_T - 18br_T + 4Aa + 9Ab + 10Ba + 15Bb}{72\left(a+b\right)^2} > 0,$$

which implies that a small tariff introduced with free trade benefits country B. This is the case even if firm B loses from a tariff in country B. The gain for the government (i.e., the tariff revenue) exceeds the losses of consumers and firm B.

If the profits of firm T are included in the welfare measurement, then the welfare effects evaluated at $\tau_A = \tau_B = 0$ are given by

$$\frac{dW_B^{\tau 2}}{d\tau_B}\mid_{\tau_A=\tau_B=0} = \frac{16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb}{72\left(a+b\right)^2},$$

the sign of which is ambiguous in general. Thus, a small tariff introduced with free trade may make country B worse off. We can verify that a tariff in country B lessens its welfare if the tariff is harmful for firm B.

We next analyze the effects of a tariff in country A on country B's welfare. In type-1 equilibrium, a tariff in country A harms firm B and firm T but does not affect consumers in country B. In type-1 equilibrium, therefore, a tariff in country A makes country B worse off whether or not the profits of firm T are included in country B's welfare.

[22] If the profits of firm T are not included in country B's welfare, we have $\frac{dW_B^{\tau 1}}{d\tau_B} = \frac{1}{24b}\left(5B - 14\tau_B - 6r_T\right)$ and $\frac{dW_B^{\tau 1}}{d\tau_B}\mid_{\tau_B=0} = \frac{1}{24b}\left(5B - 6r_T\right) > 0$.

We now check the effects in type-2 equilibrium. In type-2 equilibrium, a tariff in country A harms consumers in both countries and firm T but may benefit firm B. If the profits of firm T are not included in country B's welfare, the welfare effects evaluated at $\tau_A = \tau_B = 0$ are given by

$$\frac{dW_B^{\tau 2}}{d\tau_A}|_{\tau_A=\tau_B=0} = \frac{16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb}{72\,(a+b)^2}, \tag{5}$$

which could be positive, meaning that a tariff in country A could make country B better off. Country B gains only if a tariff in country A benefits firm B.[23] If the profits of firm T are included in the welfare measurement, on the other hand, the welfare effects evaluated at $\tau_A = \tau_B = 0$ are given by

$$\frac{dW_B^{\tau 2}}{d\tau_A}|_{\tau_A=\tau_B=0} = \frac{40ar_T + 30br_T - 20Aa - 15Ab - 14Ba - 9Bb}{72\,(a+b)^2} < 0.$$

Thus, country B as a whole, which includes firm T, loses from a small tariff in country A introduced under free trade.

The above results are summarized in Table 1.

Table 1 here

3.2 Import Quotas

In this subsection, we investigate import quotas. In fact, the effects of import quotas are similar to those of tariffs. We begin with an import quota set by country B, the level of which is $q_B (> 0)$. As long as the quota is binding, it decreases x_{AB} and may decrease x_{BA}. We check whether the quota affects x_{BA}. As long as $q_B \geq x_{BA}(\widetilde{T}_{BA}^F) = \frac{A}{6a}$ holds, there are no effects on T_{BA} and x_{BA}. T_{AB} is determined such that $q_B = \frac{B-2T_{AB}}{3b}$. Thus, we obtain type-1 equilibrium with quotas, which corresponds to type 1 with tariffs:

$$\begin{aligned} T_{AB}^{Q1B} &= \frac{1}{2}B - \frac{3}{2}bq_B, T_{BA}^{Q1B} = \frac{1}{4}A, \\ x_{AA}^{Q1B} &= \frac{5A}{12a}, x_{BA}^{Q1B} = \frac{A}{6a}, \\ x_{BB}^{Q1B} &= \frac{1}{2b}\left(B - bq_B\right), x_{AB}^{Q1B} = q_B. \end{aligned}$$

[23] If $b = 2a$ and $B = 2A$, for example, type-2 equilibrium arises and firm B gains from a tariff in country A. With these parameter values, (5) becomes $\frac{dW_B^{\tau 2}}{d\tau_A}|_{\tau_A=\tau_B=0} = -\frac{2a}{72(a+b)^2}(3A - 14r_T)$, which is positive if $3A < 14r_T$.

An import quota set by country B affects supplies only in country B. Firm T adjusts T_{AB} so that the quota is just binding. As a result, T_{AB} falls.

Now suppose $x_{BA} > q_B$ holds with the quota. Then the profits of firm T become

$$\Pi_T = T_{AB}q_B + T_{BA}\frac{A-2T_{BA}}{3a} - (f_T + r_T\frac{A-2T_{BA}}{3a}).$$

Thus, we have

$$\widetilde{T}^{QB}_{AB} = \frac{1}{2}B - \frac{3}{2}bq_B, \widetilde{T}^{QB}_{BA} = \frac{1}{4}A + \frac{1}{2}r_T.$$

Just as in the free-trade case, there are two subcases depending on whether $x_{BA}(\widetilde{T}^{QB}_{BA}) = \frac{1}{6a}(A-2r_T) > q_B$ or $x_{BA}(\widetilde{T}^{QB}_{BA}) = \frac{1}{6a}(A-2r_T) \leq q_B(< \frac{A}{6a})$ holds. With $x_{BA}(\widetilde{T}^{QB}_{BA}) = \frac{1}{6a}(A-2r_T) \leq q_B$, which is inconsistent with $x_{BA} > q_B$, we have $x_{AB} = x_{BA} = q_B$. The equilibrium is

$$\begin{aligned}
T^{Q2B}_{AB} &= \frac{1}{2}B - \frac{3}{2}bq_B, T^{Q2B}_{BA} = \frac{1}{2}A - \frac{3}{2}aq_B,\\
x^{Q2B}_{AA} &= \frac{1}{2a}(A - aq_B), x^{Q2B}_{BA} = q_B,\\
x^{Q2B}_{BB} &= \frac{1}{2b}(B - bq_B), x^{Q2B}_{AB} = q_B.
\end{aligned}$$

This equilibrium is type 2 with country B's quotas, which corresponds to type 2 equilibrium with tariffs. An import quota set by country B decreases both x_{AB} and x_{BA} and increases both x_{AA} and x_{BB}. Firm T sets the shipping capacity equal to the quota and adjusts both T_{AB} and T_{BA} so that the capacity is just binding in both directions.

If $x_{BA}(\widetilde{T}^{QB}_{BA}) = \frac{1}{6a}(A-2r_T) > q_B$ holds on the other hand, the equilibrium can be obtained by substituting $\widetilde{T}^{QB}_{AB}$ and $\widetilde{T}^{QB}_{BA}$ in (1) and (2).

$$\begin{aligned}
T^{Q3B}_{AB} &= \frac{1}{2}B - \frac{3}{2}bq_B, T^{Q3B}_{BA} = \frac{1}{4}A + \frac{1}{2}r_T,\\
x^{Q3B}_{AA} &= \frac{1}{12a}(5A + 2r_T), x^{Q3B}_{BA} = \frac{1}{6a}(A - 2r_T),\\
x^{Q3B}_{BB} &= \frac{1}{2b}(B - bq_B), x^{Q3B}_{AB} = q_B.
\end{aligned}$$

This equilibrium, which is type 3 with country B's quotas, arises when q_B is very small in the sense that the inequality in $x_{AB} \geq x_{BA}$ under free trade is reversed because of the quota. It should be noted that T_{BA} is greater in this equilibrium than in the other two equilibria. This is because firm T now sets the shipping capacity equal to x^{Q3B}_{BA}.

Figure 3 here

The three types of equilibrium with the quotas are depicted in Figure 3. In Figure 3 (a), $x_{AB} > x_{BA}$ holds under free trade, which arises if $\frac{A}{6a} < \frac{1}{6b}(B - 2r_T)$ holds. x_{AB} and x_{BA} under free trade are, respectively, indicated by F_A and F_B. Since $x_{AB} = q_B$ holds, x_{AB} with the quota is located on F_AO (i.e., the 45 degree line from the origin). x_{BA} with the quota is located on $F_BB_1B_2B_0$. If $\frac{A}{6a} < q_B < \frac{1}{6b}(B - 2r_T)$, then type-1 equilibrium arises and hence $q_B = x_{AB} > x_{BA}$ holds. For example, suppose that a quota, the level of which is q^*, is imposed. Then x_{AB} and x_{BA} with the quota are, respectively, given by Q_A and Q_B. If $\frac{1}{6a}(A - 2r_T) \leq q_B \leq \frac{A}{6a}$, then type-2 equilibrium arises and hence $q_B = x_{AB} = x_{BA}$ holds. When the quota level is given by $q^{*'}$, for example, x_{AB} and x_{BA} with the quota are given by Q'. If $0 < q_B < (A - 2r_T)$ holds, then type-3 equilibrium arises and hence $q_B = x_{AB} < x_{BA}$ holds. When the quota level is given by $q^{*''}$, for example, x_{AB} and x_{BA} with the quota are, respectively, given by Q''_A and Q''_B.

In Figure 3 (b), $x_{AB} = x_{BA}$ holds under free trade, which arises if $\frac{1}{6b}(B - 2r_T) < \frac{A}{6a}$ holds. x_{AB} and x_{BA} under free trade are indicated by F. When the quota is introduced, x_{AB} and x_{BA} are located on FO and FB_2B_0, respectively. If $\frac{1}{6a}(A - 2r_T) \leq q_B < \frac{1}{6(a+b)}(A + B - 2r_T)$, then type-2 equilibrium arises and hence $q_B = x_{AB} = x_{BA}$ holds. If $0 < q_B < \frac{1}{6a}(A - 2r_T)$ holds, then type-3 equilibrium arises and hence $q_B = x_{AB} < x_{BA}$ holds.

Thus, the following proposition is established.

Proposition 4 *Suppose that country B introduces an import quota,* $q_B(> 0)$*, under the free-trade equilibrium with* $x_{AB} \geq x_{BA}$*. The quota also decreases the exports from country B to country A if either* $q_B < \frac{A}{6a} \leq \frac{1}{6b}(B - 2r_T)$ *holds or if* $\frac{1}{6b}(B - 2r_T) < \frac{A}{6a}$ *holds.*

We turn to an import quota set by country A, the level of which is q_A. If $\frac{A}{6a}(= x_{BA}(\widetilde{T}^F_{BA})) \leq \frac{1}{6b}(B - 2r_T)(= x_{AB}(\widetilde{T}^F_{AB}))$, then type-1 equilibrium arises under free trade. When an import quota is set, we have

$$\begin{aligned} T^{Q1A}_{AB} &= \frac{1}{4}B + \frac{1}{2}r_T, T^{Q1A}_{BA} = \frac{1}{2}A - \frac{3}{2}aq_A, \\ x^{Q1A}_{AA} &= \frac{1}{2a}(A - aq_A), x^{Q1A}_{BA} = q_A, \\ x^{Q1A}_{BB} &= \frac{1}{12b}(5B + 2r_T), x^{Q1A}_{AB} = \frac{1}{6b}(B - 2r_T). \end{aligned}$$

The import quota does not affect T_{AB}, x_{AB} and x_{BB}, increases T_{BA} and x_{AA}, and decreases x_{BA}. This case is illustrated in Figure 4 (a). x_{AB} and x_{BA} under free trade are, respectively, indicated by F_A and F_B and those under the quota respectively lie on F_AA_0 and F_BO.

Figure 4 here

If $\frac{1}{6b}(B-2r_T) < \frac{A}{6a}$, on the other hand, type-2 equilibrium arises under free trade. This case is illustrated in Figure 4 (b). Whereas x_{AB} and x_{BA} under free trade are given by F, those under the quota respectively lie on FA_1A_0 and FO. If $0 < q_A \leq \frac{1}{6b}(B-2r_T)$, the equilibrium is the same as above. However, the import quota increases T_{AB}, T_{BA}, x_{AA}, and x_{BB}, and decreases both x_{AB} and x_{BA}. A decrease in x_{AB} is less than that in x_{BA}. If $\frac{1}{6b}(B-2r_T) < q_A < \frac{1}{6(a+b)}(A+B-2r_T)$,[24] then the equilibrium with the quota is given by

$$\begin{aligned} T_{AB}^{Q2A} &= \frac{1}{2}B - \frac{3}{2}bq_A, T_{BA}^{Q2A} = \frac{1}{2}A - \frac{3}{2}aq_A, \\ x_{AA}^{Q2A} &= \frac{1}{2a}(A - aq_A), x_{BA}^{Q2A} = q_A, \\ x_{BB}^{Q2A} &= \frac{1}{2b}(B - bq_B), x_{AB}^{Q2A} = q_A. \end{aligned}$$

Therefore, we obtain

Proposition 5 *Suppose that country A sets an import quota, q_A, under the free-trade equilibrium with $x_{AB} \geq x_{BA}$. If $\frac{1}{6b}(B-2r_T) < \frac{A}{6a}$ holds, then the import quota also decreases the exports from country A to country B.*

As in the case of tariffs, there exist parameter values under which firm B loses and/or firm A gains from an import quota in country B in type-2 equilibrium. First, we examine the effect of introducing a quota on the profits of firm B under type-2 free-trade equilibrium. The profits of firm B in type-2 equilibrium are

$$\Pi_B^{Q2B} = \frac{1}{4b}(B - bq_B)^2 + aq_B^2,$$

where the first and the second terms are the profits from country B and those from country A, respectively. We check if the following holds at $q_B = x_{AB}^{F2}$:

$$\frac{d\Pi_B^{Q2B}}{dq_B} = -\frac{1}{2}(B - 4aq_B - bq_B) > 0.$$

If it does, then the introduction of an import quota in country B (the level of which is close to the free trade level) under type-2 free-trade equilibrium reduces the profits of firm B. At $q_B = x_{AB}^{F2}$, we obtain

$$\frac{d\Pi_B^{Q2B}}{dq_B}\Big|_{q_B = x_{AB}^{F2}} = -\frac{1}{12(a+b)}(8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb).$$

[24]We can verify $\frac{1}{6(a+b)}(A+B-2r_T) > \frac{1}{6b}(B-2r_T)$.

Again, suppose $a = 2b$. Then we need to check if $\frac{d\Pi_B^{Q2B}}{dq_B}\Big|_{q_B = x_{AB}^{F2}} = \frac{1}{4}(A - B - 2r_T) > 0$ holds. With $A = 2B$, for example, this equality holds and the equilibrium is type 2. Thus, firm B actually loses from an import quota set by country B under some parameterization.

We next examine the effect of a quota in country B on the profits of firm A in type-2 free-trade equilibrium. The profits of firm A in type-2 equilibrium are

$$\Pi_A^{Q2B} = \frac{1}{4a}(A - aq_B)^2 + bq_B^2.$$

If the following holds:

$$\begin{aligned} \frac{d\Pi_A^{Q2B}}{dq_B}\Big|_{q_B = x_{AB}^{F2}} &= -\frac{1}{2}(A - aq_B - 4bq_B) \\ &= -\frac{1}{12(a+b)}(2ar_T + 8br_T + 5Aa + 2Ab - Ba - 4Bb) < 0, \end{aligned}$$

then the introduction of an import quota in country B (the level of which is close to the free trade level) increases the profits of firm A. Suppose $a = 2b$ and $A = 2B$. Then type-2 equilibrium arises and $\frac{d\Pi_A^{Q2B}}{dq_B}\Big|_{q_B = x_{AB}^{F2}} < 0$ holds. Thus, firm A actually gains from an import quota set by country B under some parameterization.

The above shows that an import quota set by country B (the level of which is close to the free trade level) in type-2 free-trade equilibrium harms firm B and benefits firm A with $a = 2b$ and $A = 2B$. The economic intuition behind this result is the same as that for tariffs. The direct effect of an import quota in country B is a decrease in firm A's exports. The direct effect harms firm A and benefits firm B. However, the quota also restricts firm B's exports to country A under type-2 equilibrium. This indirect effect, which stems from the presence of the transport sector, benefits firm A and harms firm B. Thus, an import quota set by country B generates two conflicting effects on profits. When country A's market is larger than country B's, the indirect effect could dominate the direct effect. This actually arises with $a = 2b$ and $A = 2B$.

It is straightforward to confirm that an import quota set by country A could harm firm A and benefit firm B in type-2 equilibrium. We can also verify that if the two markets are identical (i.e., $A = B$ and $a = b$), both firms A and B gain from either of the quotas.

Thus, we have the following proposition.

Proposition 6 *When country B (country A) introduces an import quota, firm B (firm A) may not gain and firm A (firm B) may not lose. Depending on the parameter values, the following situations could arise: i) both firms gain; or ii) firm B loses while firm A gains. If the two countries are identical, an import quota in country i benefits both firms A and B,* *harms consumers in both countries and firm T, and reduces the welfare of both countries.*

3.3 Production Subsidies

In this subsection, we briefly examine production subsidies. When a specific subsidy, the rate of which is s_i $(i = A, B)$, is provided by country i, the profits of firm i $(i = A, B)$, Π_i, are

$$\Pi_A = (P_A + s_A)x_{AA} + (P_B + s_A - T_{AB})x_{AB}, \Pi_B = (P_B + s_B)x_{BB} + (P_A + s_B - T_{BA})x_{BA}.$$

Then (1) and (2) are modified as follows with $c_i = 0$ $(i = A, B)$.

$$\begin{aligned} x_{AA} &= \frac{A + 2s_A + (T_{BA} - s_B)}{3a}, x_{BA} = \frac{A - s_A - 2(T_{BA} - s_B)}{3a}, \\ x_{BB} &= \frac{B + 2s_B + (T_{AB} - s_A)}{3b}, x_{AB} = \frac{B - s_B - 2(T_{AB} - s_A)}{3b}. \end{aligned}$$

As in the case of tariffs, we have three types of equilibrium. In type-1 equilibrium, we have

$$\begin{aligned} T_{AB}^{s1} &= \frac{1}{4}B + \frac{1}{2}s_A - \frac{1}{4}s_B + \frac{1}{2}r_T, T_{BA}^{s1} = \frac{1}{4}A - \frac{1}{4}s_A + \frac{1}{2}s_B, \\ x_{AA}^{s1} &= \frac{1}{12a}\left(5A + 7s_A - 2s_B\right), x_{BA}^{s1} = \frac{1}{6a}\left(A - s_A + 2s_B\right), \\ x_{BB}^{s1} &= \frac{1}{12b}\left(5B - 2s_A + 7s_B + 2r_T\right), x_{AB}^{s1} = \frac{1}{6b}\left(B + 2s_A - s_B - 2r_T\right). \end{aligned}$$

In type-2 equilibrium, we have

$$\begin{aligned} T_{AB}^{s2} &= \frac{1}{4\left(a+b\right)}\left(-2as_B + 4as_A + 3bs_A - 3bs_B + 2br_T - Ab + 2Ba + Bb\right), \\ T_{BA}^{s2} &= \frac{1}{4\left(a+b\right)}\left(-3as_A + 3as_B - 2bs_A + 4bs_B + 2ar_T + Aa + 2Ab - Ba\right), \\ x_{AA}^{s2} &= \frac{1}{12a\left(a+b\right)}\left(-as_B + 5as_A + 6bs_A + 2ar_T + 5Aa + 6Ab - Ba\right), \\ x_{BB}^{s2} &= \frac{1}{12b\left(a+b\right)}\left(-bs_A + 6as_B + 5bs_B + 2br_T - Ab + 6Ba + 5Bb\right), \\ x_{AB}^{s2} &= x_{BA}^{s2} = \frac{1}{6\left(a+b\right)}\left(A + B - 2r_T + s_A + s_B\right). \end{aligned}$$

In type-3 equilibrium, we have

$$\begin{aligned}
T_{AB}^{s3} &= \frac{1}{4}B+\frac{1}{2}s_A-\frac{1}{4}s_B, T_{BA}^{s3}=\frac{1}{4}A-\frac{1}{4}s_A+\frac{1}{2}s_B+\frac{1}{2}r_T,\\
x_{AA}^{s3} &= \frac{1}{12a}\left(5A+7s_A-2s_B+2r_T\right), x_{BA}^{s3}=\frac{1}{6a}\left(A-s_A+2s_B-2r_T\right),\\
x_{BB}^{s3} &= \frac{1}{12b}\left(5B-2s_A+7s_B\right), x_{AB}^{s3}=\frac{1}{6b}\left(B+2s_A-s_B\right).
\end{aligned}$$

In any type of equilibrium, both T_{AB} and T_{BA} are affected by both s_A and s_B. An increase in s_i increases T_{ij} and decreases T_{ji} $(i=A,B,i\neq j)$. Thus, firm T adjusts the freight rates and shifts a part of the subsidy rent from the firm receiving the subsidy. It is straightforward to verify that an increase in s_A or s_B benefits firm T and consumers in both countries.

In type-1 and type-3 equilibria, a production subsidy provided by country i benefits firm i and harms firm j $(i,j=A,B,i\neq j)$. In type-2 equilibrium, however, a production subsidy provided by country i could benefit both firms A and B. Below, we show that firm B gains from a production subsidy provided by country A. The profits of firm B with $s_B=0$ in type-2 equilibrium are

$$\Pi_B^{s2}=\frac{1}{144b\left(a+b\right)^2}(-bs_A+2br_T-Ab+6Ba+5Bb)^2+\frac{a}{36\left(a+b\right)^2}(A+B-2r_T+s_A)^2.$$

Differentiating this with respect to s_A, we have

$$\frac{d\Pi_B^{s2}}{ds_A}=\frac{1}{72\left(a+b\right)^2}\left(4as_A+bs_A-8ar_T-2br_T+4Aa+Ab-2Ba-5Bb\right).$$

Suppose $a=2$ and $b=1$. Then $\frac{d\Pi_B^{s2}}{ds_A}>0$ if $A-B-2r_T>0$, which holds with $A=2B$, for example. As was shown, $a=2$, $b=1$ and $A=2B$ are consistent with type-2 equilibrium.

Thus, with $a=2$, $b=1$ and $A=2B$, a production subsidy provided by country A is beneficial for firm B (as well as for firm A).[25] The economic intuition behind the result is similar to that in the tariff case. A production subsidy in country A increases firm A's total output. As a result, firm A's exports increase and firm B's domestic supply decreases, which is harmful for firm B. However, firm B's exports also increase in type-2 equilibrium. This benefits firm B. When country A's market is larger than country B's, the latter effect could dominate the former.

Thus, we obtain the following proposition.

[25]Since $\frac{d\Pi_B^{s2}}{ds_A}>0$ holds even if $s_A\neq 0$, not only the provision of the subsidy but also an increase in s_A increases the profits of firm B.

Proposition 7 *Suppose that country i provides a production subsidy, s_i ($i = A, B$). Firm T raises the freight rate from country i to country j, T_{ij}, but lowers the freight from country j to country i, T_{ji} ($i, j = A, B, i \neq j$). Firm i, firm T and consumers in both countries gain. In type-1 and type-3 equilibria, country i's exports increase, its imports decrease, and firm j loses. In type-2 equilibrium, however, country i's imports as well as its exports increase and firm j could gain.*

4 Presence of FDI

In this section, we introduce the possibility of foreign direct investment (FDI) into the basic model and examine trade policies. We consider the standard trade-off between transport costs and FDI costs.[26] When undertaking FDI, the investing firm i ($i = A, B$) can save trade costs including transport costs T_{ij} ($j = A, B; i \neq j$) but has to incur fixed costs for FDI, Φ_i. We assume that FDI does not affect the MCs of production (which are still assumed to be zero).

If firm A (firm B) undertakes FDI, then firm B (firm A) could lose from a decrease in the effective MC of firm A (firm B). Firm B (firm A) may also face an increase in T_{BA} (T_{AB}). Obviously, firm T loses from FDI and hence tries to prevent manufacturing firms from undertaking FDI. In this section, we specifically show that although in the previous section the effects of quotas and those of tariffs are similar, these effects are quite different with the possibility of FDI.

We begin with the case of tariffs. Suppose that country B sets a specific tariff, the rate of which is τ_B. Since an increase in the tariff rate decreases the profits of firm A in type-1 and type-3 equilibria, there may exist a critical tariff rate, $\tau_B^{\max}$, at which firm A is indifferent between exports and FDI. With $\tau_B > \tau_B^{\max}$, therefore, firm T has an incentive to lower the freight rate to prevent FDI. In fact, firm T sets the freight rate so that firm A's trade cost which is the sum of the tariff and the freight rate equals $\tau_B^{\max} + T_{AB}(\tau_B^{\max})$. As long as the trade cost remains at the level of $\tau_B^{\max} + T_{AB}(\tau_B^{\max})$, firm A has no incentive for FDI. Thus, government B can raise the tariff without increasing the consumer price when $\tau_B \geq \tau_B^{\max}$. There are no effects on firms A or B or on consumers. The tariff simply results in full rent-shifting from firm T to government B.[27]

It should be noted that x_{AB} and x_{BA} may drop at some tariff levels. Figure 5 shows a possible case. When $\tau_B > \tau_B^{\max}$, an increase in τ_B decreases T_{AB} but the trade cost is

[26] Daniels and Ruhr (2014) find that shipping costs have a positive and significant relationship with U.S. manufacturing foreign direct investment.

[27] A similar argument is valid when country A imposes a tariff.

constant at $\tau_B^{\max} + T_{AB}(\tau_B^{\max})$. Suppose that τ_1 is the tariff rate at which $T_{AB} = r_T$ holds. Then x_{AB} and x_{BA}, respectively, drop from G_{A1} to G_1 and G_{B1} to G_1, because firm T cannot cover the MC, r_T, for the capacity beyond the level of $x_{AB}(\tau_1)$ with $\tau_B > \tau_1$. By reducing the capacity from $x_{AB}(\tau_B^{\max})$ to $x_{AB}(\tau_1)$ to realize a full load in both directions, firm T can cover the MC of the whole capacity. Now suppose that τ_2 is the tariff rate at which $T_{AB} + T_{BA}(\tau_2) = r_T$ holds. Then x_{AB} and x_{BA}, respectively, drop from G_2 to G_{A2} and G_2 to G_{B2}, because firm T can no longer keep a full load in both directions with $\tau_B > \tau_2$.[28] By reducing the capacity from $x_{AB}(\tau_1)$ to $x_{AB}(\tau_2)$ to realize a full load only in the direction from country B to country A, firm T can cover the MC of the capacity. x_{AB} and x_{BA} are constant with $\tau_1 < \tau_B < \tau_2$ and with $\tau_B > \tau_2$.[29]

Figure 5 here

We obtain the following proposition.

Proposition 8 *Suppose $\tau_B \geq \tau_B^{\max}$. Then an increase in τ_B leads firm T to lower the freight rate. Even if τ_B increases, the trade cost could be constant. If this is the case, firms A and B and consumers are not affected. Government B gains but firm T loses.*

Next we examine the case of quotas. Suppose that country B sets an import quota, the level of which is q_B. As was shown, the freight rate is $T_{AB} = \frac{1}{2}B - \frac{3}{2}bq_B$. In type-1 and type-3 equilibria, firm A's profits decrease as q_B decreases. Thus, there may exist a critical quota level, $q_B^{\min}$, at which firm A is indifferent between exports and FDI. That is, with $q_B < q_B^{\min}$, firm A chooses FDI if $T_{AB} = \frac{1}{2}B - \frac{3}{2}bq_B$. Then firm T has an incentive to lower the freight rate to prevent FDI. More specifically, firm T sets the freight rate so that firm A is indifferent between exports and FDI. Even if firm T decreases the freight rate, the effects of a decrease in q_B on firm B and consumers remain the same; that is, a decrease in q_B benefits firm B and harms consumers in country B.

Interestingly, there may exist a situation in which the quota becomes unbinding as it becomes tighter. Figure 6 shows a possible case. Suppose $\frac{A}{6a} < q_1 < q_B^{\min}$ where q_1 is the quota level at which $T_{AB} = r_T$ holds. At $q_B = q_1$, firm T sets $k_T = \frac{A}{6a}(= x_{BA}^{Q2})$, because firm T cannot cover the MC, r_T, for capacity beyond the level of $\frac{A}{6a}(= x_{BA}^{Q2})$. By reducing the capacity from q_1 to x_{BA}^{Q2} to realize a full load in both directions, firm T can cover the MC of the whole capacity. In the figure, x_{AB} shifts from Q_1 to Q_1' at $q_B = q_1$. This implies that the quota becomes unbinding and $x_{AB} = x_{BA} = \frac{A}{6a}$ holds. In the figure, the quota is unbinding with $\frac{A}{6a} < q_B < q_1$ and becomes binding again at $q_B = \frac{A}{6a}$.

[28]With $\tau_1 < \tau_B < \tau_2$, $\frac{1}{6a}(A - 2r_T) < x_{AB} = x_{BA} < \frac{A}{6a}$ holds.

[29]Firm T stops shipping the good from country A to country B at the tariff rate with which firm T has to set $T_{AB} = 0$ to prevent FDI.

Figure 6 here

As long as the quota is binding, a decrease in q_B decreases the profits of firm T. It is also harmful for consumers in country B, because the imports decrease and the consumer price increases. T_{BA} increases if $x_{AB} = x_{BA} = q_B$ but does not change otherwise.

Thus, we have the following proposition.

Proposition 9 *Suppose that country B sets an import quota and $q_B \leq q_B^{\min}$ holds. As the level of (binding) quota decreases, firm T lowers the freight rate T_{AB} to make firm A indifferent between exports and FDI; and raises T_{BA} if $x_{AB} = x_{BA} = q_B$. Firm B gains, while consumers in country B and firm T lose. Tightening the quota may make the quota unbinding.*

5 Multiple Goods

In this section, we extend the basic model with tariffs to the case with multiple final goods. We begin with a simple symmetric case. Suppose that there are n independent goods produced by n sectors in both countries. Each sector is characterized by the sector in the basic model. There is a single firm producing good j $(j = 1, ..., n)$ in each country. The inverse demand for good j in countries A and B is given by

$$P_{Aj} = A_j - a_j X_{Aj}, P_{Bj} = B_j - b_j X_{Bj}.$$

The profits of the firm manufacturing good j in country i $(i = A, B)$, Π_{ij}, are

$$\Pi_{Aj} = P_{Aj} x_{jAA} + (P_{Bj} - \tau_{Bj} - T_{AB}) x_{jAB}, \Pi_{Bj} = P_{Bj} x_{jBB} + (P_{Aj} - \tau_{Aj} - T_{BA}) x_{jBA}.$$

Suppose that n sectors are symmetric, that is, $A \equiv A_1 = ... = A_n$, $B \equiv B_1 = ... = B_n$, $a \equiv a_1 = ... = a_n$, $\tau_A \equiv \tau_{A1} = ... = \tau_{An}$, and $\tau_B \equiv \tau_{B1} = ... = \tau_{Bn}$. Then we can easily verify that the analysis and results are essentially the same as those in the basic model with a single good.

We next examine the case without symmetry. For this, we consider a simple model with two goods, goods X and Z. As in the basic model, firms A and B produce good X and supply it to both countries. Good Z is produced only by firm α in country A but is consumed in both countries. We take substitutability between goods X and Z into account.

We assume that the inverse demand for good X in countries A and B is given by

$$P_{xA} = A_x - (x_{AA} + x_{BA}) - \phi z_{AA}, P_{xB} = B_x - (x_{AB} + x_{BB}) - \phi z_{AB},$$

where $\phi \in [0,1)$ stands for the degree of substitutability between goods X and Z. The extreme value 0 corresponds to the case of independent goods. Similarly the inverse demand for good Z in countries A and B is given by

$$P_{zA} = A_z - z_{AA} - \phi(x_{AA} + x_{BA}), P_{zB} = B_z - z_{AB} - \phi(x_{AB} + x_{BB}).$$

The profits of firm T now become

$$\Pi_T = T_{AB}(x_{AB} + z_{AB}) + T_{BA}x_{BA} - (f_T + r_T k_T).$$

The profits of firm α, Π_α, are given by

$$\Pi_\alpha = P_{zA}z_{AA} + (P_{zB} - \tau_{zB} - T_{AB})z_{AB},$$

where τ_{zB} is a specific tariff on good Z imposed by country B. Although no firm produces good Z in country B, government B has incentive to impose a tariff to shift the rent from firm α to government B.

Given the freight rates, we obtain the supplies with Cournot competition as follows

$$\begin{aligned}
x_{AB} &= -\frac{1}{2(\phi^2-3)}\begin{pmatrix} 2B_x - 4\tau_{xB} - 4T_{AB} + \phi\tau_{zB} \\ -\phi B_z + \phi T_{AB} + \phi^2\tau_{xB} + \phi^2 T_{AB}\end{pmatrix}, \\
x_{BB} &= -\frac{1}{2(\phi^2-3)}\begin{pmatrix} 2\tau_{xB} + 2B_x + 2T_{AB} + \phi\tau_{zB} \\ -\phi B_z + \phi T_{AB} - \phi^2\tau_{xB} - \phi^2 T_{AB}\end{pmatrix}, \\
z_{AB} &= \frac{1}{2(\phi^2-3)}(3\tau_{zB} - 3B_z + 3T_{AB} - \phi\tau_{xB} + 2\phi B_x - \phi T_{AB}), \\
x_{BA} &= -\frac{1}{2(\phi^2-3)}(2A_x - 4\tau_{xA} - 4T_{BA} - \phi A_z + \phi^2\tau_{xA} + \phi^2 T_{BA}), \\
x_{AA} &= -\frac{1}{2(\phi^2-3)}(2\tau_{xA} + 2A_x + 2T_{BA} - \phi A_z - \phi^2\tau_{xA} - \phi^2 T_{BA}), \\
z_{AA} &= -\frac{1}{2(\phi^2-3)}(3A_z + \phi\tau_{xA} - 2\phi A_x + \phi T_{BA}).
\end{aligned}$$

First, we examine the case with $x_{AB} + z_{AB} > x_{BA}$. In this case, we have

$$\max \Pi_T = \max\{T_{AB}(x_{AB} + z_{AB}) + T_{BA}x_{BA} - (f_T + r_T(x_{AB} + z_{AB}))\}.$$

Solving this, we have

$$\begin{aligned} T_{AB}^{M1} &= \frac{1}{4\phi + 2\phi^2 - 14} \begin{pmatrix} -2B_x - 3B_z + r_T\left(2\phi + \phi^2 - 7\right) \\ -\left(\phi^2 + \phi - 4\right)\tau_{xB} + 2\phi B_x + \phi B_z - \phi\tau_{zB} + 3\tau_{zB} \end{pmatrix}, \\ T_{BA}^{M1} &= -\frac{1}{2\phi^2 - 8}\left(2A_x - \phi A_z - 4\tau_{xA} + \phi^2\tau_{xA}\right). \end{aligned}$$

Second, we consider the case with $x_{AB} + z_{AB} < x_{BA}$.

$$\max \Pi_T = \max\{T_{AB}(x_{AB} + z_{AB}) + T_{BA}x_{BA} - (f_T + r_T x_{BA})\}.$$

Solving this, we have

$$\begin{aligned} T_{AB}^{M3} &= -\frac{1}{4\phi + 2\phi^2 - 14}\left(2B_x + 3B_z + \phi\tau_{zB} - 2\phi B_x - \phi B_z - 3\tau_{zB} + \left(\phi^2 + \phi - 4\right)\tau_{xB}\right), \\ T_{BA}^{M3} &= \frac{1}{2\phi^2 - 8}\left(-2A_x + r\left(\phi^2 - 4\right) + \phi A_z + 4\tau_{xA} - \phi^2\tau_{xA}\right). \end{aligned}$$

In both cases, therefore, an increase in τ_{xB} or τ_{zB} decreases T_{AB}, while an increase in τ_{xA} decreases T_{BA}. Thus, an increase in τ_{xB} (τ_{zB}) harms firm A (firm α) but benefits firm α (firm A). This is the case even with $\phi = 0$. It is obvious that, with $\phi = 0$, firm B gains from an increase in τ_{xB} but loses from an increase in τ_{zB}.

If $x_{AB} + z_{AB} = x_{BA}$ holds, then spillover effects do exist. That is, an increase in τ_{xB} or τ_{zB} not only decreases T_{AB} but also increases T_{BA} and an increase in τ_{xA} not only decreases T_{BA} but also increases T_{AB}. It should be noted that the spillover effects arise even if $\phi = 0$. With $x_{AB} + z_{AB} = x_{BA}$, we have

$$\begin{aligned} \max \Pi_T &= \max\{T_{AB}(x_{AB} + z_{AB}) + T_{BA}x_{BA} - (f_T + r_T(x_{AB} + z_{AB}))\} \\ s.t. x_{BA} &= x_{AB} + z_{AB} \end{aligned}$$

With $\phi = 0$, we obtain[30]

$$\begin{aligned}
T^{M2}_{AB}\big|_{\phi=0} &= \frac{1}{77}\left(14r - 7A_x + 18B_x + 27B_z + 14\tau_{xA} - 36\tau_{xB} - 27\tau_{zB}\right), \\
T^{M2}_{BA}\big|_{\phi=0} &= \frac{1}{44}\left(14r + 15A_x - 4B_x - 6B_z - 30\tau_{xA} + 8\tau_{xB} + 6\tau_{zB}\right), \\
x^{M2}_{AB}\big|_{\phi=0} &= -\frac{1}{231}\left(28r - 14A_x - 41B_x + 54B_z + 28\tau_{xA} + 82\tau_{xB} - 54\tau_{zB}\right), \\
z^{M2}_{AB}\big|_{\phi=0} &= -\frac{1}{154}\left(14r - 7A_x + 18B_x - 50B_z + 14\tau_{xA} - 36\tau_{xB} + 50\tau_{zB}\right), \\
x^{M2}_{BA}\big|_{\phi=0} &= -\frac{1}{66}\left(14r - 7A_x - 4B_x - 6B_z + 14\tau_{xA} + 8\tau_{xB} + 6\tau_{zB}\right).
\end{aligned}$$

An increase in τ_{xB} (τ_{zB}) decreases x_{AB} (z_{AB}) and increases z_{AB} (x_{AB}). Since the decrease in x_{AB} (z_{AB}) dominates the increase in z_{AB} (x_{AB}), $x_{AB}+z_{AB} = x_{BA}$ decreases. The economic intuition behind the spillover effects is as follows. When τ_{xB} or τ_{zB} rises, to keep a full load in both directions, firm T decreases the reduction of the load from country A to country B by lowering T_{AB} and decreases the load from country B to country A by raising T_{BA}. Similarly, when the load from country B to country A falls because of an increase in τ_{xA}, firm T increases T_{AB} to reduce the load from country A to country B. As in the case with $x_{AB} + z_{AB} \neq x_{BA}$, firm A (firm α) necessarily gains from an increase in τ_{zB} (τ_{xB}). However, the gain for firm A is magnified, because τ_{zB} also increases T_{BA}.[31]

Table 2 here

The above results are summarized in the following proposition (see also Table 2).

Proposition 10 *If $x_{AB} + z_{AB} \neq x_{BA}$, then an increase in τ_{xB} or τ_{zB} decreases T_{AB}. An increase in τ_{xB} (τ_{zB}) harms firm A (firm α) and benefits firm α (firm A) even if $\phi = 0$. If $x_{AB} + z_{AB} = x_{BA}$, then an increase in τ_{xB} or τ_{zB} decreases T_{AB} and increases T_{BA}. An increase in τ_{xB} (τ_{zB}) benefits firm α (firm A) even if $\phi = 0$. Firm B loses from an increase in τ_{zB} if $\phi = 0$.*

When country B sets a tariff on good X or Z, firm T lowers the freight rate T_{AB} and its profits decrease. Thus, firm T may stop serving firm A (firm α) when τ_{xB} (τ_{zB}) is large enough. To verify this, we assume $\phi = 0$, $\tau_{xB} > 0$, $\tau_{zB} = 0$ and $x_{AB} + z_{AB} < x_{BA}$ for the

[30]Tedious calculations reveal that the spillover effects are qualitatively the same even with $\phi \neq 0$.
[31]This is also the case for firm α unless $\phi = 0$.

sake of simplicity.[32] Then we have

$$\begin{aligned} T_{AB}^{M3}\big|_{\phi=0,\tau_{zB}=0} &= \frac{1}{14}\left(2B_x + 3B_z - 4\tau_{xB}\right), \\ x_{AB}^{M3}\big|_{\phi=0,\tau_{zB}=0} &= \frac{1}{3}\left(B_x - 2T_{AB} - 2\tau_{xB}\right), \ z_{AB}^{M3}\big|_{\phi=0,\tau_{zB}=0} = \frac{1}{2}\left(B_z - T_{AB}\right). \end{aligned}$$

The profits of firm T from serving both firms A and α are $\frac{1}{168}\left(2B_x + 3B_z - 4\tau_{xB}\right)^2$. When firm T serves only firm α, we have $T_{AB} = \frac{1}{2}B_z$ and the profits from serving only firm α are $\frac{1}{8}B_z^2$. Thus, if $\tau_{xB} > \frac{1}{2}B_x + \frac{3}{4}B_z - \frac{1}{4}\sqrt{21}B_z$, then the profits from serving only firm α are greater than those from serving both firm A and firm α. Stopping serving firm A makes firm B a monopolist in country B.

It should be noted that even if $x_{AB} + z_{AB} > x_{BA}$ initially holds, stopping serving firm A may lead to $x_{AB} + z_{AB} \leq x_{BA}$ (where $x_{AB} = 0$). If this is the case, T_{BA} increases.

Thus, we obtain the following proposition.

Proposition 11 *An increase in τ_{xB} (τ_{zB}) may lead firm T to stop serving firm X (firm Z). This may increase T_{BA}.*

Next we introduce another asymmetry into the model. We specifically assume that firm T price-discriminates across firms. With price discrimination, the profits of firm T become

$$\Pi_T = T_{AB}x_{AB} + \Gamma_{AB}z_{AB} + T_{BA}x_{BA} - (f_T + r_T k_T),$$

where Γ_{AB} is the freight rate for firm α. Firm T sets three freight rates, T_{AB}, T_{BA} and Γ_{AB}. The profits of firm α, Π_α, are given by

$$\Pi_\alpha = P_{zA}z_{AA} + (P_{zB} - \tau_{zB} - \Gamma_{AB})z_{AB}.$$

[32]Even with $\phi \neq 0$ and $\tau_{zB} \neq 0$, the essence of the following argument holds.

Given the freight rates, the supplies in country B are modified as follows

$$
\begin{aligned}
x_{AB} &= -\frac{1}{2\left(\phi^2-3\right)}\begin{pmatrix} 2B_x - 4\tau_{xB} - 4T_{AB} + \phi\tau_{zB} \\ -\phi B_z + \phi\Gamma_{AB} + \phi^2\tau_{xB} + \phi^2 T_{AB} \end{pmatrix}, \\
x_{BB} &= -\frac{1}{2\left(\phi^2-3\right)}\begin{pmatrix} 2\tau_{xB} + 2B_x + 2T_{AB} + \phi\tau_{zB} \\ -\phi B_z + \phi\Gamma_{AB} - \phi^2\tau_{xB} - \phi^2 T_{AB} \end{pmatrix}, \\
z_{AB} &= \frac{1}{2\left(\phi^2-3\right)}\left(3\tau_{zB} - 3B_z + 3\Gamma_{AB} - \phi\tau_{xB} + 2\phi B_x - \phi T_{AB}\right), \\
x_{BA} &= -\frac{1}{2\left(\phi^2-3\right)}\left(2A_x - 4\tau_{xA} - 4T_{BA} - \phi A_z + \phi^2\tau_{xA} + \phi^2 T_{BA}\right), \\
x_{AA} &= -\frac{1}{2\left(\phi^2-3\right)}\left(2\tau_{xA} + 2A_x + 2T_{BA} - \phi A_z - \phi^2\tau_{xA} - \phi^2 T_{BA}\right), \\
z_{AA} &= -\frac{1}{2\left(\phi^2-3\right)}\left(3A_z + \phi\tau_{xA} - 2\phi A_x + \phi T_{BA}\right).
\end{aligned}
$$

In the following, we show that the effects of tariffs depend on whether or not a full load occurs in both directions (i.e., $x_{AB} + z_{AB} = x_{BA}$). First, we examine the case with $x_{AB} + z_{AB} > x_{BA}$. In this case, we have

$$
\max \Pi_T = \max\{T_{AB}x_{AB} + T_{BA}x_{BA} + \Gamma_{AB}z_{AB} - (f_T + r_T(x_{AB} + z_{AB}))\}.
$$

Solving this, we have

$$
\begin{aligned}
T_{AB}^{m1} &= \frac{1}{13\phi^2 - 48}\begin{pmatrix} \left(24 - 7\phi^2\right)\tau_{xB} - 3\phi\tau_{zB} \\ -12B_x - 24r_T + 3\phi B_z + 3\phi r_T + 2\phi^2 B_x + 7\phi^2 r_T \end{pmatrix}, \\
\Gamma_{AB}^{m1} &= \frac{1}{13\phi^2 - 48}\begin{pmatrix} \left(24 - 7\phi^2\right)\tau_{zB} + \phi\left(-4 + \phi^2\right)\tau_{xB} - 24B_z - 24r_T \\ +14\phi B_x + 4\phi r_T - 4\phi^3 B_x + 7\phi^2 B_z + 7\phi^2 r_T - \phi^3 r_T \end{pmatrix}, \\
T_{BA}^{m1} &= \frac{1}{2\phi^2 - 8}\left(4\tau_{xA} - 2A_x + \phi A_z - \phi^2\tau_{xA}\right).
\end{aligned}
$$

These imply that an increase in τ_{xB} (τ_{zB}) lowers T_{AB} (Γ_{AB}) and raises Γ_{AB} (T_{AB}) unless the two goods are independent (i.e., $\phi = 0$). The economic intuition is as follows. When τ_{xB} (τ_{zB}) increases, the demand shifts from good X (good Z) to good Z (good X) with $\phi \neq 0$. Facing this shift, firm T adjusts T_{AB} and Γ_{AB} to restore the balance between x_{AB} and z_{AB}. We should note that an increase in τ_{xB} increases the effective marginal cost for firm A (i.e., $\tau_{xB} + T_{AB}$) and an increase in τ_{zB} increases the effective marginal cost for firm α (i.e., $\tau_{zB} + \Gamma_{AB}$). Thus, the effective marginal costs of both firms increase when τ_{xB} or τ_{zB} rises, implying that firms A and α lose and firm B gains. If the two goods are independent (i.e., $\phi = 0$), a change in τ_{xB} (τ_{zB}) lowers T_{AB} (Γ_{AB}) but does not affect Γ_{AB} (T_{AB}).

Second, we consider the case with $x_{AB} + z_{AB} < x_{BA}$.

$$\max \Pi_T = \max\{T_{AB}x_{AB} + T_{BA}x_{BA} + \Gamma_{AB}z_{AB} - (f_T + r_T x_{BA})\}.$$

Solving this, we have

$$\begin{aligned}
T_{AB}^{m3} &= \frac{1}{13\phi^2 - 48}\left(\left(24 - 7\phi^2\right)\tau_{xB} - 3\phi\tau_{zB} - 12B_x + 3\phi B_z + 2\phi^2 B_x\right), \\
\Gamma_{AB}^{m3} &= \frac{1}{13\phi^2 - 48}\left(\phi\left(\phi^2 - 4\right)\tau_{xB} + \left(24 - 7\phi^2\right)\tau_{zB} - 24B_z + 14\phi B_x - 4\phi^3 B_x + 7\phi^2 B_z\right), \\
T_{BA}^{m3} &= \frac{1}{2\phi^2 - 8}\left(-4r_T + 4\tau_{xA} - 2A_x + \phi A_z + r_T\phi^2 - \phi^2\tau_{xA}\right).
\end{aligned}$$

Again, an increase in τ_{xB} (τ_{zB}) leads firm T to reduce T_{AB} (Γ_{AB}) and raise Γ_{AB} (T_{AB}) if $\phi \neq 0$.

We next consider the case with $x_{AB} + z_{AB} = x_{BA}$. Again we show that a change in the tariff in one sector affects not only that sector but also the other independent sector even if $\phi = 0$.

$$\begin{aligned}
\max \Pi_T &= \max\{T_{AB}x_{AB} + T_{BA}x_{BA} + \Gamma_{AB}z_{AB} - (f_T + r_T x_{BA})\} \\
s.t. x_{BA} &= x_{AB} + z_{AB}
\end{aligned}$$

If $\phi = 0$ holds, we obtain

$$\begin{aligned}
T_{AB}^{m2}\Big|_{\phi=0} &= \frac{1}{44}\left(8r - 30\tau_{xB} + 8\tau_{xA} - 6\tau_{zB} - 4A_x + 15B_x + 6B_z\right), \\
\Gamma_{AB}^{m2}\Big|_{\phi=0} &= \frac{1}{11}\left(2r - 2\tau_{xB} + 2\tau_{xA} - 7\tau_{zB} - A_x + B_x + 7B_z\right), \\
T_{BA}^{m2}\Big|_{\phi=0} &= \frac{1}{44}\left(14r + 8\tau_{xB} - 30\tau_{xA} + 6\tau_{zB} + 15A_x - 4B_x - 6B_z\right), \\
x_{AB}^{m2}\Big|_{\phi=0} &= -\frac{1}{66}\left(8r + 14\tau_{xB} + 8\tau_{xA} - 6\tau_{zB} - 4A_x - 7B_x + 6B_z\right), \\
z_{AB}^{m2}\Big|_{\phi=0} &= -\frac{1}{22}\left(2r - 2\tau_{xB} + 2\tau_{xA} + 4\tau_{zB} - A_x + B_x - 4B_z\right), \\
x_{BA}^{m2}\Big|_{\phi=0} &= -\frac{1}{66}\left(14r + 8\tau_{xB} + 14\tau_{xA} + 6\tau_{zB} - 7A_x - 4B_x - 6B_z\right).
\end{aligned}$$

An increase in τ_{xB} or τ_{zB} decreases both T_{AB} and Γ_{AB} and increases T_{BA} while an increase in τ_{xA} increases both T_{AB} and Γ_{AB} and decreases T_{BA}.[33] In contrast to the case with

[33] As in the case without price discrimination, the spillover effects are qualitatively the same even with $\phi \neq 0$.

$x_{AB} + z_{AB} \neq x_{BA}$, therefore, firm T adjusts T_{BA} as well as T_{AB} and Γ_{AB} to keep a full load in both directions. That is, when τ_{xB} or τ_{zB} rises, firm T avoids the reduction in the load from country A to country B by lowering Γ_{AB} and T_{AB} and decrease the load from country B to country A by raising T_{BA}. Analogously, when the load from country B to country A falls because of an increase in τ_{xA}, firm T increases both T_{AB} and Γ_{AB} to reduce the load from country A to country B. The effects of tariffs on profits are not straightforward with $x_{AB} + z_{AB} = x_{BA}$ but firm α (firm A) necessarily gains from an increase in τ_{xB} (τ_{zB}).

Table 3 here

Thus, with respect to the tariffs imposed by country B, we obtain the following proposition (see also Table 3).

Proposition 12 *Suppose that firm T price-discriminates across firms. If $x_{AB} + z_{AB} \neq x_{BA}$ and $\phi \neq 0$, then an increase in τ_{xB} (τ_{zB}) decreases T_{AB} (Γ_{AB}) but increases Γ_{AB} (T_{AB}). An increase in τ_{xB} or τ_{zB} harms both firm A and firm α and benefits firm B. If $x_{AB}+z_{AB} \neq x_{BA}$ and $\phi = 0$, then the effect of an increase in τ_{xB} (τ_{zB}) is just to decrease T_{AB} (Γ_{AB}). An increase in τ_{xB} harms firm A and benefits firm B while an increase in τ_{zB} harms firm α. If $x_{AB} + z_{AB} = x_{BA}$, then an increase in τ_{xB} or τ_{zB} decreases both T_{AB} and Γ_{AB} but increases T_{BA}. Even if $\phi = 0$, an increase in τ_{xB} benefits firm α and an increase in τ_{zB} benefits firm A and harms firm B.*

6 Multiple Carriers

In this section, we extend the basic model with tariffs to the case with multiple carriers. We assume that there are two transport firms: firm T_1 and firm T_2 and that these firms are engaged in Cournot competition. Without loss of generality, we assume that $r_1 \leq r_2$, where r_i ($i = 1, 2$) is the MC of operating a means of transport for firm T_i. The firms face the following derived demands.

$$x_{AB} = \frac{B - 2(T_{AB} + \tau_B)}{3b}, x_{BA} = \frac{A - 2(T_{BA} + \tau_A)}{3a}. \quad (6)$$

We have $x_{AB} = x_{1AB} + x_{2AB}$ and $x_{BA} = x_{1BA} + x_{2BA}$ (where a subscript $i = 1, 2$ stands for firm T_i).

The appendix shows that there are five possible equilibria with $r_1 \leq r_2$, which are stated in the following lemma (see Figure 7).

Lemma 1 *1)* $x_{1AB} > x_{1BA}$ *and* $x_{2AB} > x_{2BA}$ *holds if* $\Lambda(\equiv Ab - Ba + 2a\tau_B - 2b\tau_A) < 2a(r_1 - 2r_2)$*, 2)* $x_{1AB} = x_{1BA}$ *and* $x_{2AB} = x_{2BA}$ *holds if* $-2ar_1 \leq \Lambda \leq 2br_1$*, 3)* $x_{1AB} < x_{1BA}$ *and* $x_{2AB} < x_{2BA}$ *holds if* $2b(2r_2 - r_1) < \Lambda$*, 4)* $x_{1AB} > x_{1BA}$ *and* $x_{2AB} = x_{2BA}$ *holds if* $2a(r_1 - 2r_2) \leq \Lambda < -2ar_1$*, and 5)* $x_{1AB} < x_{1BA}$ *and* $x_{2AB} = x_{2BA}$ *if* $2br_1 < \Lambda \leq 2b(2r_2 - r_1)$*.*

Figure 7 here

If $r_1 = r_2$, we have only three types of equilibrium, that is, $x_{1AB} > x_{1BA}$ and $x_{2AB} > x_{2BA}$ (type 1), $x_{1AB} = x_{1BA}$ and $x_{2AB} = x_{2BA}$ (type 2), and $x_{1AB} < x_{1BA}$ and $x_{2AB} < x_{2BA}$ (type 3). If $r_1 < r_2$, we have two more types, that is, $x_{1AB} > x_{1BA}$ and $x_{2AB} = x_{2BA}$ (type 4) and $x_{1AB} < x_{1BA}$ and $x_{2AB} = x_{2BA}$ (type 5). This implies that firm T_1 is more likely to operate without a full load.

Thus, we obtain the following proposition.

Proposition 13 *With* $r_1 < r_2$*, the range of parameterization for operating without a full load is larger for firm* T_1 *than for firm* T_2*.*

The economic intuition behind this result is as follows. The MC of operating a means of transport is lower for firm T_1 than for firm T_2, implying that the cost to operate shipping without a full load is lower for firm T_1 than for firm T_2. Thus, firm T_1 has less incentive to adjust freight rates to have a full load in both directions.

With $x_{1AB} > x_{1BA}$ and $x_{2AB} > x_{2BA}$, we obtain

$$\begin{aligned}
x_{1AB}^{C1} &= \frac{1}{9b}(B - 2\tau_B - 4r_1 + 2r_2), x_{2AB}^{C1} = \frac{1}{9b}(B - 2\tau_B + 2r_1 - 4r_2), \\
x_{AB}^{C1} &= x_{1AB}^{C1} + x_{2AB}^{C1} = \frac{2}{9b}(B - 2\tau_B - r_1 - r_2), \\
x_{1BA}^{C1} &= x_{2BA}^{C1} = \frac{1}{9a}(A - 2\tau_A), \\
x_{BA}^{C1} &= x_{1BA}^{C1} + x_{2BA}^{C1} = 2x_{1BA}^{C1} = \frac{2}{9a}(A - 2\tau_A), \\
T_{AB}^{C1} &= \frac{1}{6}(B - 2\tau_B + 2r_1 + 2r_2), T_{BA}^{C1} = \frac{1}{6}(A - 2\tau_A).
\end{aligned}$$

The characteristics of this equilibrium are essentially the same as those of type-1 equilibrium with a single carrier. A change in τ_B (τ_A) affects only x_{1AB} and x_{2AB} (x_{1BA} and x_{2BA}). We have $x_{1AB} > x_{2AB}$ and $x_{1BA} = x_{2BA}$. It should be noted that $x_{1BA} = x_{2BA}$ holds even if $x_{1AB} \neq x_{2AB}$. This is because T_{BA} is independent of r_1 and r_2. Obviously, the characteristics of type-3 equilibrium are essentially the same as those of type-3 equilibrium with a single carrier.

With $x_{1AB} = x_{1BA}$ and $x_{2AB} = x_{2BA}$, we have

$$\begin{aligned}
x_{1AB}^{C2} &= x_{1BA}^{C2} = \frac{1}{9(a+b)}(A + B - 2\tau_A - 2\tau_B - 4r_1 + 2r_2), x_{AB}^{C1} = 2x_{2AB}^{C2}, \\
x_{2AB}^{C2} &= x_{2BA}^{C2} = \frac{1}{9(a+b)}(A + B - 2\tau_A - 2\tau_B - 4r_2 + 2r_1), x_{BA}^{C1} = 2x_{2BA}^{C2}, \\
T_{AB}^{C2} &= \frac{1}{6(a+b)}(4b\tau_A - 6a\tau_B - 2b\tau_B + 2br_1 + 2br_2 - 2Ab + 3Ba + Bb), \\
T_{BA}^{C2} &= \frac{1}{6(a+b)}(4a\tau_B - 2a\tau_A - 6b\tau_A + 2ar_1 + 2ar_2 + Aa + 3Ab - 2Ba).
\end{aligned}$$

The characteristics of this equilibrium are basically the same as those of type-2 equilibrium with a single carrier. A change in τ_B or τ_A equally affects all shipping volumes (i.e., x_{1AB}, x_{2AB}, x_{1BA} and x_{2BA}).

With $x_{1AB} > x_{1BA}$ and $x_{2AB} = x_{2BA}$, we have

$$\begin{aligned}
x_{1AB}^{C4} &= -\frac{1}{18b(a+b)}(6a\tau_B - 2b\tau_A + 4b\tau_B + 6ar_1 - 4br_2 + 8br_1 + Ab - 3Ba - 2Bb), \\
x_{1BA}^{C4} &= -\frac{1}{18a(a+b)}(4a\tau_A - 2a\tau_B + 6b\tau_A - 4ar_2 + 2ar_1 - 2Aa - 3Ab + Ba), \\
x_{2AB}^{C4} &= x_{2BA}^{C4} = \frac{1}{9(a+b)}(A + B - 2\tau_A - 2\tau_B - 4r_2 + 2r_1), \\
x_{AB}^{C4} &= -\frac{1}{18b(a+b)}(6a\tau_B + 2b\tau_A + 8b\tau_B + 6ar_1 + 4br_1 + 4br_2 - Ab - 3Ba - 4Bb), \\
x_{BA}^{C4} &= \frac{1}{18a(a+b)}(2ar_1 - 2a\tau_B - 6b\tau_A - 8a\tau_A - 4ar_2 + 4Aa + 3Ab + Ba), \\
T_{AB}^{C4} &= \frac{1}{12(a+b)}(2b\tau_A - 6a\tau_B - 4b\tau_B + 6ar_1 + 4br_2 + 4br_1 - Ab + 3Ba + 2Bb), \\
T_{BA}^{C4} &= -\frac{1}{12(a+b)}(4a\tau_A - 2a\tau_B + 6b\tau_A - 4ar_2 + 2ar_1 - 2Aa - 3Ab + Ba).
\end{aligned}$$

Although $x_{AB} > x_{BA}$ holds, the characteristics of this equilibrium are different from those of type-1 equilibrium with a single carrier. In this equilibrium, a change in τ_A or τ_B affects both x_{AB} and x_{BA}, which does not occur in type-1 equilibrium with a single carrier. In particular, we should note that a change in τ_A or τ_B could affect both x_{1AB} and x_{1BA} even though $x_{1AB} > x_{1BA}$ holds. The direct effect of an increase in τ_B (τ_A) is to decrease x_{1AB} (x_{1BA}) and x_{2AB} (x_{2BA}). The indirect effect is to decrease x_{2BA} (x_{2AB}) because $x_{2AB} = x_{2BA}$, which in turn increases x_{1BA} (x_{1AB}), because x_{1BA} (x_{1AB}) and x_{2BA} (x_{2AB}) are strategic substitutes. The decrease in x_{2BA} (x_{2AB}) dominates the increase in x_{1BA} (x_{1AB}) and hence x_{BA} (x_{AB}) falls. We should note that since an increase in τ_B (τ_A) decreases x_{BA} (x_{AB}) as well as x_{AB} (x_{BA}), both the decrease in the profits of firm A (firm B) and the increase in the profits of firm B (firm A) are mitigated.

It is straightforward that the characteristics of this equilibrium (i.e., type-4 equilibrium) and those of type-5 equilibrium are similar. Thus, the following proposition is obtained.

Proposition 14 *Suppose $r_1 < r_2$. $x_{AB} > x_{BA}$ holds if $2a(r_1 - 2r_2) \leq \Lambda < -2ar_1$ and $x_{AB} < x_{BA}$ holds if $2br_1 < \Lambda \leq 2b(2r_2 - r_1)$. In these cases, although $x_{AB} = x_{BA}$ does not hold, a tariff imposed by either country decreases both x_{AB} and x_{BA}. As a result, the protection effect of a tariff is mitigated.*

In section 3, we showed that a tariff set by country B (country A) could harm firm B (firm A) when $x_{AB} = x_{BA}$ holds. Here we show that a tariff set by country B (country A) could harm firm B (firm A) even when $x_{AB} = x_{BA}$ does not hold. This is the case in which a tariff leads one of the carriers to exit from the market. To show this, we assume that country A introduces a tariff with $x_{1AB} > x_{1BA}$, $x_{2AB} > x_{2BA}$, $f_1 < f_2$ and $\tau_B = 0$. Suppose that a tariff in country A results in $\Pi_{T2} < 0$ and firm T_2 exits. Then firm T_1 becomes the monopolist with $\tau_A > 0$.

Under free trade, both firms T_1 and T_2 operate. Thus, the profits of firm A with $x_{1AB} > x_{1BA}$ and $x_{2AB} > x_{2BA}$ are given by

$$\Pi_A^{C1} = \frac{4}{81b}(B - r_1 - r_2)^2 + \frac{49A^2}{324a}.$$

With $\tau_A > 0$, the equilibrium becomes type-1 of our basic model. The profits of firm A with $\tau_A > 0$ are

$$\Pi_A^{\tau 1} = \frac{1}{36b}(B - 2r_1)^2 + \frac{1}{144a}(5A + 2\tau_A)^2.$$

Thus, we have

$$\Pi_A^{C1} - \Pi_A^{\tau 1} = -\frac{1}{1296ab}(29bA^2 + 180bA\tau_A - 28aB^2 - 16aBr_1 + 128aBr_2 + 36b\tau_A^2 + 80ar_1^2 - 128ar_1r_2 - 64ar_2^2),$$

which is more likely to be positive when B is large relative to A and/or b is small relative to a.[34]

Therefore, we obtain

Proposition 15 *If demand is much larger in country B (country A) than in country A (country B), then a tariff in country A (country B) may lead one of the transport firms to exit and harm firm A (firm B).*

[34] This is consistent with $x_{1AB} > x_{1BA}$, $x_{2AB} > x_{2BA}$.

7 Conclusion

This paper studied the effects of trade policies given endogenous transport costs. We developed a simple model that captures key stylized facts about international transportation: market power by transport firms and asymmetric transport costs across countries. Transport firms need to commit to a shipping capacity sufficient for a round trip. Given such "backhaul problems," we demonstrated how the price of shipping from one country to another, as well as the price of the return trip, is determined and explored the effects of tariffs, import quotas and production subsidies.

Tariffs and import quotas, which benefit domestic firms and harm foreign firms in a standard international oligopoly model, can harm domestic firms and benefit foreign firms once transport costs are endogenized. It is also possible that both domestic and foreign firms gain from tariffs and import quotas. Moreover, production subsidies could benefit both domestic and foreign firms. These unconventional results occur because transport firms determine a shipping capacity and manufacturing firms cannot export beyond the shipping capacity.

The effects of tariffs and those of import quotas are similar. However, once we consider firms' option to conduct FDI, they are no longer similar. A tighter import quota and a higher tariff rate both induce the transport firm to charge lower freight rates. However, because of their differential impacts on the transport firm's capacity choice, these trade restrictions have different impacts on domestic firms and consumers.

The extensions of our basic model revealed that non-conventional impacts of trade policies also follow in richer contexts. We also obtained additional results in the extensions. In the presence of multiple goods, a tariff affects not only that sector but also other independent sectors. Furthermore, the effects of a tariff depend on whether a full load is realized in both directions. In the presence of multiple carriers, even if the shipping volumes are not balanced between the two directions, a tariff could decrease the shipping volumes of both directions.

In concluding this paper, three final remarks are in order. First, we focused on trade policies on the goods sector. We can easily explore policies on the transport sector. Obviously, a subsidy on shipping capacity encourages trade in goods, but the effect depends on whether a full load is realized in both directions. With a full load in both directions, the subsidy increases the shipping volume in both directions. Without a full load, however, the subsidy increases the shipping volume only in the direction with a full load. If a foreign country will not lower tariffs, the domestic country can increase its exports by providing export subsidies. However, export subsidies are prohibited by the WTO. As long as a full load is realized from the domestic country to the foreign country, the domestic country can increase its exports by providing subsidies to carriers. The subsidies may also increase domestic imports (i.e., foreign exports).

Second, we introduced the transport sector into a standard international oligopoly model. Even if the goods sectors are not oligopolistic, the basic feature of our model would not change. That is, if a full load is realized in both directions, domestic import restrictions decrease domestic exports as well as domestic imports. If the goods sectors are perfectly competitive, for example, domestic import restrictions increase the output and the producer surplus of the import sectors and decrease those of the export sectors.

Lastly, to explore the effects of various policies, we constructed a simple international duopoly model with a single carrier and a single good. Then we extended the basic model by introducing multiple carriers and multiple goods. A promising direction for future research is to investigate multiple countries.[35]

Appendix

In this appendix, we show Lemma 1. From (6), we have

$$T_{AB} = (\frac{1}{2}B - \tau_B) - \frac{3}{2}bx_{AB} \equiv \Omega_B - \mu_B x_{AB}, T_{BA} = (\frac{1}{2}A - \tau_A) - \frac{3}{2}ax_{BA} \equiv \Omega_A - \mu_A x_B.$$

The two transport firms T_1 and T_2 compete in a Cournot fashion with these inverse demands.

There are nine possible combinations: $x_{1AB} > x_{1BA}$ and $x_{2AB} > x_{2BA}$; $x_{1AB} > x_{1BA}$ and $x_{2AB} = x_{2BA}$; $x_{1AB} > x_{1BA}$ and $x_{2AB} < x_{2BA}$; $x_{1AB} = x_{1BA}$ and $x_{2AB} > x_{2BA}$; $x_{1AB} = x_{1BA}$ and $x_{2AB} = x_{2BA}$; $x_{1AB} = x_{1BA}$ and $x_{2AB} < x_{2BA}$; $x_{1AB} < x_{1BA}$ and $x_{2AB} > x_{2BA}$; $x_{1AB} < x_{1BA}$ and $x_{2AB} = x_{2BA}$; and $x_{1AB} < x_{1BA}$ and $x_{2AB} < x_{2BA}$. As shown below, however, only five combinations occur in equilibrium.

We start by characterizing each equilibrium. First, suppose that $x_{1AB} > x_{1BA}$ and $x_{2AB} > x_{2BA}$ hold in equilibrium. Then the profits of firms T_1 and T_2 are given by

$$\Pi_1 = T_{AB}x_{1AB} + T_{BA}x_{1BA} - r_1 x_{1AB} - f_1, \Pi_2 = T_{AB}x_{2AB} + T_{BA}x_{2BA} - r_2 x_{2AB} - f_2.$$

In equilibrium, we have

$$x_{1AB}^{C1} = \frac{1}{3\mu_B}\left(\Omega_B - 2r_1 + r_2\right), x_{2AB} = \frac{1}{3\mu_B}\left(\Omega_B - 2r_2 + r_1\right), x_{1BA}^{C1} = x_{2BA}^{C1} = \frac{1}{3\mu_A}\Omega_A.$$

[35] See Higashida (2015) for a three-country shipping model with capacity choice by transport firms with market power.

Second, suppose that $x_{1AB} = x_{1BA}$ and $x_{2AB} = x_{2BA}$ hold in equilibrium. Then

$$\Pi_1 = (T_{AB} + T_{BA})x_{1AB} - r_1 x_{1AB} - f_1, \Pi_2 = (T_{AB} + T_{BA})x_{2AB} - r_2 x_{2AB} - f_2.$$

In equilibrium, we have

$$\begin{aligned} x_{1AB}^{C2} &= x_{1BA}^{C2} = \frac{1}{3(\mu_A + \mu_B)} (\Omega_A + \Omega_B - 2r_1 + r_2), \\ x_{2AB}^{C2} &= x_{2BA}^{C2} = \frac{1}{3(\mu_A + \mu_B)} (\Omega_A + \Omega_B + r_1 - 2r_2). \end{aligned}$$

Third, suppose that $x_{1AB} < x_{1BA}$ and $x_{2AB} < x_{2BA}$ hold in equilibrium. Then the profits of firms T_1 and T_2 are given by

$$\Pi_1 = T_{AB}x_{1AB} + T_{BA}x_{1BA} - r_1 x_{1AB} - f_1, \Pi_2 = T_{AB}x_{2AB} + T_{BA}x_{2BA} - r_2 x_{2AB} - f_2.$$

In equilibrium, we have

$$x_{1AB}^{C3} = x_{2AB}^{C3} = \frac{1}{3\mu_B}\Omega_B, x_{1BA}^{C3} = \frac{1}{3\mu_A}(\Omega_A - 2r_1 + r_2), x_{2BA}^{C3} = \frac{1}{3\mu_A}(\Omega_A + r_1 - 2r_2).$$

Fourth, suppose that $x_{1AB} > x_{1BA}$ and $x_{2AB} = x_{2BA}$ hold in equilibrium. Then

$$\Pi_1 = T_{AB}x_{1AB} + T_{BA}x_{1BA} - r_1 x_{1AB} - f_1, , \Pi_2 = (T_{AB} + T_{BA})x_{2AB} - r_2 x_{2AB} - f_2.$$

In equilibrium, we have

$$\begin{aligned} x_{1AB}^{C4} &= -\frac{1}{6\mu_B(\mu_A + \mu_B)} (\Omega_A\mu_B - 3\Omega_B\mu_A - 2\Omega_B\mu_B + 3\mu_A r_1 - 2\mu_B r_2 + 4\mu_B r_1), \\ x_{1BA}^{C4} &= \frac{1}{6\mu_A(\mu_A + \mu_B)} (2\Omega_A\mu_A + 3\Omega_A\mu_B - \Omega_B\mu_A + 2\mu_A r_2 - \mu_A r_1), \\ x_{2AB}^{C4} &= x_{2BA}^{C4} = \frac{1}{3(\mu_A + \mu_B)} (\Omega_A + \Omega_B - 2r_2 + r_1). \end{aligned}$$

Fifth, suppose that $x_{1AB} < x_{1BA}$ and $x_{2AB} = x_{2BA}$ hold in equilibrium. Then

$$\Pi_1 = T_{AB}x_{1AB} + T_{BA}x_{1BA} - r_1 x_{1AB} - f_1, , \Pi_2 = (T_{AB} + T_{BA})x_{2AB} - r_2 x_{2AB} - f_2.$$

In equilibrium, we have

$$\begin{aligned}
x_{1AB}^{C5} &= \frac{1}{6\mu_B(\mu_A+\mu_B)}\left(3\Omega_B\mu_A - \Omega_A\mu_B + 2\Omega_B\mu_B - \mu_B r_1 + 2\mu_B r_2\right), \\
x_{1BA}^{C5} &= -\frac{1}{6\mu_A(\mu_A+\mu_B)}\left(\Omega_B\mu_A - 3\Omega_A\mu_B - 2\Omega_A\mu_A + 4\mu_A r_1 - 2\mu_A r_2 + 3\mu_B r_1\right), \\
x_{2AB}^{C5} &= x_{2BA} = \frac{1}{3(\mu_A+\mu_B)}\left(\Omega_A + \Omega_B - 2r_2 + r_1\right).
\end{aligned}$$

Sixth, suppose that $x_{1AB} = x_{1BA}$ and $x_{2AB} > x_{2BA}$ hold in equilibrium. Then

$$\Pi_1 = (T_{AB} + T_{BA})x_{1AB} - r_1 x_{1AB} - f_1, \Pi_2 = T_{AB}x_{2AB} + T_{BA}x_{2BA} - r_2 x_{2AB} - f_2.$$

In equilibrium, we have

$$\begin{aligned}
x_{1AB}^{C6} &= x_{1BA}^{C6} = \frac{1}{3(\mu_A+\mu_B)}\left(\Omega_A + \Omega_B - 2r_1 + r_2\right), \\
x_{2AB}^{C6} &= -\frac{1}{6\mu_B(\mu_A+\mu_B)}\left(\Omega_A\mu_B - 3\Omega_B\mu_A - 2\Omega_B\mu_B + 3\mu_A r_2 - 2\mu_B r_1 + 4\mu_B r_2\right), \\
x_{2BA}^{C6} &= \frac{1}{6\mu_A(\mu_A+\mu_B)}\left(2\Omega_A\mu_A + 3\Omega_A\mu_B - \Omega_B\mu_A + 2\mu_A r_1 - \mu_A r_2\right).
\end{aligned}$$

Seventh, suppose that $x_{1AB} = x_{1BA}$ and $x_{2AB} < x_{2BA}$ hold in equilibrium. Then

$$\Pi_1 = (T_{AB} + T_{BA})x_{1AB} - r_1 x_{1AB} - f_1, \Pi_2 = T_{AB}x_{2AB} + T_{BA}x_{2BA} - r_2 x_{2AB} - f_2.$$

In equilibrium, we have

$$\begin{aligned}
x_{1AB}^{C7} &= x_{1BA}^{C7} = \frac{1}{3(\mu_A+\mu_B)}\left(\Omega_A + \Omega_B - 2r_1 + r_2\right), \\
x_{2AB}^{C7} &= \frac{1}{6\mu_B(\mu_A+\mu_B)}\left(3\Omega_B\mu_A - \Omega_A\mu_B + 2\Omega_B\mu_B + 2\mu_B r_1 - \mu_B r_2\right), \\
x_{2BA}^{C7} &= -\frac{1}{6\mu_A(\mu_A+\mu_B)}\left(\Omega_B\mu_A - 3\Omega_A\mu_B - 2\Omega_A\mu_A - 2\mu_A r_1 + 4\mu_A r_2 + 3\mu_B r_2\right).
\end{aligned}$$

It should be pointed out that the combination of $x_{1AB} > x_{1BA}$ and $x_{2AB} < x_{2BA}$ never arises in equilibrium. To show this, suppose in contradiction that the combination arises in equilibrium. Then we should have

$$\begin{aligned}
x_{1AB} &= \frac{1}{3\mu_B}\left(\Omega_B - 2r_1\right), x_{2AB} = \frac{1}{3\mu_B}\left(\Omega_B + r_1\right), \\
x_{1BA} &= \frac{1}{3\mu_A}\left(\Omega_A + r_2\right), x_{2BA} = \frac{1}{3\mu_A}\left(\Omega_A - 2r_2\right).
\end{aligned}$$

We need $x_{1AB} - x_{1BA} = -\frac{1}{3\mu_A\mu_B}(\Omega_A\mu_B - \Omega_B\mu_A + 2\mu_A r_1 + \mu_B r_2) > 0$, which implies $\Omega_A\mu_B < \Omega_B\mu_A$. However, we also need $x_{2BA} - x_{2AB} = -\frac{1}{3\mu_A\mu_B}(\Omega_B\mu_A - \Omega_A\mu_B + \mu_A r_1 + 2\mu_B r_2) > 0$, which implies $\Omega_A\mu_B > \Omega_B\mu_A$. Thus, the combination of $x_{1AB} > x_{1BA}$ and $x_{2AB} < x_{2BA}$ never arises. Similarly, the combination of $x_{1AB} < x_{1BA}$ and $x_{2AB} > x_{2BA}$ never arises.

We next examine the conditions under which the above equilibria are actually realized as Nash equilibria.

The condition under which $x_{2AB} > x_{2BA}$ arises given $x_{1AB} > x_{1BA}$ is that $x_{2AB}(= \frac{1}{3\mu_B}(\Omega_B - 2r_2 + r_1)) > x_{2BA}(= \frac{1}{3\mu_A}\Omega_A)$, which becomes $\Omega_A\mu_B - \Omega_B\mu_A - \mu_A r_1 + 2\mu_A r_2 < 0$. This condition is equivalent to $\Lambda\,(\equiv 2a\tau_B - 2b\tau_A + Ab - Ba) < 2a(r_1 - 2r_2)$. Now the condition under which $x_{1AB} > x_{1BA}$ arises given $x_{2AB} > x_{2BA}$ is that $x_{1AB}(= \frac{1}{3\mu_B}(\Omega_B - 2r_1 + r_2)) > x_{1BA}(= \frac{1}{3\mu_A}\Omega_A)$, which becomes $\Omega_A\mu_B - \Omega_B\mu_A + 2\mu_A r_1 - \mu_A r_2 < 0$. This condition is equivalent to $\Lambda < 2a(r_2 - 2r_1)$. Since $2a(r_1 - 2r_2) < 2a(r_2 - 2r_1)$ with $r_1 < r_2$, the combination of $x_{2AB} > x_{2BA}$ and $x_{1AB} > x_{1BA}$ arises as a Nash equilibrium if $\Lambda < 2a(r_1 - 2r_2)$.

The condition under which $x_{2AB} = x_{2BA}$ arises given $x_{1AB} = x_{1BA}$ is that neither $x_{2AB} > x_{2BA}$ nor $x_{2AB} < x_{2BA}$ holds given $x_{1AB} = x_{1BA}$. Suppose $x_{2AB} > x_{2BA}$ given $x_{1AB} = x_{1BA}$. Then

$$x_{2AB}\left(= -\frac{1}{6\mu_B(\mu_A+\mu_B)}(\Omega_A\mu_B - 3\Omega_B\mu_A - 2\Omega_B\mu_B + 3\mu_A r_2 - 2\mu_B r_1 + 4\mu_B r_2)\right)$$
$$> x_{2BA}\left(= -\frac{1}{6\mu_A(\mu_A+\mu_B)}(\Omega_B\mu_A - 3\Omega_A\mu_B - 2\Omega_A\mu_A - 2\mu_A r_1 + 4\mu_A r_2 + 3\mu_B r_2)\right).$$

Thus, the condition under which $x_{2AB} > x_{2BA}$ does not hold given $x_{1AB} = x_{1BA}$ is $x_{2AB} - x_{2BA} \leq 0$, i.e., $\Lambda \geq -2ar_2$. Suppose $_{2AB} < x_{2BA}$ given $x_{1AB} = x_{1BA}$. Then

$$x_{2AB}\left(= \frac{1}{6\mu_B(\mu_A+\mu_B)}(3\Omega_B\mu_A - \Omega_A\mu_B + 2\Omega_B\mu_B + 2\mu_B r_1 - \mu_B r_2)\right)$$
$$< x_{2BA}\left(= \frac{1}{6\mu_A(\mu_A+\mu_B)}(2\Omega_A\mu_A + 3\Omega_A\mu_B - \Omega_B\mu_A + 2\mu_A r_1 - \mu_A r_2)\right).$$

Thus, the condition under which $x_{2AB} < x_{2BA}$ does not hold given $x_{1AB} = x_{1BA}$ is $x_{2AB} - x_{2BA} \geq 0$, i.e., $\Lambda \leq 2br_2$. The condition under which $x_{1AB} = x_{1BA}$ arises given $x_{2AB} = x_{2BA}$ is that neither $x_{1AB} > x_{1BA}$ nor $x_{1AB} < x_{1BA}$ holds given $x_{2AB} = x_{2BA}$. Suppose $x_{1AB} > x_{1BA}$ given $x_{2AB} = x_{2BA}$. Then

$$x_{1AB}\left(= -\frac{1}{6\mu_B(\mu_A+\mu_B)}(\Omega_A\mu_B - 3\Omega_B\mu_A - 2\Omega_B\mu_B + 3\mu_A r_1 - 2\mu_B r_2 + 4\mu_B r_1)\right)$$

$$> x_{1BA}^{C4}\left(=\frac{1}{6\mu_A\left(\mu_A+\mu_B\right)}\left(2\Omega_A\mu_A+3\Omega_A\mu_B-\Omega_B\mu_A+2\mu_Ar_2-\mu_Ar_1\right)\right).$$

Thus, the condition under which $x_{1AB} > x_{1BA}$ does not hold given $x_{2AB} = x_{2BA}$ is $x_{1AB} \leq x_{1BA}$, i.e., $\Lambda \geq -2ar_1$. Suppose $x_{1AB} < x_{1BA}$ given $x_{2AB} = x_{2BA}$. Then

$$x_{1BA}\left(=\frac{1}{6\mu_B\left(\mu_A+\mu_B\right)}\left(3\Omega_B\mu_A-\Omega_A\mu_B+2\Omega_B\mu_B-\mu_Br_1+2\mu_Br_2\right)\right)$$

$$\leq x_{1BA}\left(=-\frac{1}{6\mu_A\left(\mu_A+\mu_B\right)}\left(\Omega_B\mu_A-3\Omega_A\mu_B-2\Omega_A\mu_A+4\mu_Ar_1-2\mu_Ar_2+3\mu_Br_1\right)\right).$$

Thus, the condition under which $x_{1AB} < x_{1BA}$ does not hold given $x_{2AB} = x_{2BA}$ is $x_{1AB} \geq x_{1BA}$, i.e., $\Lambda \leq 2br_1$. Therefore, the combination of $x_{1AB} = x_{1BA}$ and $x_{2AB} = x_{2BA}$ arises as a Nash equilibrium if $-2ar_1 < \Lambda < 2br_1$.

The condition under which $x_{2AB} < x_{2BA}$ arises given $x_{1AB} < x_{1BA}$ is that $x_{2AB}(=\frac{1}{3\mu_B}\left(\Omega_B\right)) < x_{2BA}(=\frac{1}{3\mu_A}\left(\Omega_A+r_1-2r_2\right))$, which becomes $\Omega_A\mu_B-\Omega_B\mu_A+\mu_Br_1-2\mu_Br_2 > 0$. This condition is equivalent to $\Lambda > 2b(2r_2-r_1)$. Now the condition under which $x_{1AB} < x_{1BA}$ arises given $x_{2AB} < x_{2BA}$ is that $x_{1AB}(=\frac{1}{3\mu_B}\Omega_B) > x_{1BA}(=\frac{1}{3\mu_A}\left(\Omega_A-2r_1+r_2\right))$, which becomes $(\Omega_A\mu_B-\Omega_B\mu_A-2\mu_Br_1+\mu_Br_2) > 0$. This condition is equivalent to $\Lambda > 2b(2r_1-2r_2)$. Since $2b(2r_2-r_1) > 2b(2r_1-2r_2)$ with $r_1 < r_2$, the combination of $x_{2AB} > x_{2BA}$ and $x_{1AB} > x_{1BA}$ arises as a Nash equilibrium if $\Lambda > 2b(2r_2-r_1)$.

The condition under which $x_{2AB} = x_{2BA}$ arises given $x_{1AB} > x_{1BA}$ is that neither $x_{2AB} > x_{2BA}$ nor $x_{2AB} < x_{2BA}$ holds given $x_{1AB} > x_{1BA}$. Suppose $x_{2AB} > x_{2BA}$ holds given $x_{1AB} > x_{1BA}$. Then we have $x_{2AB}(=\frac{1}{3\mu_B}\left(\Omega_B-2r_2+r_1\right)) > x_{2BA}(=\frac{1}{3\mu_A}\left(\Omega_A\right))$. As pointed out above, the combination of $x_{2AB} < x_{2BA}$ and $x_{1AB} > x_{1BA}$ never occurs. Thus, the condition under which $x_{2AB} = x_{2BA}$ arises given $x_{1AB} > x_{1BA}$ is that $\frac{1}{3\mu_B}\left(\Omega_B-2r_2+r_1\right) < \frac{1}{3\mu_A}\Omega_A$ holds, that is, $(\Omega_A\mu_B-\Omega_B\mu_A-\mu_Ar_1+2\mu_Ar_2) > 0$ holds. Thus, the condition becomes $2a\left(r_1-2r_2\right) < \Lambda$. Now the condition under which $x_{1AB} > x_{1BA}$ arises given $x_{2AB} = x_{2BA}$ is that

$$x_{1AB}\left(=-\frac{1}{6\mu_B\left(\mu_A+\mu_B\right)}\left(\Omega_A\mu_B-3\Omega_B\mu_A-2\Omega_B\mu_B+3\mu_Ar_1-2\mu_Br_2+4\mu_Br_1\right)\right)$$

$$> x_{1BA}\left(=\frac{1}{6\mu_A\left(\mu_A+\mu_B\right)}\left(2\Omega_A\mu_A+3\Omega_A\mu_B-\Omega_B\mu_A+2\mu_Ar_2-\mu_Ar_1\right)\right),$$

which becomes $(\Omega_A\mu_B-\Omega_B\mu_A+\mu_Ar_1) < 0$. This condition is equivalent to $\Lambda < -2ar_1$.Thus, the combination of $x_{2AB} = x_{2BA}$ and $x_{1AB} > x_{1BA}$ arises as a Nash equilibrium if $2a\left(r_1-2r_2\right) < \Lambda < -2ar_1$.

The condition under which $x_{2AB} = x_{2BA}$ arises given $x_{1AB} < x_{1BA}$ is that neither $x_{2AB} >$

x_{2BA} nor $x_{2AB} < x_{2BA}$ holds given $x_{1AB} < x_{1BA}$. The combination of $x_{2AB} > x_{2BA}$ and $x_{1AB} < x_{1BA}$ never occurs. Suppose that $x_{2AB} < x_{2BA}$ holds given $x_{1AB} < x_{1BA}$. Then we have $x_{2AB}\left(= \frac{1}{3\mu_B}\Omega_B) < x_{2BA}(= \frac{1}{3\mu_A}\left(\Omega_A - 2r_2 + r_1\right)\right)$. Thus, the condition under which $x_{2AB} = x_{2BA}$ arises given $x_{1AB} < x_{1BA}$ is that $\frac{1}{3\mu_B}\Omega_B > \frac{1}{3\mu_A}\left(\Omega_A - 2r_2 + r_1\right)$ holds, that is, $(\Omega_A\mu_B - \Omega_B\mu_A + 2\mu_B r_2 - \mu_B r_1) < 0$ holds. Thus, the condition becomes $\Lambda < 2b(2r_2 - r_1)$. Now the condition under which $x_{1AB} < x_{1BA}$ arises given $x_{2AB} = x_{2BA}$ is that

$$x_{1AB}\left(= \frac{1}{6\mu_B\left(\mu_A + \mu_B\right)}\left(3\Omega_B\mu_A - \Omega_A\mu_B + 2\Omega_B\mu_B - \mu_B r_1 + 2\mu_B r_2\right)\right)$$

$$< x_{1BA}\left(= -\frac{1}{6\mu_A\left(\mu_A + \mu_B\right)}\left(\Omega_B\mu_A - 3\Omega_A\mu_B - 2\Omega_A\mu_A + 4\mu_A r_1 - 2\mu_A r_2 + 3\mu_B r_1\right)\right),$$

which becomes $(\Omega_B\mu_A - \Omega_A\mu_B + \mu_B r_1) < 0$. This condition is equivalent to $\Lambda > 2br_1$. Thus, the combination of $x_{2AB} = x_{2BA}$ and $x_{1AB} < x_{1BA}$ arises as a Nash equilibrium if $2br_1 < \Lambda < 2b(2r_2 - r_1)$. The condition under which $x_{1AB} = x_{1BA}$ arises given $x_{2AB} > x_{2BA}$ is that neither $x_{1AB} > x_{1BA}$ nor $x_{1AB} < x_{1BA}$ holds given $x_{2AB} > x_{2BA}$. Suppose $x_{2AB} > x_{2BA}$ holds given $x_{1AB} > x_{1BA}$. Then we have $x_{1AB}\left(= \frac{1}{3\mu_B}\left(\Omega_B - 2r_1 + r_2\right)\right) > x_{1BA}\left(= \frac{1}{3\mu_A}\Omega_A\right)$. The combination of $x_{1AB} < x_{1BA}$ and $x_{2AB} > x_{2BA}$ never occurs. Thus, the condition under which $x_{1AB} = x_{1BA}$ arises given $x_{2AB} > x_{2BA}$ is that $\frac{1}{3\mu_B}\left(\Omega_B - 2r_1 + r_2\right) < \frac{1}{3\mu_A}\Omega_A$ holds, that is, $(\Omega_A\mu_B - \Omega_B\mu_A - \mu_A r_2 + 2\mu_A r_1) > 0$ holds. Thus, the condition becomes $2a\left(r_2 - 2r_1\right) < \Lambda$. Now the condition under which $x_{2AB} > x_{2BA}$ arises given $x_{1AB} = x_{1BA}$ is that

$$x_{2AB}\left(= -\frac{1}{6\mu_B\left(\mu_A + \mu_B\right)}\left(\Omega_A\mu_B - 3\Omega_B\mu_A - 2\Omega_B\mu_B + 3\mu_A r_2 - 2\mu_B r_1 + 4\mu_B r_2\right)\right)$$

$$> x_{2BA}\left(= \frac{1}{6\mu_A\left(\mu_A + \mu_B\right)}\left(2\Omega_A\mu_A + 3\Omega_A\mu_B - \Omega_B\mu_A + 2\mu_A r_1 - \mu_A r_2\right)\right),$$

which becomes $(\Omega_A\mu_B - \Omega_B\mu_A + \mu_A r_2) < 0$. This condition is equivalent to $\Lambda < -2ar_2$. Since $-2ar_2 < 2a\left(r_2 - 2r_1\right)$ with $r_1 < r_2$, the combination of $x_{2AB} = x_{2BA}$ and $x_{1AB} > x_{1BA}$ never arises as a Nash equilibrium.

The condition under which $x_{1AB} = x_{1BA}$ arises given $x_{2AB} < x_{2BA}$ is that neither $x_{1AB} > x_{1BA}$ nor $x_{1AB} < x_{1BA}$ holds given $x_{2AB} < x_{2BA}$. The combination of $x_{1AB} > x_{1BA}$ and $x_{2AB} < x_{2BA}$ never occurs. Suppose $x_{1AB} < x_{1BA}$ holds given $x_{2AB} < x_{2BA}$. Then we have $x_{1AB}\left(= \frac{1}{3\mu_B}\Omega_B\right) < x_{1BA}\left(= \frac{1}{3\mu_A}\left(\Omega_A - 2r_1 + r_2\right)\right)$. Thus, the condition under which $x_{1AB} = x_{1BA}$ arises given $x_{2AB} < x_{2BA}$ is that $\frac{1}{3\mu_B}\Omega_B > \frac{1}{3\mu_A}\left(\Omega_A - 2r_1 + r_2\right)$ holds, that is, $(\Omega_A\mu_B - \Omega_B\mu_A - 2\mu_B r_1 + \mu_B r_2) < 0$ holds. Thus, the condition becomes $\Lambda < 2b\left(2r_1 - r_2\right)$.

Now the condition under which $x_{2AB} < x_{2BA}$ arises given $x_{1AB} = x_{1BA}$ is that

$$x_{2AB} \left(= \frac{1}{6\mu_B (\mu_A + \mu_B)} (3\Omega_B \mu_A - \Omega_A \mu_B + 2\Omega_B \mu_B + 2\mu_B r_1 - \mu_B r_2) \right)$$

$$< x_{2BA} \left(= -\frac{1}{6\mu_A (\mu_A + \mu_B)} (\Omega_B \mu_A - 3\Omega_A \mu_B - 2\Omega_A \mu_A - 2\mu_A r_1 + 4\mu_A r_2 + 3\mu_B r_2) \right),$$

which becomes $(\Omega_B \mu_A - \Omega_A \mu_B + \mu_B r_2) < 0$. This condition is equivalent to $\Lambda > 2br_2$. Since $2b(2r_1 - r_2) < 2br_2$ with $r_1 < r_2$, the combination of $x_{1AB} = x_{1BA}$ and $x_{2AB} > x_{2BA}$ never arises as a Nash equilibrium.

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Figure 1 (a): Tariffs set by country B

($x_{AB} > x_{BA}$ with free trade)

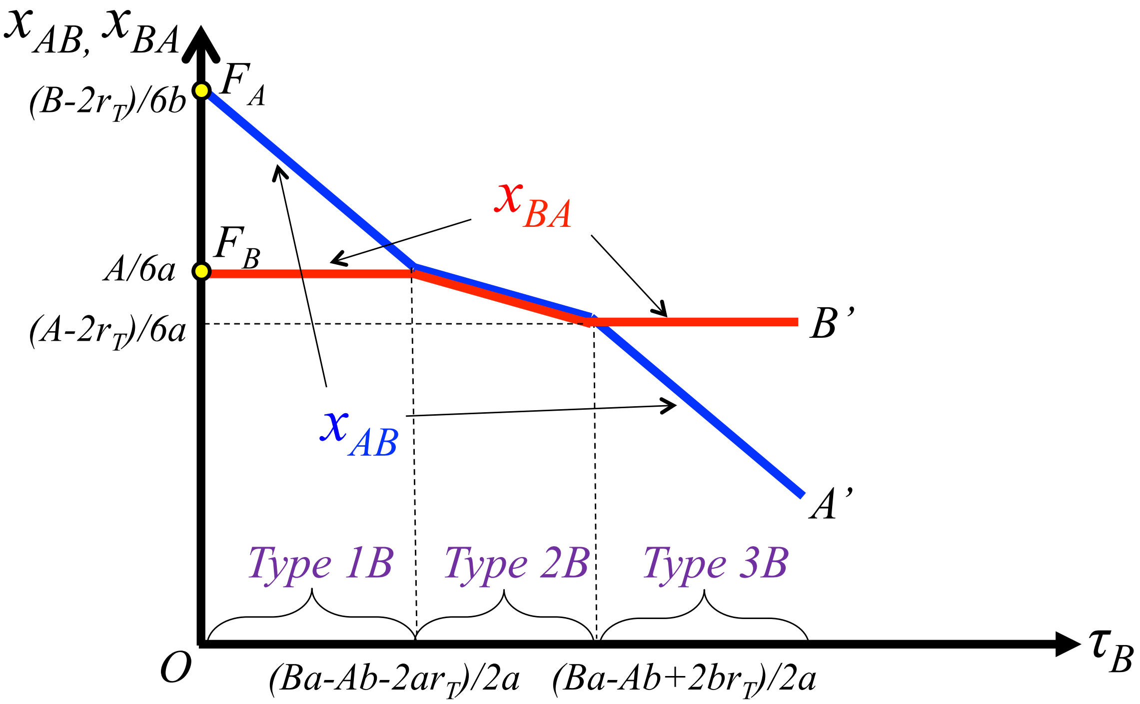

Figure 1 (b): Tariffs set by country *B*

($x_{AB} = x_{BA}$ with free trade)

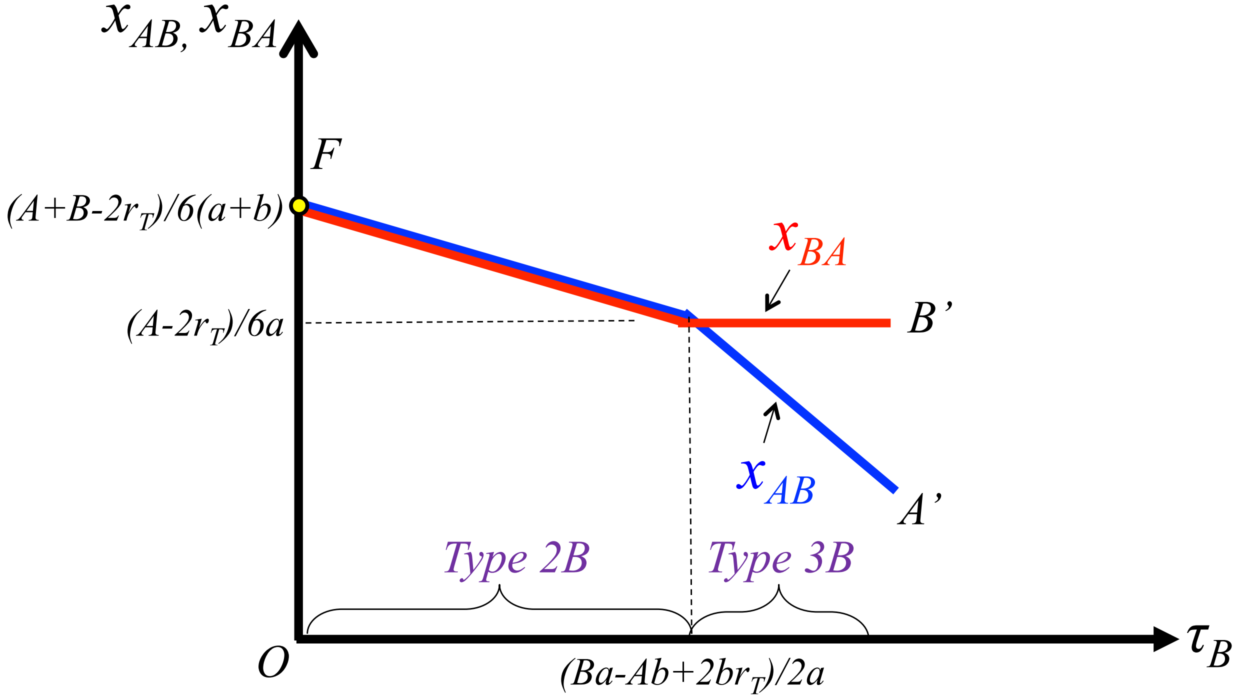

Figure 2 (a): Tariffs set by country A
($x_{AB} > x_{BA}$ with free trade)

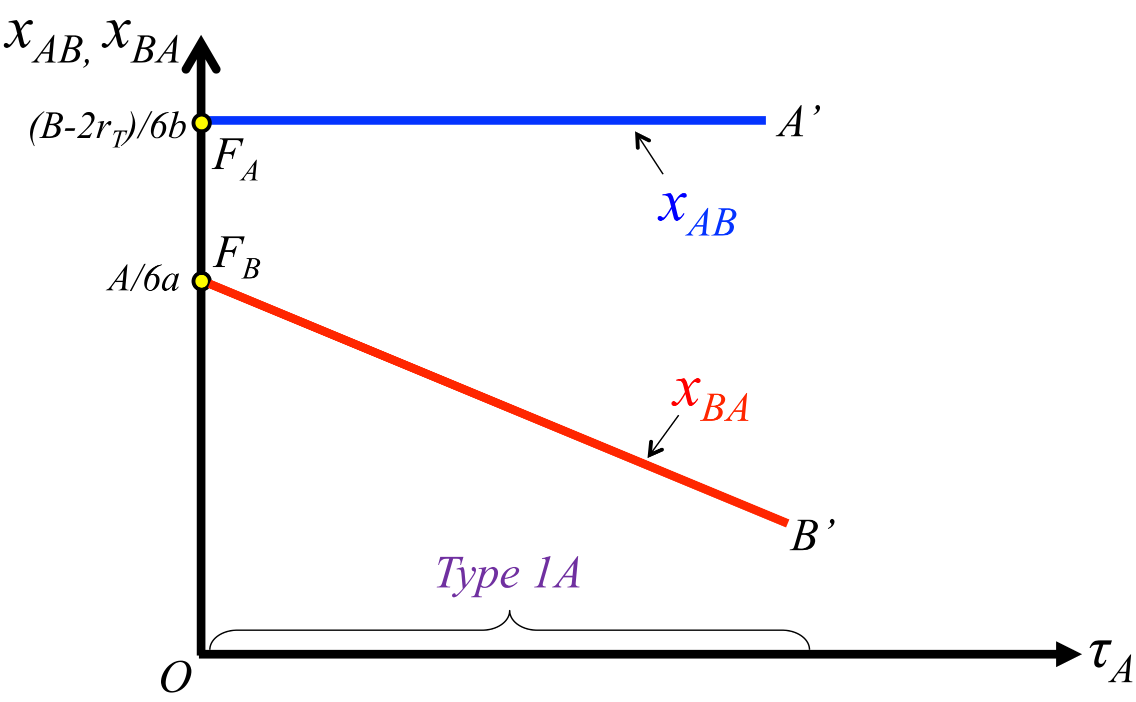

Figure 2 (b): Tariffs set by country *A*

($x_{AB} = x_{BA}$ with free trade)

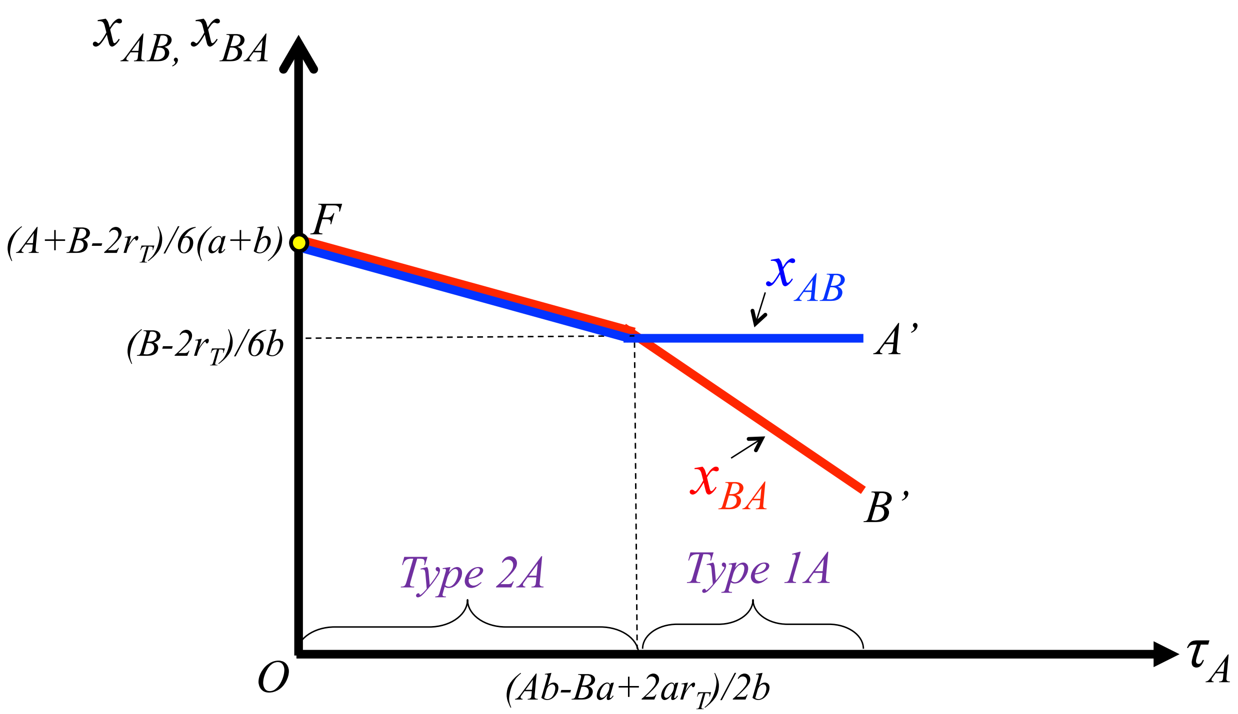

Figure 3 (a): Import quotas set by country *B*

($x_{AB} > x_{BA}$ with free trade)

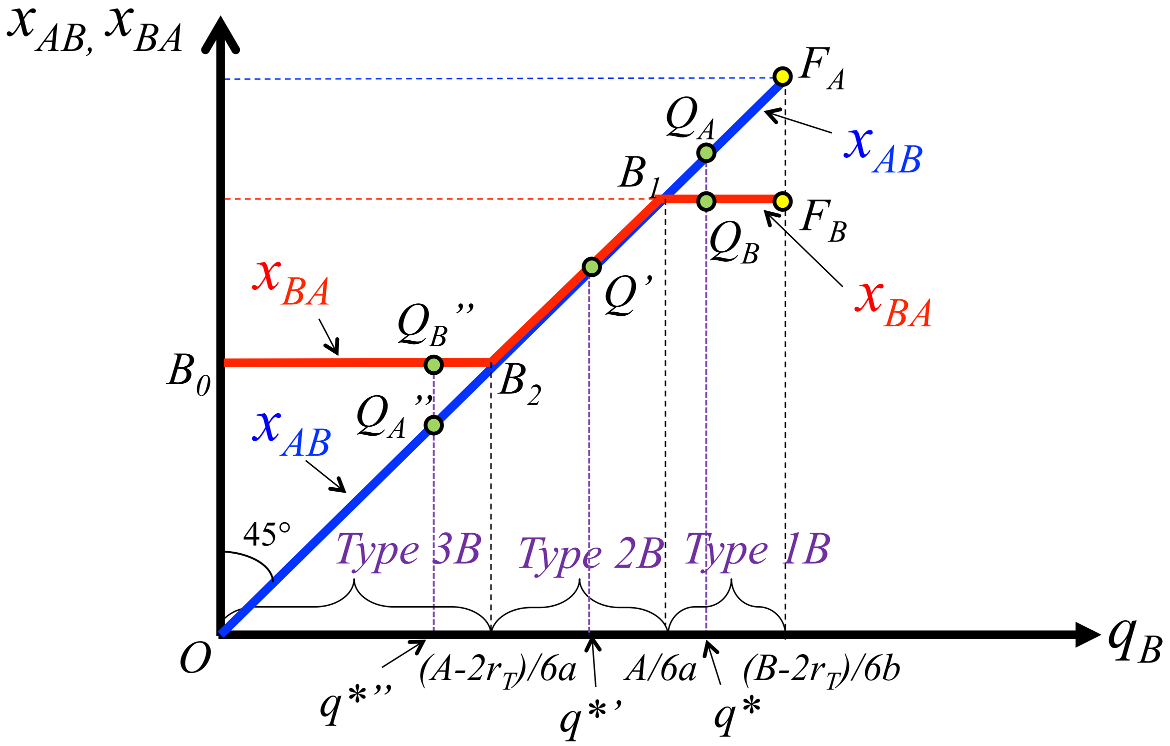

Figure 3 (b): Import quotas set by country *B*

($x_{AB} = x_{BA}$ with free trade)

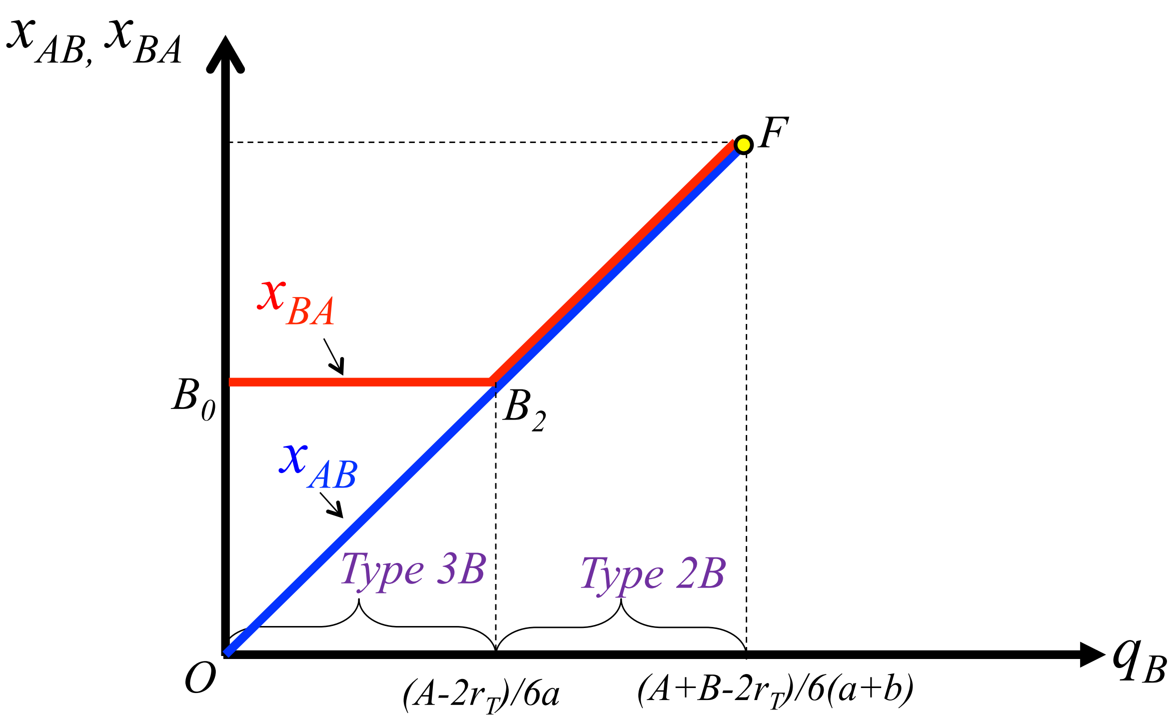

Figure 4 (a): Import quotas set by country A
($x_{AB} > x_{BA}$ with free trade)

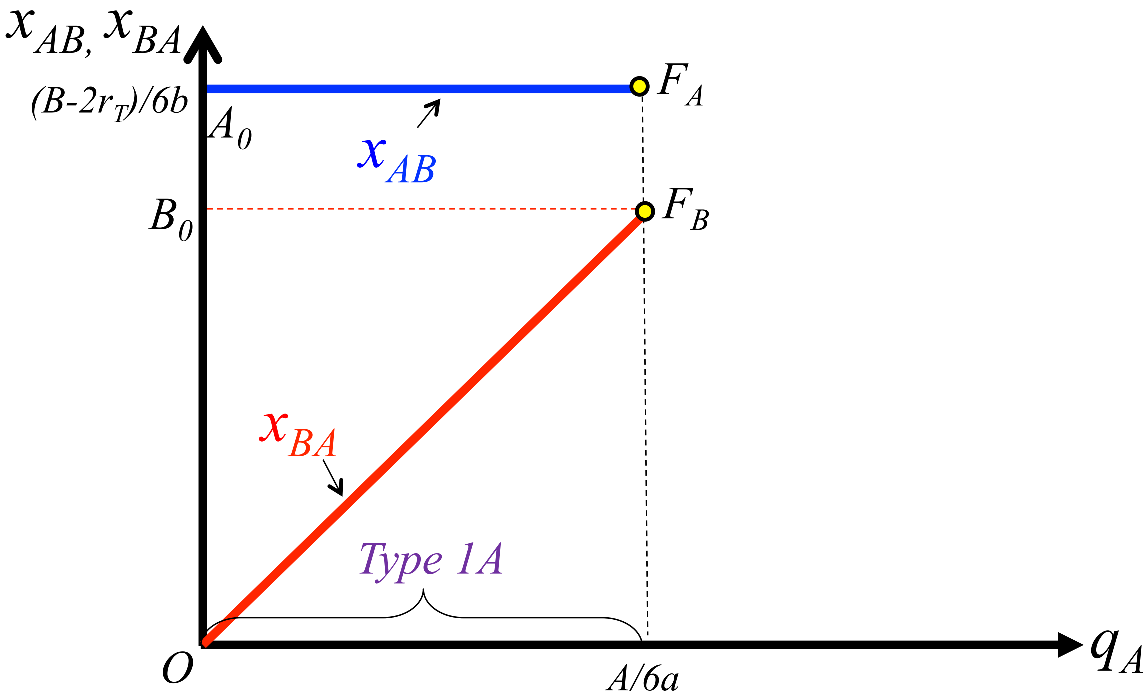

Figure 4 (b): Import quotas set by country *A*

($x_{AB} = x_{BA}$ with free trade)

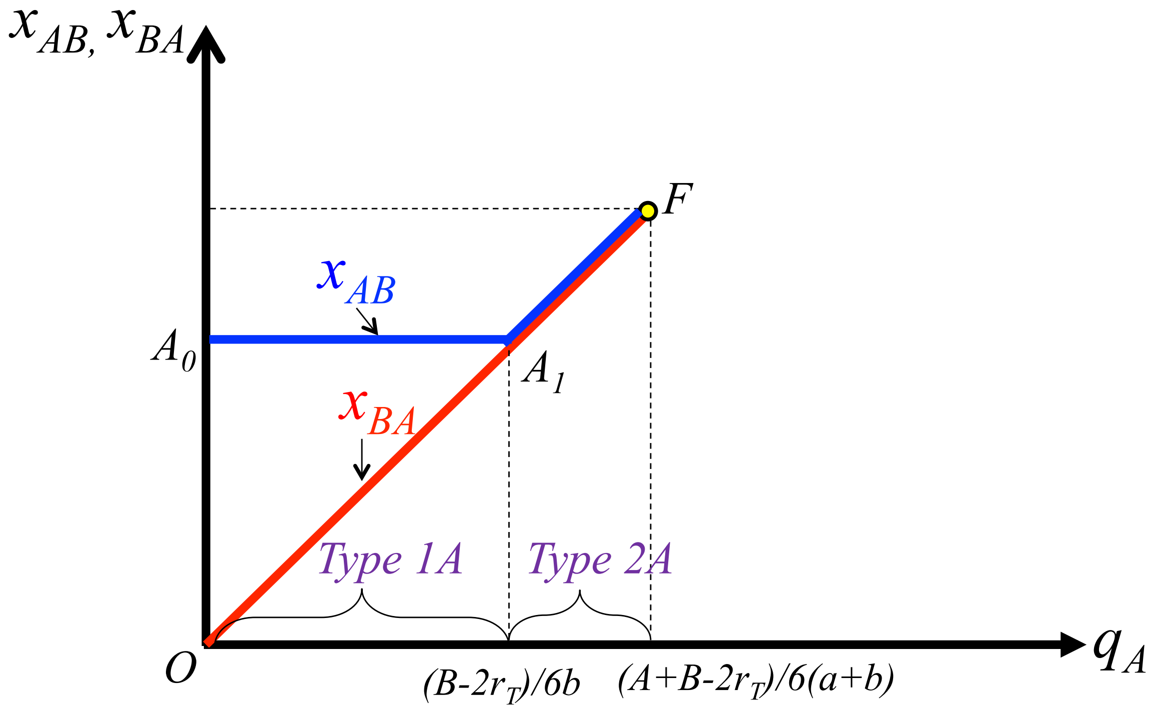

Figure 5: Tariffs set by country *B* with FDI
($x_{AB} > x_{BA}$ with free trade)

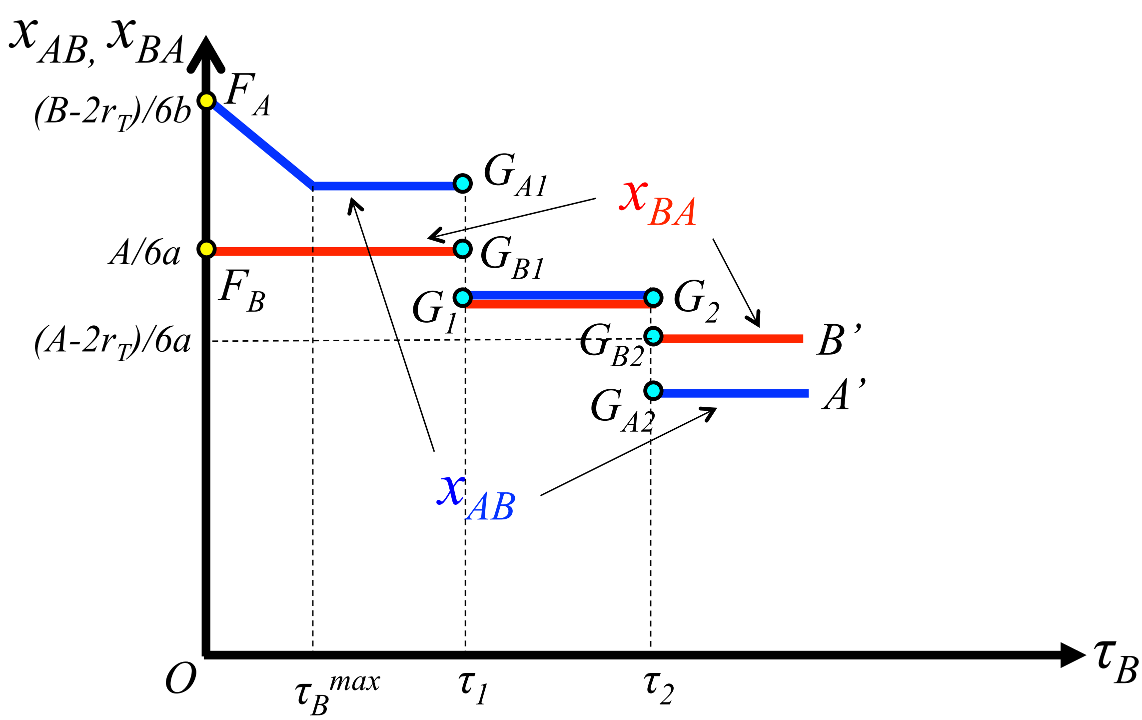

Figure 6: Import quotas set by country *B* with FDI

($x_{AB} > x_{BA}$ with free trade)

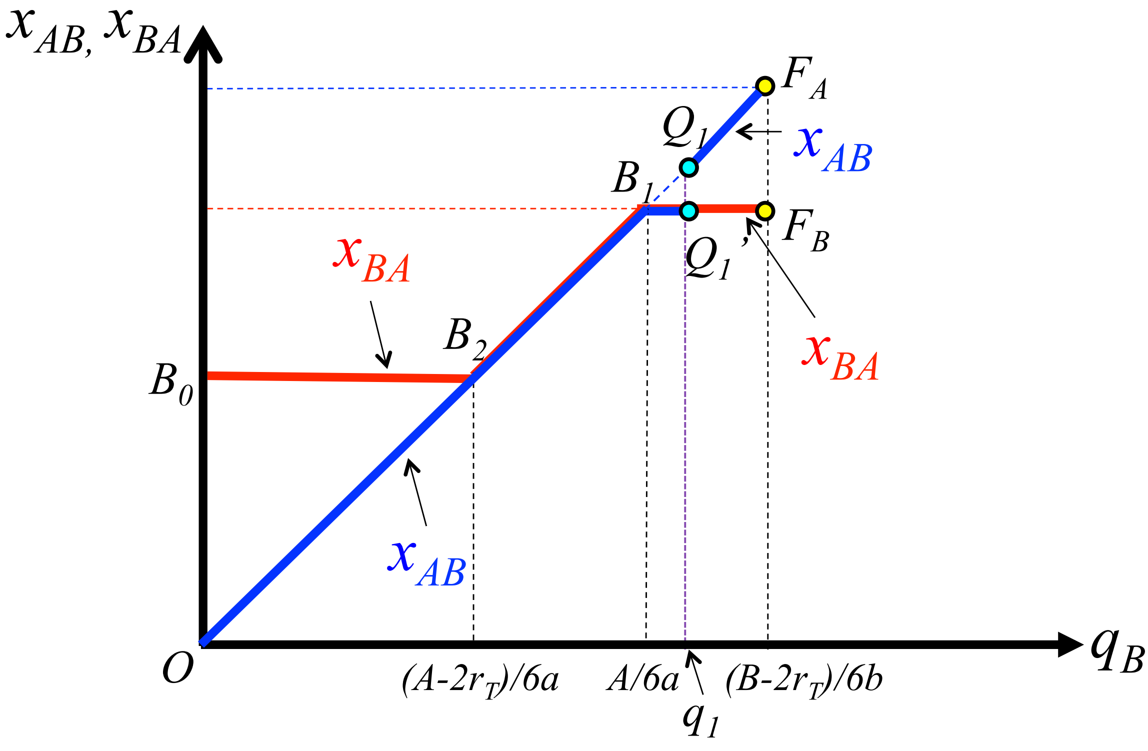

Figure 7: Multiple transport firms
(with $r_1 < r_2$)

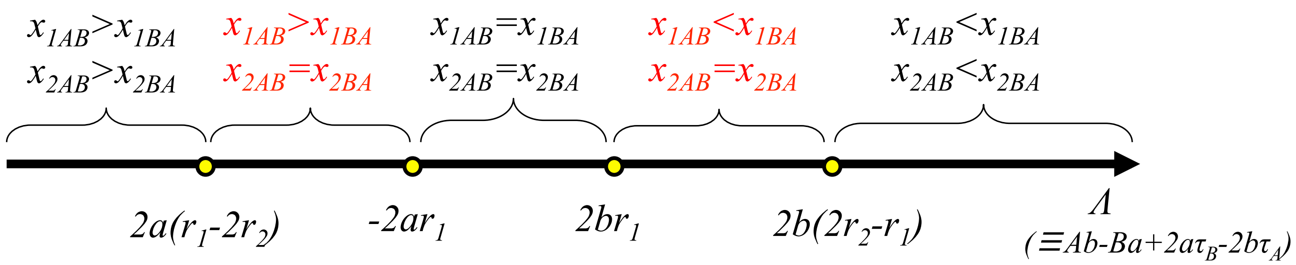

Table 1: Effects of tariffs on country *B*'s welfare

	Welfare with firm *T*		Welfare without firm T	
	Without a full load	With a full load	Without a full load	With a full load
Country *B*'s tariff	+	?	+	+
Country *A*'s tariff	-	-	-	?

Table 2: Effects of $\tau_{xB} \uparrow$ on freight rates and shipping without price discrimination

	Without a full load	With a full load
ΔT_{AB}	-	-
Δx_{AB}	-	-
Δz_{AB}	+	+
ΔT_{BA}	0	+
Δx_{BA}	0	-

Table 3: Effects of $\tau_{xB} \uparrow$ on freight rates and shipping with price discrimination

	Without a full load		With a full load
	($\phi = 0$)	($\phi \neq 0$)	
ΔT_{AB}	-	-	-
Δx_{AB}	-	-	-
$\Delta \Gamma_{AB}$	0	+	-
Δz_{AB}	0	-	+
ΔT_{BA}	0	0	+
Δx_{BA}	0	0	-