Backfiring with backhaul problems*

Trade and Industrial Policies with Endogenous Transport Costs

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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 economics effects of trade policies. Transport firms need to commit to a shipping capacity sufficient for a round trip. With imbalance in shipping volume in two directions, the "backhaul problem" could arise. Because of the 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.

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1 Introduction

The recent literature on international trade documents the important role of transportation 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 transportation 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 transportation costs, along with underlying transport sectors, to trade theory in an explicit manner.

Though trade theory has incorporated transportation costs for a long time, its treatment tends to be ad hoc. The standard way to incorporate transportation 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 the transportation costs are exogenous and symmetric across countries. However, several trade facts indicate that such assumptions are not ideal when studying the impacts of transportation 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 various modes, maritime (sea) transport is the most dominant.[2] Liner shipping, which accounts for about two-thirds of the U.S. waterborn foreign trade in value (Fink et al., 2002), is oligopolistic. The top five firms account for more than 45% of the global liner fleet capacity.[3] The liner shipping firms form "conferences," where they agree on the freight rates

[1] Anderson and van Wincoop (2004) estimates 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 accounts for more than 75% in volume (46% in value) of the 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 Alphaliner Top 100, `www.alphaliner.com/top100/`.

to be charged on any given route.[4] An empirical investigation by Hummels et al. (2009) finds 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 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 transportation sector, with exogenously fixed transport costs, may be altered once we consider the markets for transportation explicitly by taking into account the transportation firms' market power in influencing the shipping costs.[6]

Trade costs exhibit asymmetry in several dimensions. First, developing countries pay substantially higher transportation costs than developed nations (Hummels et al., 2009). Second, depending on the direction of shipments, the freight charges differ on the same route. For example, the market average freight rates for shipping from Asia to the Unite 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 the iceberg transportation costs in the standard trade theory.

Such asymmetry of transport costs may have a large economic consequence. 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

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

[5]Regulations may also be responsible for enhancing the 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 Act's impact on the U.S. ocean shipping costs.

[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 the freight costs exhibit asymmetry.

constrained by the capacity (e.g., the number of ships) of each transportation firm, and hence the 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.

Several recent studies on trade theory apply models with an explicit transportation sector. 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 regions are determined endogenously, subject to backhaul problems. They 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 exports of two countries are, the more 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). They both find that imbalance of transportation costs between two regions tends to induce dispersion of economic activities across regions. Abe et al. (2014) focuses 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.

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

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

of departure is in investigating how the effects of trade policies change once the transport sector and its decision making are explicitly considered. Specifically, 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 the 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 endogenously, where the backhaul problem is 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 on the effects of trade policies based on standard trade models. In particular, countries' 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 the transport firm's endogenous response to trade policy. The transport firm with market power makes decisions on two margins: the freight rate to be charged for each direction as well as the capacity for transport. With changes in trade

[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.

restrictions, the transport firm makes adjustments only in the freight rates, or also in the capacity, depending on the stringency of the trade policy.

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

In our basic model, the transport firm is a monopolistic carrier and two manufacturing firms produce a homogeneous good. Then, we 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 some more results. 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 what follows, Section 2 describes our trade model with an endogenous transport sector. Section 3 studies the impacts of import quotas and tariffs on the trading firms' profits and the equilibrium transport costs. We provide extensions of our analysis when exporting firms has 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 transportation sector

There are two countries A and B. There are a single 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.

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

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

$$\begin{aligned} P_A &= A - aX_A, \\ P_B &= B - bX_B. \end{aligned}$$

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

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

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

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 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:

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

[11] With 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 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.

We will use 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 $x_{AB} \geq x_{BA}$ without loss of generality. Then we have

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

Differentiating this equation with respect to T_{AB} and T_{BA} and setting them equal to zero, we obtain

$$\begin{aligned}\frac{\partial \Pi_T}{\partial T_{AB}} &= \frac{B + c_B - 2(c_A + T_{AB})}{3b} - \frac{2T_{AB}}{3b} + \frac{2r_T}{3b} = 0, \\ \frac{\partial \Pi_T}{\partial T_{BA}} &= \frac{A + c_A - 2(c_B + T_{BA})}{3a} - \frac{2T_{BA}}{3a} = 0.\end{aligned}$$

Thus, we have[13]

$$\begin{aligned}\widetilde{T}^F_{AB} &= \frac{1}{4}B - \frac{1}{2}c_A + \frac{1}{4}c_B + \frac{1}{2}r_T, \\ \widetilde{T}^F_{BA} &= \frac{1}{4}A + \frac{1}{4}c_A - \frac{1}{2}c_B.\end{aligned}$$

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

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

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 $x_{AB}\geq x_{BA}$ (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 $\frac{1}{6b}\left(B-2c_A+c_B-2r_T\right)\geq\frac{1}{6a}\left(A+c_A-2c_B\right)$, then T_{BA} is independent of r_T. A change in r_T does not affect the supply of both firms in country A. If $\frac{1}{6b}\left(B-2c_A+c_B-2r_T\right)<\frac{1}{6a}\left(A+c_A-2c_B\right)$, 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

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

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 the freight rates not to have an excess shipping capacity, or, to realize a full load in both directions. Obviously, type-2 equilibrium arises if the two countries 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 quotas and import tariffs 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 this section.

3.1 Import Quotas

We begin with an import quota set by country B, the level of which is q_B. The quota necessarily decreases x_{AB} and may decrease x_{BA}. We check whether the quota affects x_{BA}. First, suppose that $q_B \geq x_{BA}$ holds with the quota. 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:

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

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

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

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

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

This equilibrium is type 2 with country B's quotas, which corresponds to type-2 equilibrium under free trade.

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

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

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 $x_{AB} \geq x_{BA}$ is reversed due to the quota.

Figure 1 here

The three types of equilibrium with the quotas are depicted in Figure 1. In Figure 1 (a) (where $x_{AB} > x_{BA}$ holds under free trade), 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 locates on F_AO (i.e., the 45 degree line from the origin). x_{BA} with the quota locates 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.

Figure 1 (b) shows the case where $x_{AB} = x_{BA}$ holds under free trade. x_{AB} and x_{BA} under free trade are indicated by F. When the quota is introduced, x_{AB} and x_{BA} locate 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 2 *Suppose that country B introduces an import quota q_B, under the free-trade equilibrium with $x_{AB} \geq x_{BA}$. The quota also decreases the exports from country B to country A either if both $\frac{1}{6b}(B - 2r_T) \geq \frac{A}{6a}$ and $q_B < \frac{A}{6a}$ hold 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

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

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 2 (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 2 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 2 (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 $\frac{1}{6b}(B-2r_T) < q_A < \frac{1}{6(a+b)}(A+B-2r_T)$,[15] 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 3 *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.*

Next we investigate the effects of quotas on profits. It is obvious in our model that firm B gains and firm A loses from tightening the country B's quota under both type-1 and type-3 equilibria. However, this may not be true under type-2 equilibrium. In the following, we specifically show that there exist parameter values under which firm B loses and/or firm A gains in type-2 equilibrium.

First, we examine the effect of the quota on the profits of firm B under type-2 equilibrium

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

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

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

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

If it does, then the introduction of an import quota (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

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

Suppose $a = 2b$. Then we need to check if $\left.\frac{d\Pi_B^{Q2B}}{dq_B}\right|_{q_B=x_{AB}^{F2}} = \frac{1}{4}(A - B - 2r_T) > 0$ holds. Moreover, we have to check if the case with $a = 2b$ is consistent with type-2 equilibrium, which arises with $\frac{1}{6a}(A - 2r_T) < \frac{1}{6(a+b)}(A + B - 2r_T) < \frac{A}{6a}$. We can verify that these constraints are satisfied with $A = 2B$, for example. Thus, firm B actually loses from an import quota set by country B under some parameterization.

We next examine the effect of the country B's quota on the profits of firm A in type-2 free-trade equilibrium

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

If the following holds at $q_B = x_{AB}^{F2}$

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

then the introduction of an import quota (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 $\left.\frac{d\Pi_A^{Q2B}}{dq_B}\right|_{q_B=x_{AB}^{F2}} = -\frac{1}{6}\left(2A - B + 2r_T\right) < 0$ 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 as follows. The direct effect of country B's import quota 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.[16] This actually arises with $a = 2b$ and $A = 2B$.

We should mention that both firms A and B could gain from the quota. This is the case if countries A and B are identical.[17] When the two countries are identical, type-2 equilibrium arises. With $a = b$ and $A = B$, we have $\frac{d\Pi_B^{Q2B}}{dq_B}\Big|_{q_B = x_{AB}^{F2}} < 0$ and $\frac{d\Pi_A^{Q2B}}{dq_B}\Big|_{q_B = x_{AB}^{F2}} < 0$. Thus, both firms benefit from the quota. Moreover, it is straightforward to confirm that an import quota set by country A could harm firm A and benefit firm B.

Thus, we have the following proposition.

Proposition 4 *When country B (A) introduces an import quota, firm B (A) may not gain and firm A (B) may not lose. Depending on the parameter values, the following situations could arise. i) Firm B gains while firm A loses, ii) Both firms gain, and iii) Firm B loses while firm A gains. If the two countries are identical, country i's import quota benefits both firms A and B, harms consumers and firm T, and worsens welfare in both countries.*

3.2 Tariffs

We next explore the effects of 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

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

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

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

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

[17] Strictly speaking, the two countries cannot be identical except for the case where firm T locates in the third country. The following proposition holds regardless of the location of firm T.

We should note that even if $x_{AB}(0) \geq x_{BA}(0)$ holds, $x_{AB}(\tau_A) \geq x_{BA}(\tau_B)$ may not hold.

First, suppose $x_{AB}(\tau_A) \geq x_{BA}(\tau_B)$. Firm T's profit is 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

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

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

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

An increase in τ_i decreases x_{ji} $(i, j = A, B, i \neq j)$ and does not affect x_{ij}.This is type-1 equilibrium with tariffs, which corresponds to type 1 with quotas.

If $x_{AB}(\widetilde{T}^{\tau}_{AB}) < x_{BA}(\widetilde{T}^{\tau}_{BA})$ 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:

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

An increase in τ_i decreases both x_{ji} and x_{ij} $(i, j = A, B, i \neq j)$. This is type-2 equilibrium with tariffs, which corresponds to type 2 with quotas.

Next suppose $x_{AB}(\tau_A) < x_{BA}(\tau_B)$.[18] 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

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

If $x_{AB}(\widehat{T}^{\tau}_{AB}) < x_{BA}(\widehat{T}^{\tau}_{BA})$ holds, 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, which corresponds to type 3 with quotas.

Figure 3 here

Figure 4 here

The above cases are illustrated in Figures 3 and 4. Figure 3 (4) 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 3 (a) and Figure 4 (a) and by F in Figure 3 (b) and Figure 4 (b). In Figure 3 (a), as τ_B increases, x_{AB} decreases. Both with $\tau_B < \frac{1}{2a}\left(Ba - Ab - 2ar_T\right)$ and with $\tau_B > \frac{1}{2a}\left(Ba - Ab + 2br_T\right)$, 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 3 (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 $\tau_B > \frac{1}{2a}\left(Ba - Ab + 2br_T\right)$,

[18] 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.

when τ_B rises, x_{AB} falls but x_{BA} is constant. In Figure 3, type-1 equilibrium arises if $\frac{1}{2a}(Ba - Ab - 2ar_T) > 0$, type-2 equilibrium arises if $\max\{0, \frac{1}{2a}(Ba - Ab - 2ar_T)\} \le \tau_B \le \frac{1}{2a}(Ba - Ab + 2br_T)$, and type-3 equilibrium arises if $\tau_B > \frac{1}{2a}(Ba - Ab + 2br_T)$.

In Figure 4 (a), an increase in τ_A decreases x_{BA} but does not affect x_{AB}. In Figure 4 (b), with $0 \le \tau_A \le \frac{1}{2b}(Ab - Ba + 2ar_T)$, both x_{AB} and x_{BA} decrease together as τ_A increases. With $\tau_A > \frac{1}{2b}(Ab - Ba + 2ar_T)$, when τ_A rises, x_{BA} falls but x_{AB} is constant. In Figure 4, type-1 equilibrium arises if $\max\{0, \frac{1}{2b}(Ab - Ba + 2ar_T)\} < \tau_A$ and type-2 equilibrium arises if $0 < \tau_A \le \frac{1}{2b}(Ab - Ba + 2ar_T)$.

The above results are summarized in the following proposition.

Proposition 5 *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 $x_{AB} \ge x_{BA}$ under the free-trade equilibrium. If $\max\{0, \frac{1}{2a}(Ba - Ab - 2ar_T)\} < \tau_B < \frac{1}{2a}(Ba - Ab + 2br_T)$, then country B's tariff 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 $0 < \tau_A \le \frac{1}{2b}(Ab - Ba + 2ar_T)$, then country A's tariff increases T_{AB} and decreases country A's exports as well as country A's imports.*

As in the case of quotas, there exist parameter values under which a tariff set by country B (A) harms firm B (A) and/or benefits firm A (B) in type-2 equilibrium. In the following, we examine the case in which country B introduces a small tariff in type-2 free-trade equilibrium.[19] The profits of firm B in type-2 equilibrium with $\tau_A = 0$ are

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

To examine the effect of a small tariff by country B on the profits of firm B, we check the sign of the following at $\tau_B = 0$

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

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

If the sign is negative, then a small tariff imposed by country B decreases the profits of firm B. We have

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

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, i.e., $\frac{1}{6a}(A - 2r_T) < \frac{1}{6(a+b)}(A + B - 2r_T) < \frac{A}{6a}$. We can verify that these constraints are satisfied with $A = 2B$, for example. 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

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

We check if the following holds at $\tau_B = 0$

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

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. Moreover, type-2 equilibrium is realized with $a = 2b$. Thus, firm A actually gains from a tariff set by country B under some parameterization.

The economic intuition behind the result is the same as that under quotas. The direct effect of country B's tariff is a decrease in firm A's exports. The direct effect harms firm A and benefits 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 harms firm B. When country A's market is larger than country B's, the indirect effect could dominate the direct effect.

We can easily show that a small tariff introduced by country A could harm firm A and benefit firm B and that both firms gain from a tariff imposed by either country if the two markets are identical (i.e., $A = B$ and $a = b$).

Thus, we obtain the following proposition.

Proposition 6 *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) Firm i gains but firm j loses, ii) Both firms gain, and iii) Firm i loses while firm j gains.*

Next we examine the welfare effects of tariffs. It is obvious that a tariff set by country B (A) harms firm T and consumers in country B (A). In type-2 equilibrium, a country B's (A's) tariff is also harmful for consumers in country A's (B's). In type-1 equilibrium, the effects of tariffs are standard and well known. When country B introduces a small tariff, firm B gains, consumers in country B and firm A lose, and the government obtains tariff revenue. The country B as a whole gains from the tariff if the profits of firm T are not included in the welfare.[20] We thus investigate the welfare effects of a country B's tariff when the profits of firm T are included in the welfare. 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 and in type-3 equilibria are, respectively,

$$\begin{aligned}
\Pi_T^{\tau 1} &= \frac{1}{24}\frac{(B - 2\tau_B - 2r_T)^2}{b} + \frac{1}{24}\frac{(A - 2\tau_A)^2}{a} - f_T. \\
\Pi_T^{\tau 3} &= \frac{1}{24}\frac{(B - 2\tau_B)^2}{b} + \frac{1}{24}\frac{(A - 2\tau_A - 2r_T)^2}{a} - f_T.
\end{aligned}$$

Then we obtain

$$\begin{aligned}
\frac{d\Pi_T^{\tau 1}}{d\tau_B} &= -\frac{1}{6}\frac{(B - 2\tau_B - 2r_T)}{b} < 0, \frac{d\Pi_T^{\tau 1}}{d\tau_B}|_{\tau_B=0} = -\frac{1}{6}\frac{(B - 2r_T)}{b} < 0 \\
\frac{d\Pi_T^{\tau 3}}{d\tau_B} &= -\frac{1}{6}\frac{(B - 2\tau_B)}{b} < 0, \frac{d\Pi_T^{\tau 3}}{d\tau_B}|_{\tau_B=0} = -\frac{B}{6b} < 0,
\end{aligned}$$

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

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

The welfare effects are given by

$$\begin{aligned}
\frac{dW_B^{\tau 1}}{d\tau_B} &= -\frac{1}{72}\frac{(7B-2\tau_B-2r_T)}{b}+\frac{1}{36}\frac{(5B+2\tau_B+2r_T)}{b}-\frac{1}{6}\frac{(B-2\tau_B-2r_T)}{b}+\frac{1}{6}\frac{B-4\tau_B-2r_T}{b}\\
&= \frac{1}{24}\frac{B-6\tau_B+2r_T}{b};\ \frac{dW_B^{\tau 1}}{d\tau_B}|_{\tau_B=0}=\frac{1}{24}\frac{B+2r_T}{b}>0\\
\frac{dW_B^{\tau 3}}{d\tau_B} &= -\frac{1}{72}\frac{(7B-2\tau_B)}{b}+\frac{1}{36}\frac{(5B+2\tau_B)}{b}-\frac{1}{6}\frac{(B-2\tau_B)}{b}+\frac{1}{6}\frac{B-4\tau_B}{b}\\
&= \frac{1}{24}\frac{B-6\tau_B}{b};\ \frac{dW_B^{\tau 3}}{d\tau_B}|_{\tau_B=0}=\frac{B}{24b}>0.
\end{aligned}$$

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

In type-2 equilibrium, firm B may lose from a country B's tariff. If the profits of firm T are not included in the welfare, the welfare effects are given by

$$\begin{aligned}
\frac{dW_B^{\tau 2}}{d\tau_B} &= -\frac{-2b\tau_A-2b\tau_B-2br_T+Ab+6Ba+7Bb}{72\,(a+b)^2}\\
&\quad+\frac{(8a\tau_A+8a\tau_B+2b\tau_A+2b\tau_B+8ar_T+2br_T-4Aa-Ab+2Ba+5Bb)}{36\,(a+b)^2}\\
&\quad+\frac{A+B-2\tau_A-4\tau_B-2r_T}{6(a+b)}\\
&= \frac{-8a\tau_A-32a\tau_B-18b\tau_A-42b\tau_B-8ar_T-18br_T+4Aa+9Ab+10Ba+15Bb}{72\,(a+b)^2},\\
\frac{dW_B^{\tau 2}}{d\tau_B}|_{\tau_A=\tau_B=0} &= \frac{-8ar_T-18br_T+4Aa+9Ab+10Ba+15Bb}{72\,(a+b)^2}>0,
\end{aligned}$$

which implies that a small tariff benefits country B.

If the profits of firm T are included in the welfare, the welfare effects are given by

$$\begin{aligned}
\frac{dW_B^{\tau 2}}{d\tau_B} &= -\frac{-2b\tau_A-2b\tau_B-2br_T+Ab+6Ba+7Bb}{72\,(a+b)^2}\\
&\quad+\frac{(8a\tau_A+8a\tau_B+2b\tau_A+2b\tau_B+8ar_T+2br_T-4Aa-Ab+2Ba+5Bb)}{36\,(a+b)^2}\\
&\quad-\frac{(A+B-2\tau_A-2\tau_B-2r_T)}{6(a+b)}+\frac{A+B-2\tau_A-4\tau_B-2r_T}{6(a+b)}\\
&= \frac{16a\tau_A-8a\tau_B+6b\tau_A-18b\tau_B+16ar_T+6br_T-8Aa-3Ab-2Ba+3Bb}{72\,(a+b)^2},\\
\frac{dW_B^{\tau 2}}{d\tau_B}|_{\tau_A=\tau_B=0} &= \frac{16ar_T+6br_T-8Aa-3Ab-2Ba+3Bb}{72\,(a+b)^2}.
\end{aligned}$$

Thus, a small tariff may make country B worse off.[21]

We next analyze the effects of country A's tariff on country B's welfare. In type-1 and type-3 equilibria, a country A's tariff harms firm B and firm T but does not affect consumers in country B. In type-1 and type-3 equilibria, therefore, a country A's tariff makes country B worse off. We now check the effects in type-2 equilibrium.

If the profits of firm T are not included in country B's welfare, the welfare effects are given by

$$\begin{aligned}
\frac{dW_B^{\tau 2}}{d\tau_A} &= -\frac{-2b\tau_A - 2b\tau_B - 2br_T + Ab + 6Ba + 7Bb}{72\left(a+b\right)^2} \\
&\quad + \frac{8a\tau_A + 8a\tau_B + 2b\tau_A + 2b\tau_B + 8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb}{36\left(a+b\right)^2} \\
&= \frac{\left(16a\tau_A + 16a\tau_B + 6b\tau_A + 6b\tau_B + 16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb\right)}{72\left(a+b\right)^2}, \\
\frac{dW_B^{\tau 2}}{d\tau_A}\Big|_{\tau_A=\tau_B=0} &= \frac{16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb}{72\left(a+b\right)^2},
\end{aligned}$$

which could be positive, meaning a country A's tariff could make country B better off.

If the profits of firm T are included in the welfare, the welfare effects are given by

$$\begin{aligned}
\frac{dW_B^{\tau 2}}{d\tau_A} &= -\frac{-2b\tau_A - 2b\tau_B - 2br_T + Ab + 6Ba + 7Bb}{72\left(a+b\right)^2} \\
&\quad + \frac{8a\tau_A + 8a\tau_B + 2b\tau_A + 2b\tau_B + 8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb}{36\left(a+b\right)^2} \\
&\quad - \frac{4\left(A + B - 2\tau_A - 2\tau_B - 2r_T\right)}{24(a+b)} \\
&= \frac{40a\tau_A + 40a\tau_B + 30b\tau_A + 30b\tau_B + 40ar_T + 30br_T - 20Aa - 15Ab - 14Ba - 9Bb}{72\left(a+b\right)^2}, \\
\frac{dW_B^{\tau 2}}{d\tau_A}\Big|_{\tau_A=\tau_B=0} &= \frac{40ar_T + 30br_T - 20Aa - 15Ab - 14Ba - 9Bb}{72\left(a+b\right)^2} < 0.
\end{aligned}$$

Thus, country B as a whole, which includes firm T, loses from a country A's tariff.

Table 1 here

[21] If $2a > 3b$, then country B is worse off. This is because $16ar_T + 6br_T - 8Aa - 3Ab = -8a(A - 2r_T)(8a + 3b) < 0$.

The above results are summarized in Table 1. 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).

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. When undertaking FDI, the investing firm i ($i = A, B$) can save transport costs T_{ij} ($j = A, B; i \neq j$) but has to incur fixed costs for FDI, Ω_i. We assume that FDI does not affect the MCs of production (which are still assumed to be zero).

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

We begin with 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 A and consumers remain the same.

Interestingly, however, there may exist a situation in which the quota becomes unbinding. Figure 5 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 the capacity beyond the level of $\frac{A}{6a} (= x_{BA}^{Q2})$. 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 $q_B = \frac{A}{6a}$. Now suppose q_2 is the quota level at which $T_{AB} + T_{BA}^{Q2} = r_T$ holds. Then, at $q_B = q_2$, firm T sets $k_T = \frac{1}{6a}(A - 2r_T) (= x_{BA}^{Q3})$ and $T_{BA} = T_{BA}^{Q3} = \frac{1}{4}A + \frac{1}{2}r_T$. In the figure, both x_{AB} and x_{BA} shift from Q_2 to Q_2' at $q_B = q_2$.[22] The quota is unbinding with $\frac{1}{6a}(A - 2r_T) < q_B < q_2$ and is binding with $q_B \leq \frac{1}{6a}(A - 2r_T)$.[23]

Figure 5 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 7 *Suppose that country B sets an import quota, the level of which is q_B. With $q_B \leq q_B^{\min}$, the quota may not be binding. When 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.*

We next consider 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 the critical tariff rate, $\tau_B^{\min}$, at which firm A

[22] A similar situation could arise when country A sets a quota.

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

is indifferent between exports and FDI. With $\tau_B > \tau_B^{\max}$, therefore, firm T has 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 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 $\tau_B \geq \tau_B^{\max}$. In contrast to the case of quotas, there are no effects on firms A and B and consumers. The tariff simply results in rent-shifting from firm T to government B.[24]

It should be noted that x_{AB} and x_{BA} may drop at some tariff levels. Figure 6 shows a possible case. When $\tau_B > \tau_B^{\max}$, an increase in τ_B decreases T_{AB}. The trade cost is 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, with $\tau_B > \tau_1$.[25] 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 cannot keep a full load in both directions anymore with $\tau_B > \tau_2$. x_{AB} and x_{BA} are constant with $\tau_1 < \tau_B < \tau_2$ and with $\tau_B > \tau_2$.[26]

Figure 6 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.*

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 pro-

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

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

[26] 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.

duced 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 are given by

$$\begin{aligned} P_{Aj} &= A_j - a_j X_{Aj}, \\ P_{Bj} &= B_j - b_j X_{Bj}. \end{aligned}$$

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

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

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 with 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 country A and B are given by

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

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 country A and B are given by

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

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

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

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

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

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

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

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

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

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).

If $x_{AB}+z_{AB}=x_{BA}$ holds, there do exist spillover effects. 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 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[27]

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

The economic intuition behind the spillover effects are 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}. 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 (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}.[28]

The above results are summarized in the following proposition.

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

Proposition 9 *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 (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 sake of simplicity.[29] Then we have

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

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 firms A and α.

It should be noted that stopping serving firm A may lead to $x_{AB} + z_{AB} \leq x_{BA}$ even if $x_{AB} + z_{AB} > x_{BA}$ initially holds. If this is the case, T_{BA} increases. Stopping serving firm A makes firm B a monopolist in country B.

Thus, we obtain the following proposition.

Proposition 10 *An increase in τ_{xB} (τ_{zB}) may lead firm T to stop serving firm X (Z). This may increase T_{BA}.*

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

Next we introduce another asymmetry into the model. We specifically assume that firm T price-discriminates across firms. 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

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

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 a full load in both directions occurs (i.e., $x_{AB} + z_{AB} = x_{BA}$) or not. 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

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

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., $\phi = 0$). If the two goods are independent (i.e., $\phi = 0$), a change in τ_{xB} (τ_{zB}) does not affect Γ_{AB} (T_{AB}). When τ_{xB} (τ_{zB}) increases, the demand shifts from good X (Z) to good Z (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.

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

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

Again, an increase in τ_{xB} (τ_{zB}) leads firm T to lower T_{AB} (Γ_{AB}) and raise Γ_{AB} (T_{AB}).

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 the 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

$$\begin{aligned}
\left.\widetilde{T}_{AB}^{m2}\right|_{\phi=0} &= \frac{1}{44}\left(8r - 30\tau_{xB} + 8\tau_{xA} - 6\tau_{zB} - 4A_X + 15B_X + 6B_Z\right), \\
\left.\widetilde{\Gamma}_{AB}^{m2}\right|_{\phi=0} &= \frac{1}{11}\left(2r - 2\tau_{xB} + 2\tau_{xA} - 7\tau_{zB} - A_X + B_X + 7B_Z\right), \\
\left.\widetilde{T}_{AB}^{m2}\right|_{\phi=0} &= \frac{1}{44}\left(14r + 8\tau_{xB} - 30\tau_{xA} + 6\tau_{zB} + 15A_X - 4B_X - 6B_Z\right).
\end{aligned}$$

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}.[30] In contrast to the case with $x_{AB} + z_{AB} \neq x_{BA}$, therefore, firm T adjusts T_{BA} as well as T_{AB} and Γ_{AB} to keep a full load in both directions. When τ_{xB} (τ_{zB}) rises, firm T avoids the reduction of the load from country A to country B by lowering Γ_{AB} (T_{AB}) and decrease the load from country B to country A by raising T_{BA}. 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 (A) necessarily gains from an increase in τ_{xB} (τ_{zB}).

Table 2 here

Thus, with respect to the tariffs imposed by country B, we obtain the following proposition (see also Table 2).

Proposition 11 *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 firms A and 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.*

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

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 they are engaged in Cournot competition. They face the following derived demands.

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

The appendix shows that either $x_{1AB} > x_{1BA}$ and $x_{2AB} > x_{2BA}$ or $x_{1AB} = x_{1BA}$ and $x_{2AB} = x_{2BA}$ (where a subscript $i = 1, 2$ stands for firm T_i) holds.

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

$$\begin{aligned}
x_{1AB}^{C1} &= \frac{1}{9b}\left(B - 2\tau_B - 4r_1 + 2r_2\right), x_{2AB}^{C1} = \frac{1}{9b}\left(B - 2\tau_B + 2r_1 - 4r_2\right), \\
x_{1BA}^{C1} &= x_{2BA}^{C1} = \frac{1}{9a}\left(A - 2\tau_A\right), \\
T_{AB}^{C1} &= \frac{1}{6}\left(B - 2\tau_B + 2r_1 + 2r_2\right), T_{BA}^{C1} = \frac{1}{6}\left(A - 2\tau_A\right), \\
\Pi_{T1}^{C1} &= \frac{1}{81b}\left(B - 2\tau_B - 4r_1 + 2r_2\right)^2 + \frac{1}{81a}\left(A - 2\tau_A\right)^2 - f_{T1}, \\
\Pi_{T2}^{C1} &= \frac{1}{81b}\left(B - 2\tau_B + 2r_1 - 4r_2\right)^2 + \frac{1}{81a}\left(A - 2\tau_A\right)^2 - f_{T2}.
\end{aligned}$$

The following should be noted. First, $(B - 2\tau_B)a - (A - 2\tau_A)b > 2\left(2ar_1 - ar_2\right)$ with $x_{1AB} > x_{1BA}$ and $(B - 2\tau_B)a - (A - 2\tau_A)b > 2\left(-ar_1 + 2ar_2\right)$ with $x_{2AB} > x_{2BA}$. Second, $x_{1BA} = x_{2BA}$ holds even if $x_{1AB} \neq x_{2AB}$. This is because T_{BA} is independent of r_1 and r_2.

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

$$\begin{aligned}
x_{1AB}^{C2} &= x_{1BA}^{C2} = \frac{1}{9\left(a + b\right)}\left(A + B - 2\tau_A - 2\tau_B - 4r_1 + 2r_2\right), \\
x_{2AB}^{C2} &= x_{2BA}^{C2} = \frac{1}{9\left(a + b\right)}\left(A + B - 2\tau_A - 2\tau_B - 4r_2 + 2r_1\right), \\
T_{AB}^{C2} &= \frac{1}{6\left(a + b\right)}\left(4b\tau_A - 6a\tau_B - 2b\tau_B + 2br_1 + 2br_2 - 2Ab + 3Ba + Bb\right), \\
T_{BA}^{C2} &= \frac{1}{6\left(a + b\right)}\left(4a\tau_B - 2a\tau_A - 6b\tau_A + 2ar_1 + 2ar_2 + Aa + 3Ab - 2Ba\right), \\
\Pi_{T1}^{C2} &= \frac{1}{54\left(a + b\right)}\left(A + B - 2\tau_A - 2\tau_B - 4r_1 + 2r_2\right)^2 - f_{T1}, \\
\Pi_{T2}^{C2} &= \frac{1}{54\left(a + b\right)}\left(A + B - 2\tau_A - 2\tau_B + 2r_1 - 4r_2\right)^2 - f_{T2}.
\end{aligned}$$

In section 3, we showed that a tariff set by country B (A) could harm firm B (A) when $x_{AB} = x_{BA}$ holds. Here we show that a tariff set by country B (A) could harm firm B (A) even without $x_{AB} = x_{BA}$. 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 $x_{1AB} > x_{1BA}$, $x_{2AB} > x_{2BA}$, $f_{T1} < f_{T2}$ and $\tau_B = 0$. Suppose that country A's tariff results in $\Pi_{T2} < 0$ and firm T_2 exits. Then firm T_1 becomes the monopolist with $\tau_A > 0$.

Under free trade, the profits of firm A are given by

$$\Pi_A^{C1mon} = \frac{4}{81b}\left(B - r_1 - r_2\right)^2 + \frac{49A^2}{324a}.$$

The profits of firm A with $\tau_A > 0$ are

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

Thus, we have

$$\begin{aligned}\Pi_A^{C1mon} - \Pi_A^{\tau 1} = -\frac{1}{1296ab}(29bA^2 + 180bA\tau_A - 28aB^2 - 16aBr_1 + 128aBr_2 + 36b\tau_A^2 + 80ar_1^2 \\ - 128ar_1r_2 - 64ar_2^2),\end{aligned}$$

which is more likely to be positive when B is large relative to A and/or b is small relative to a.[31]

Thus, we obtain

Proposition 12 *If demand is much larger in country B (A) than in country A (B), country A's (B's) tariff may lead one of the transport firms to exit and harm firm A (B).*

7 Conclusion

This paper studied the effects of trade policies given endogenous transportation costs. We develop a model that captures key stylized facts about international transport: market power by the transport firms and asymmetric transport costs across countries. Transport firms need

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

to commit to a shipping capacity sufficient for a round trip. Given such "backhaul problems," we demonstrated how the price of shipping from a country to another, as well as the price of the return trip, is determined.

Import quota and tariffs, which benefit the domestic firms in a standard trade model with imperfect (output) competition, could lower the profits of the domestic firm through their effects on the endogenous transport costs. The extension of our basic model revealed that non-conventional impacts of trade policies also follow in a richer context. Once we consider firms' option to conduct foreign direct investment, the impact of import quotas and tariffs is different. A smaller 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 the domestic firm's profit. In the presence of multiple goods, tariffs on one good have spillover effects on the other goods' freight rates.

Though we focused on the performance of trade policies in the presence of an endogenous transport sector, our framework will also be useful for investigating other types of policies. Exploring how industrial policies (such as production subsidies) affect trade and welfare would be a natural extension of the paper. Pollution externalities associated with international transport are sizable while they are not regulated with the same stringency as domestic pollution. Future research could address the effect of environmental policy on transport and trade.

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Figure 1 (a): Import quotas set by country B

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

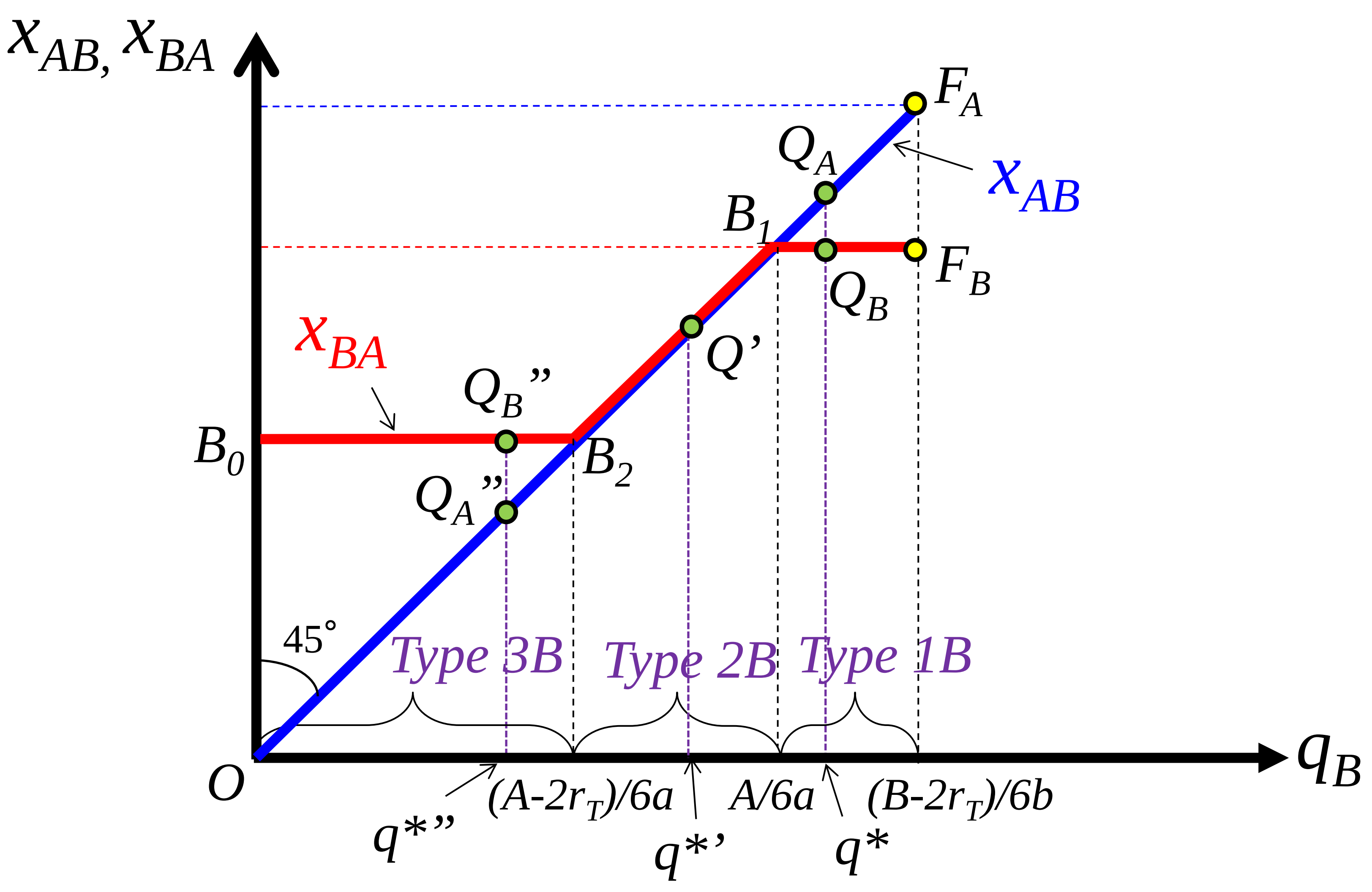

Figure 1 (b): Import quotas set by country *B*

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

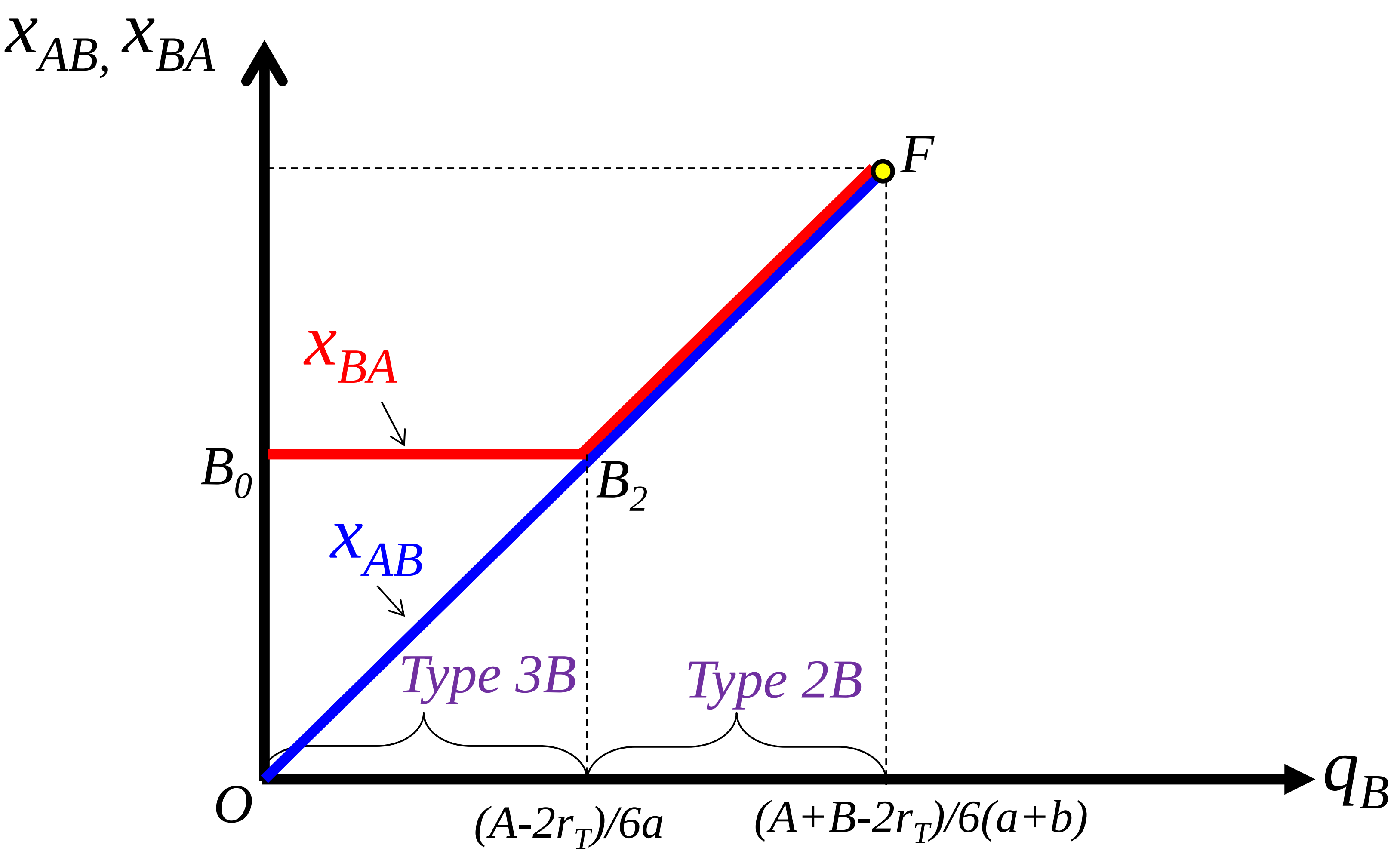

Figure 2 (a): Import quotas set by country *A*

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

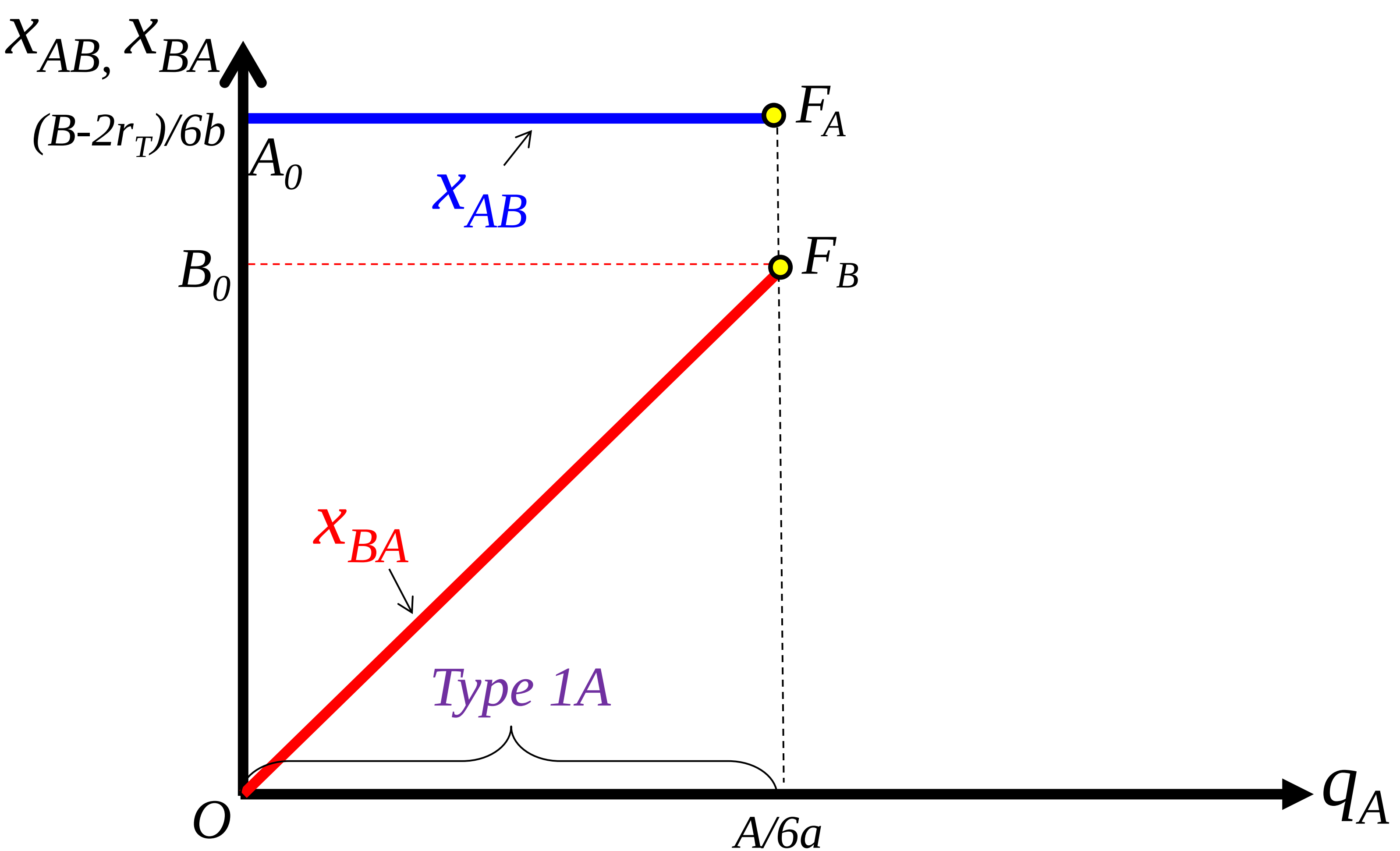

Figure 2 (b): Import quotas set by country *A*

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

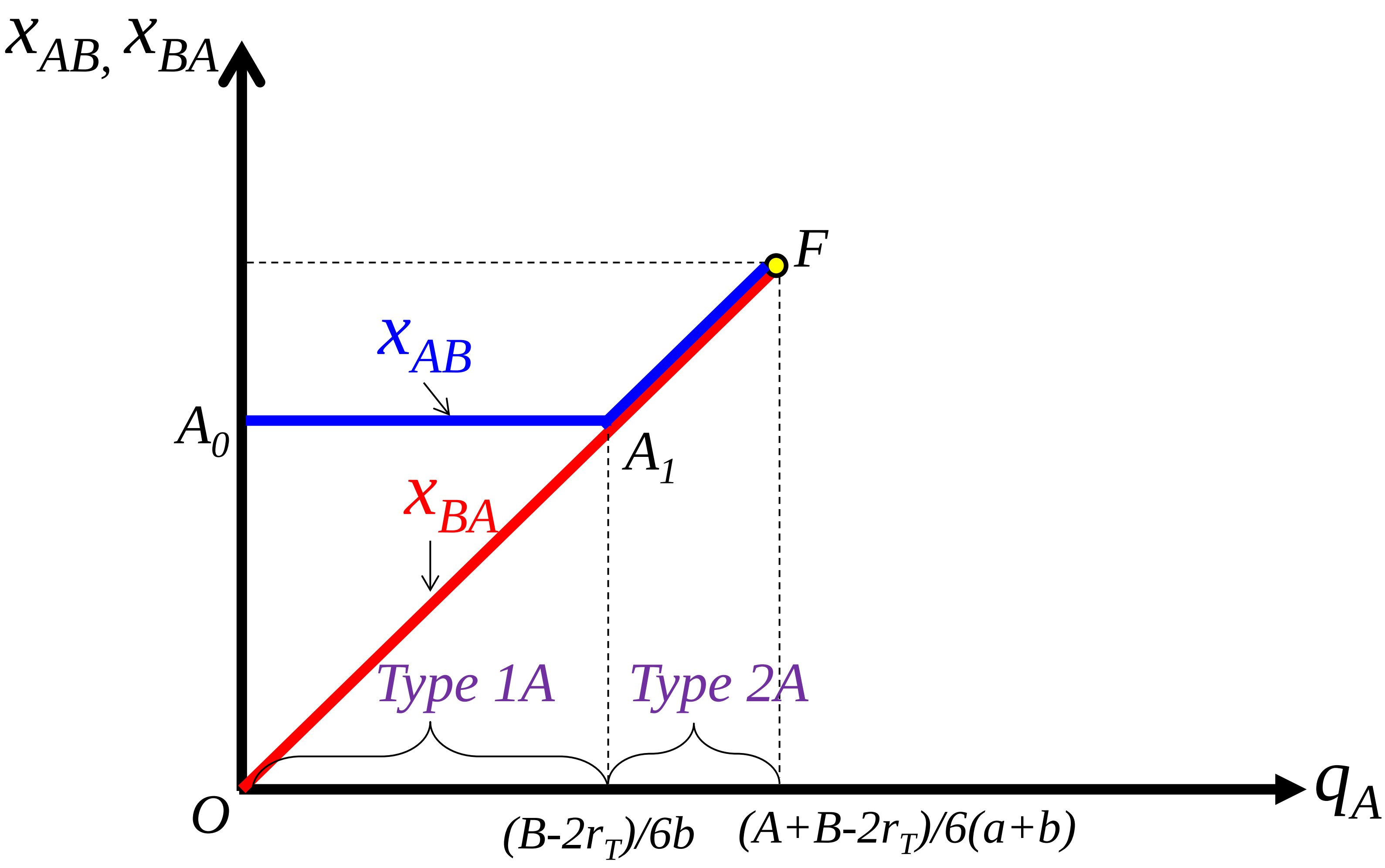

Figure 3 (a): Tariffs set by country B

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

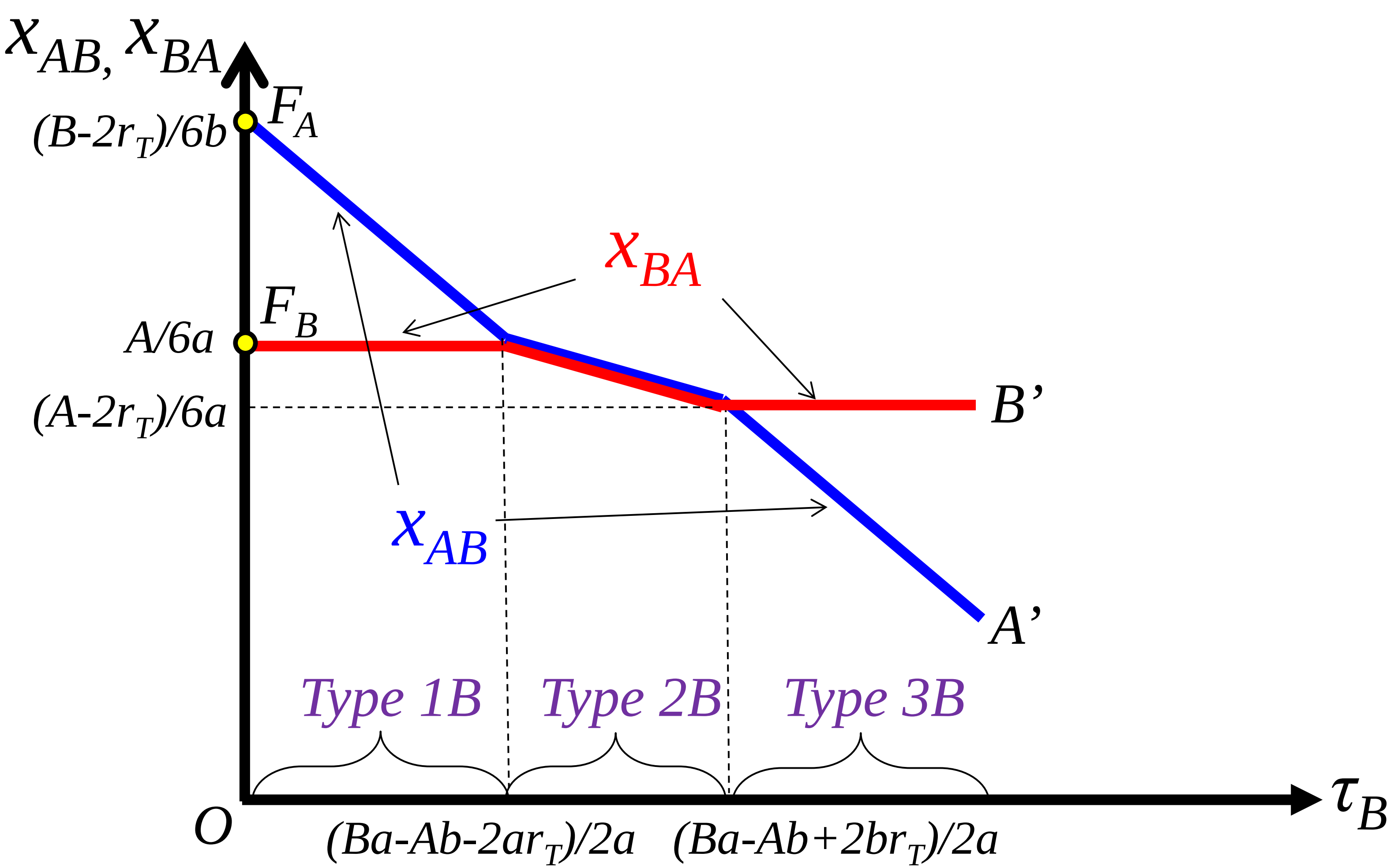

Figure 3 (b): Tariffs set by country *B*

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

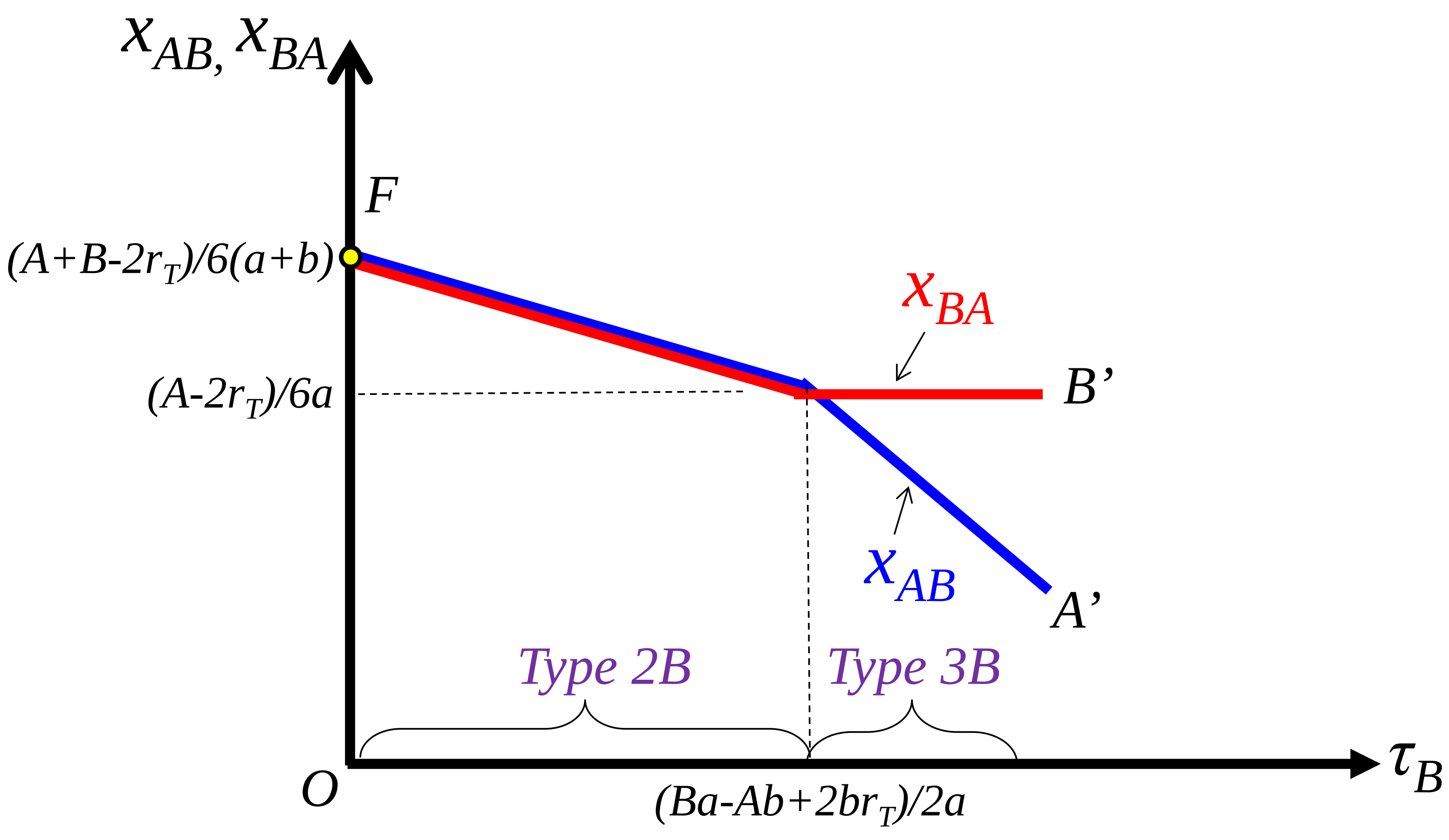

Figure 4 (a): Tariffs set by country A

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

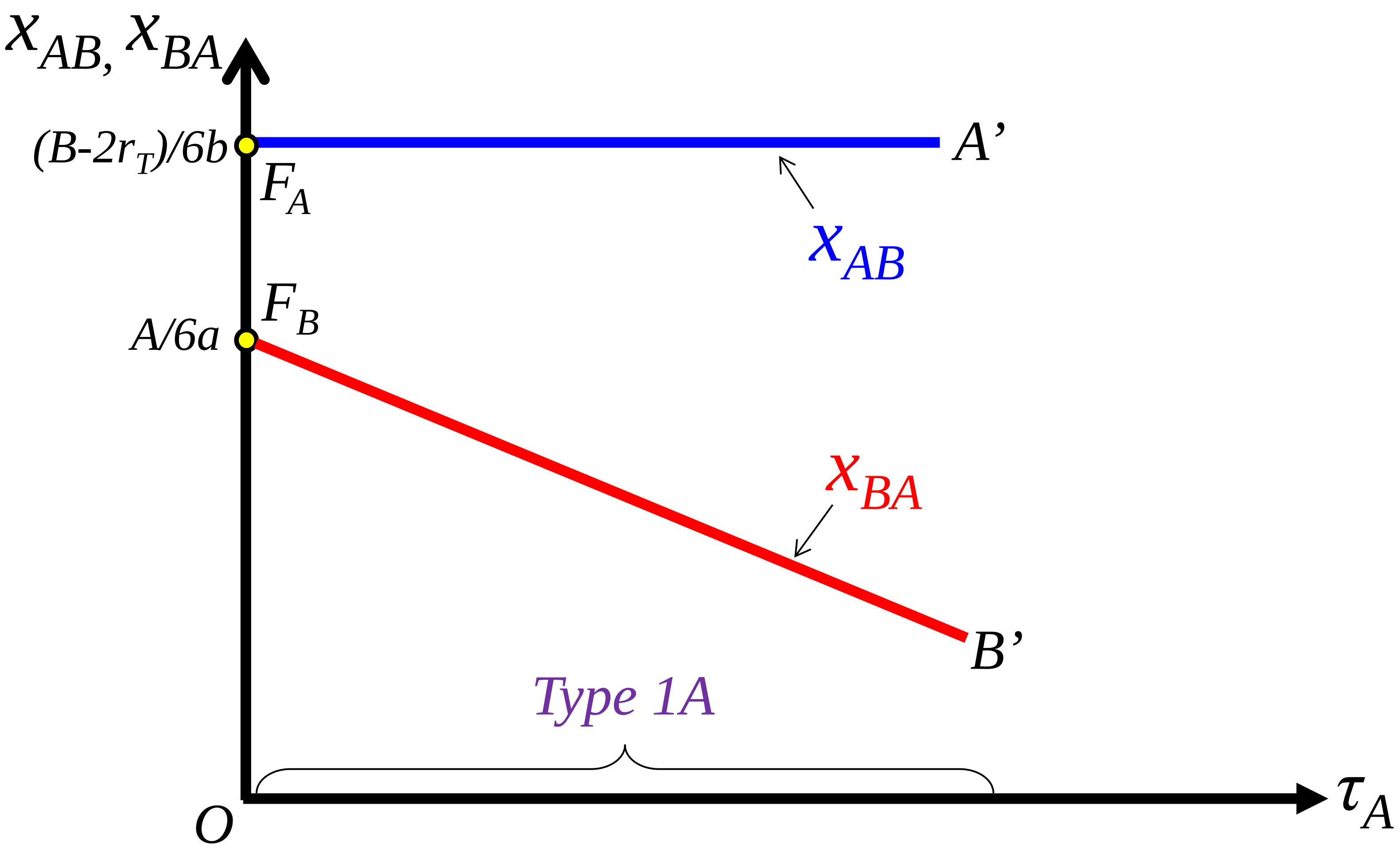

Figure 4 (b): Tariffs set by country A

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

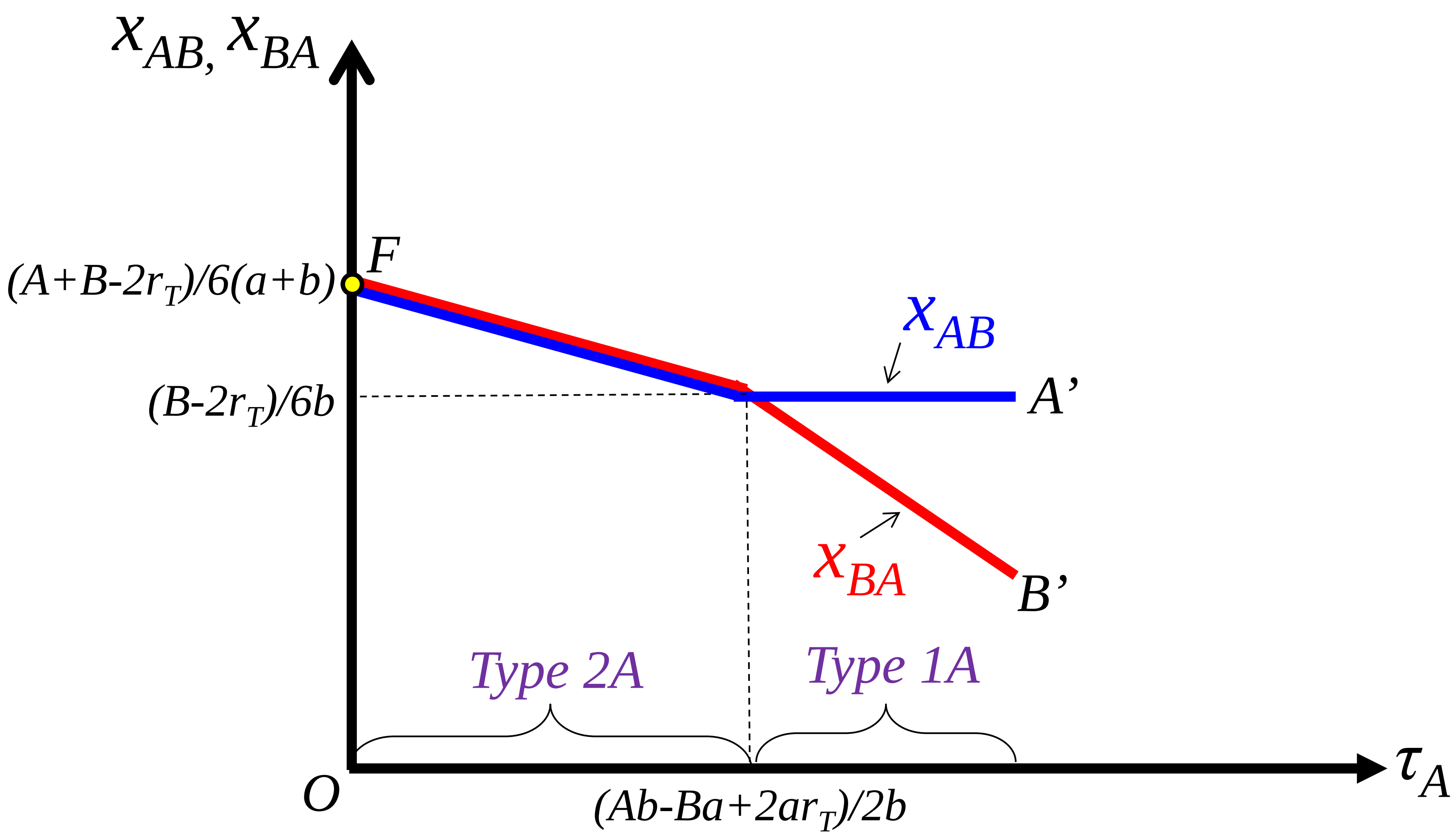

Figure 5: Import quotas set by country *B* with FDI

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

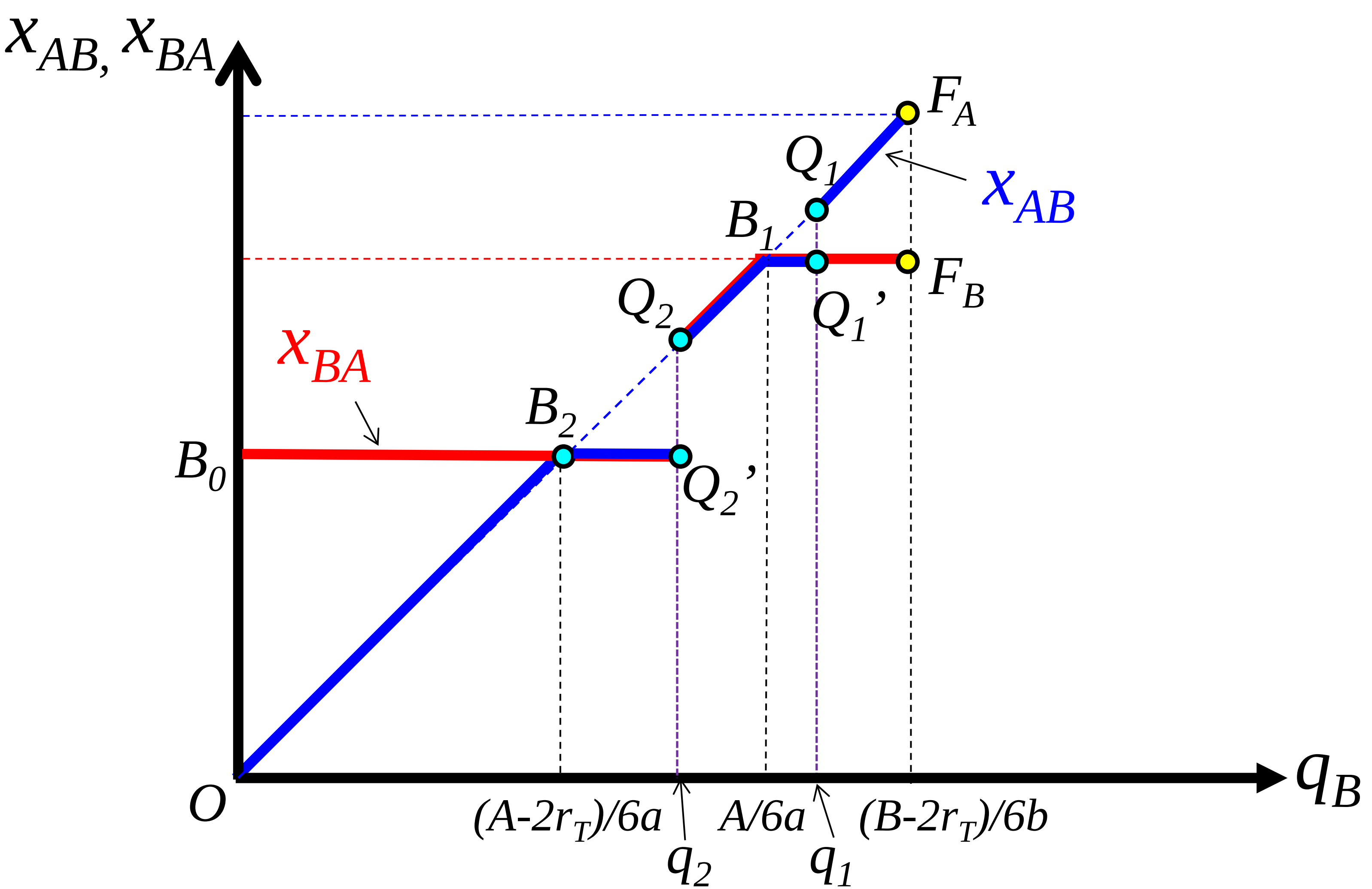

Figure 6: Tariffs set by country B with FDI ($x_{AB} > x_{BA}$ with free trade)

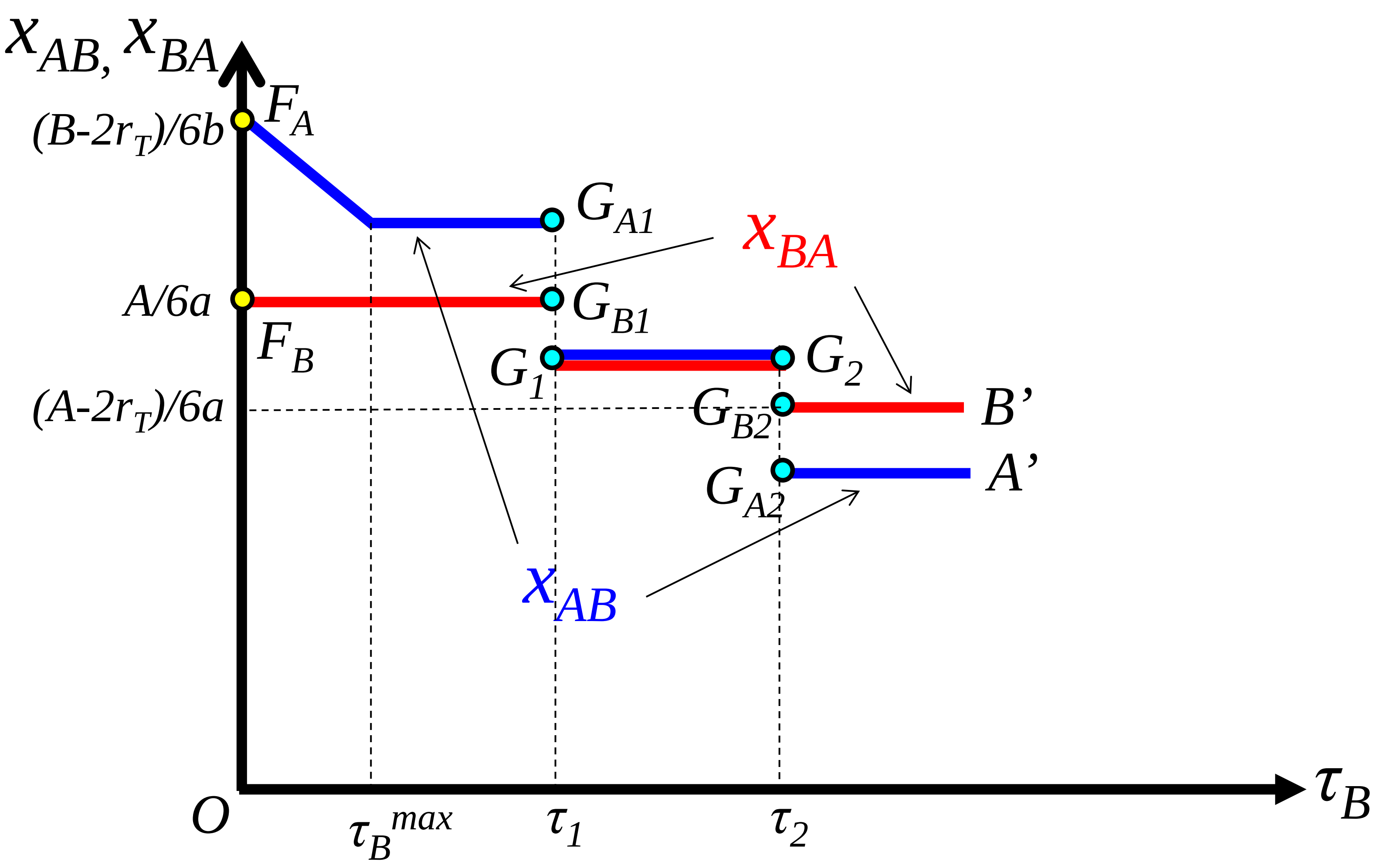

Table 1: Effects of tariffs on country *B*'s welfare

	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 with price discrimination

	Without a full load		With a full load
	$(\phi = 0)$	$(\phi \neq 0)$	
T_{AB}	-	-	-
Γ_{AB}	0	+	-
T_{BA}	0	0	+