Backfiring with backhaul problems*

Trade and Industrial Policies with Endogenous Transport Costs

Jota Ishikawa† and Nori Tarui‡

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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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†Faculty of Economics, Hitotsubashi University, Kunitachi, Tokyo 186-8601, Japan & RIETI; E-mail: jota@econ.hit-u.ac.jp.

‡Department of Economics, University of Hawaii at Manoa and the University of Hawaii Economic Research Organization (UHERO), 2424 Maile Way, Saunders Hall 542, Honolulu, HI 96822, U.S.A; E-mail: nori@hawaii.edu.
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, “[a]s 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

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\(^1\)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 non-tariffs 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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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 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).\textsuperscript{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

\textsuperscript{4}De Palma (2011) provides evidence of market power in various transportation sectors.

\textsuperscript{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.

\textsuperscript{6}Deardorff (2014) demonstrates that, even without an explicit transport sector, considering transport costs may alter the pattern of trade.

\textsuperscript{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.\textsuperscript{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

\textsuperscript{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.\footnote{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.} 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
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 $T$. 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.

\footnote{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

$$P_A = A - aX_A,$$

$$P_B = B - bX_B.$$

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 $i$ ($i = A, B$), $\Pi_i$, 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 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{align*}
  x_{AA} &= \frac{A - 2c_A + c_B + T_{BA}}{3a},
  x_{BA} &= \frac{A + c_A - 2(c_B + T_{BA})}{3a}, \\
  x_{BB} &= \frac{B - 2c_B + c_A + T_{AB}}{3b},
  x_{AB} &= \frac{B + c_B - 2(c_A + T_{AB})}{3b}, \\
  \Pi_A &= ax_{AA}^2 + bx_{AB}^2,
  \Pi_B = bx_{BB}^2 + ax_{BA}^2.
\end{align*} \(^{13}\)

\(^{11}\)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

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

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

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

$$ \frac{\partial \Pi_T}{\partial T_{BA}} = \frac{A + c_A - 2(c_B + T_{BA})}{3a} - \frac{2T_{BA}}{3a} = 0. $$

Thus, we have\(^{13}\)

$$ T_{AB}^F = \frac{1}{4B} - \frac{1}{2} \frac{c_A}{2} + \frac{1}{4} \frac{c_B}{2} + \frac{1}{2} r_T, $$

$$ T_{BA}^F = \frac{1}{4} A + \frac{1}{4} c_A - \frac{1}{2} \frac{c_B}{2}. $$

There are two cases. In Case 1, $x_{AB}(T_{AB}^F) = \frac{1}{6b} (B - 2c_A + c_B - 2r_T) \geq x_{BA}(T_{BA}^F) = \frac{1}{6a} (A + c_A - 2c_B)$ 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

\[
T_{AB}^{F_1} = \frac{1}{4} B - \frac{1}{2} c_A + \frac{1}{4} c_B + \frac{1}{2} r_T, \quad T_{BA}^{F_1} = \frac{1}{4} A + \frac{1}{4} c_A - \frac{1}{2} c_B,
\]

\[
x_{AA}^{F_1} = \frac{1}{12a} (5A - 7c_A + 2c_B), \quad x_{BA}^{F_1} = \frac{1}{6a} (A + c_A - 2c_B),
\]

\[
x_{BB}^{F_1} = \frac{1}{12b} (5B + 2c_A - 7c_B + 2r_T), \quad x_{AB}^{F_1} = \frac{1}{6b} (B - 2c_A + c_B - 2r_T).
\]

In Case 2, \( x_{AB}(\tilde{T}_{AB}^F) = \frac{1}{6b} (B - 2c_A + c_B - 2r_T) < x_{BA}(\tilde{T}_{BA}^F) = \frac{1}{6a} (A + c_A - 2c_B) \) 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.,

\[
\max \Pi_T = \max \{ T_{AB} \frac{B + c_B - 2(c_A + T_{AB})}{3b} + T_{BA} \frac{A + c_A - 2(c_B + T_{BA})}{3a} \}
\]

\[-(f_T + r_T k_T) \}

\[s.t. T_{AB} = \frac{1}{2a} (ac_B - 2ac_A - bc_A + 2bc_B + 2bT_{BA} - Ab + Ba) \iff x_{AB} = x_{BA}.
\]

Then we obtain the following equilibrium:

\[
T_{AB}^{F_2} = \frac{1}{4(a + b)} (2ac_B - 4ac_A - 3bc_A + 3bc_B + 2br_T - Ab + 2Ba + Bb)
\]

\[
T_{BA}^{F_2} = \frac{1}{4(a + b)} (3ac_A - 3ac_B + 2bc_A - 4bc_B + 2ar_T + Aa + 2Ab - Ba)
\]

\[
x_{AB}^{F_2} = x_{BA}^{F_2} = \frac{1}{6(a + b)} (A + B - 2r_T - c_A - c_B).
\]

We thus obtain the following proposition.\(^\text{14}\)

**Proposition 1** Suppose \( x_{AB} \geq x_{BA} \) (that is, \( \frac{1}{6b} (B - 2c_A + c_B) \geq \frac{1}{6a} (A + c_A - 2c_B - 2r_T) \)). If \( \frac{1}{6b} (B - 2c_A + c_B - 2r_T) \geq \frac{1}{6a} (A + c_A - 2c_B) \), 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 \( \frac{1}{6b} (B - 2c_A + c_B - 2r_T) < \frac{1}{6a} (A + c_A - 2c_B) \), 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 \( \frac{1}{6b} (B - 2c_A + c_B) < \frac{1}{6a} (A + c_A - 2c_B - 2r_T) \), 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 \( T_{AB}^{F1} + T_{BA}^{F1} = T_{AB}^{F2} + T_{BA}^{F2} = \frac{1}{4} \left( A + B - c_A - c_B + 2r_T \right) \) 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 \( q_B \geq x_{BA}(\bar{T}_{BA}) = \frac{A}{6a} \) 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:

\[
T_{AB}^{Q1} = \frac{1}{2} B - \frac{3}{2} bq_B, \quad T_{BA}^{Q1} = \frac{1}{4} A, \\
x_{AA}^{Q1} = \frac{5A}{12a}, \quad x_{BA}^{Q1} = \frac{A}{6a}, \\
x_{BB}^{Q1} = \frac{1}{2b} (B - bq_B), \quad x_{AB}^{Q1} = q_B.
\]

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

\[
\bar{T}_{AB}^{QB} = \frac{1}{2} B - \frac{3}{2} bq_B, \\
\bar{T}_{BA}^{QB} = \frac{1}{4} A + \frac{1}{2} r_T.
\]
Just like the free-trade case, there are two subcases depending on whether $x_{BA}(\tilde{T}_{BA}) = \frac{1}{6a} (A - 2r_T) > q_B$ or $x_{BA}(\tilde{T}_{BA}) = \frac{1}{6a} (A - 2r_T) \leq q_B(\frac{A}{6a})$ holds. With $x_{BA}(\tilde{T}_{BA}) = \frac{1}{6a} (A - 2r_T) \leq q_B$, which is inconsistent with $x_{BA} > q_B$, we have $x_{AB} = x_{BA} = q_B$. The equilibrium is

$$T_{AB}^{Q_2B} = \frac{1}{2} B - \frac{3}{2} b q_B, T_{BA}^{Q_2B} = \frac{1}{2} A - \frac{3}{2} a q_B,$$

$$x_{AA}^{Q_2B} = \frac{1}{2a} (A - a q_B), x_{BA}^{Q_2B} = q_B,$$

$$x_{BB}^{Q_2B} = \frac{1}{2b} (B - b q_B), x_{AB}^{Q_2B} = q_B.$$  

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

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

$$T_{AB}^{Q_3B} = \frac{1}{2} B - \frac{3}{2} b q_B, T_{BA}^{Q_3B} = \frac{1}{4} A + \frac{1}{2} r_T,$$

$$x_{AA}^{Q_3B} = \frac{1}{12a} (5A + 2r_T), x_{BA}^{Q_3B} = \frac{1}{6a} (A - 2r_T),$$

$$x_{BB}^{Q_3B} = \frac{1}{2b} (B - b q_B), x_{AB}^{Q_3B} = q_B.$$  

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 \( \frac{1}{6a} (A - 2r_T) < q_B < \frac{1}{6a} (A + B - 2r_T) \), 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 \( \frac{A}{6a} (= x_{BA}(\tilde{T}^F_{BA})) \leq \frac{1}{6b} (B - 2r_T) (= x_{AB}(\tilde{T}^F_{AB})) \), then type-1 equilibrium arises under free trade. When an import quota is set, we have

\[
T^{Q_{1A}}_{AB} = \frac{1}{4} B + \frac{1}{2} r_T, \quad T^{Q_{1A}}_{BA} = \frac{1}{2} A - \frac{3}{2} aq_A, \\
x^{Q_{1A}}_{AA} = \frac{1}{2a} (A - aq_A), \quad x^{Q_{1A}}_{BA} = q_A, \\
x^{Q_{1A}}_{BB} = \frac{1}{12b} (5B + 2r_T), \quad x^{Q_{1A}}_{AB} = \frac{1}{6b} (B - 2r_T).
\]

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 \( \frac{1}{66} (B - 2r_T) < \frac{A}{66} \), 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 \( 0 < q_A \leq \frac{1}{66} (B - 2r_T) \), 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 \( \frac{1}{66} (B - 2r_T) < q_A \leq \frac{1}{66} (A + B - 2r_T) \),\(^{15}\) then the equilibrium with the quota is given by

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

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 \( \frac{1}{66} (B - 2r_T) < \frac{A}{66} \) 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 \( \frac{1}{6(a+b)} (A + B - 2r_T) > \frac{1}{66} (B - 2r_T) \).
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 $q_B = x^F_{AB}$, we obtain

$$\frac{d\Pi^Q_{Q2B}}{dq_B} \bigg|_{q_B=x^F_{AB}} = -\frac{1}{12(a+b)}(8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb).$$

Suppose $a = 2b$. Then we need to check if $\frac{d\Pi^Q_{Q2B}}{dq_B} \bigg|_{q_B=x^F_{AB}} = \frac{1}{4}(A - B - 2r_T) > 0$ 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

$$\Pi^Q_{Q2A} = \frac{1}{4a}(A - aq_B)^2 + bq_B^2.$$ 

If the following holds at $q_B = x^F_{AB}$

$$\frac{d\Pi^Q_{Q2A}}{dq_B} \bigg|_{q_B=x^F_{AB}} = -\frac{1}{2} (A - aq_B - 4bq_B)$$

$$= -\frac{1}{12(a+b)}(2ar_T + 8br_T + 5Aa + 2Ab - Ba - 4Bb) < 0,$$

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 $\frac{d\Pi^Q_{Q2A}}{dq_B} \bigg|_{q_B=x^F_{AB}} = -\frac{1}{6}(2A - B + 2r_T) < 0$ 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 \(\frac{d\Pi^{Q2B}}{dq_B} \bigg|_{q_B = x_{AB}^{F2}} < 0\) and \(\frac{d\Pi^{Q2B}}{dq_B} \bigg|_{q_B = x_{AB}^{F2}} < 0\). 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 \(\tau_i\) \((i = A, B)\),
is imposed by country i, the profits of firm i \((i = A, B)\), \(\Pi_i\), 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 \(c_i = 0\) \((i = A, B)\).

\[
x_{AA}(\tau_A) = \frac{A + T_{BA} + \tau_A}{3a}, x_{BA}(\tau_A) = \frac{A - 2(T_{BA} + \tau_A)}{3a},
\]

\[
x_{BB}(\tau_B) = \frac{B + T_{AB} + \tau_B}{3b}, x_{AB}(\tau_B) = \frac{B - 2(T_{AB} + \tau_B)}{3b}.
\]

\(^{16}\)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 \( \chi_{AB}(0) \geq \chi_{BA}(0) \) holds, \( \chi_{AB}(\tau_A) \geq \chi_{BA}(\tau_B) \) may not hold.

First, suppose \( \chi_{AB}(\tau_A) \geq \chi_{BA}(\tau_B) \). 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

\[
\tilde{T}_{AB}^\tau = \frac{1}{4} B - \frac{1}{2} \tau_B + \frac{1}{2} r_T,
\]

\[
\tilde{T}_{BA}^\tau = \frac{1}{4} A - \frac{1}{2} \tau_A.
\]

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

\[
T_{AB}^1 = \frac{1}{4} B - \frac{1}{2} \tau_B + \frac{1}{2} r_T, T_{BA}^1 = \frac{1}{4} A - \frac{1}{2} \tau_A,
\]

\[
x_{AA}^1 = \frac{1}{12a} (5A + 2\tau_A), x_{BA}^1 = \frac{1}{6a} (A - 2\tau_A),
\]

\[
x_{BB}^1 = \frac{1}{12b} (5B + 2\tau_B + 2r_T), x_{AB}^1 = \frac{1}{6b} (B - 2\tau_B - 2r_T).
\]

An increase in \( \tau_i \) 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 \( \chi_{AB}(\tilde{T}_{AB}^\tau) < \chi_{BA}(\tilde{T}_{BA}^\tau) \) holds, firm \( T \) maximizes its profits subject to \( \chi_{AB} = \chi_{BA} \), i.e.,

\[
\max \Pi_T = \max\{T_{AB} \frac{B - 2(T_{AB} + \tau_B)}{3b} + T_{BA} \frac{A - 2(T_{BA} + \tau_A)}{3a} - (f_T + r_T)k_T\}
\]

\[
s.t. T_{AB} = \frac{1}{2a} (2b\tau_A - 2a\tau_B + 2bT_{BA} - Ab + Ba) \iff \chi_{AB} = \chi_{BA}
\]

Then we obtain the following equilibrium:

\[
T_{AB}^2 = \frac{1}{4(a + b)} (2b\tau_A - 4a\tau_B - 2b\tau_B + 2br_T - Ab + 2Ba + Bb),
\]

\[
T_{BA}^2 = \frac{1}{4(a + b)} (-2a\tau_A + 2a\tau_B - 4b\tau_A + 2ar_T + Aa + 2Ab - Ba),
\]

\[
x_{AB}^2 = x_{BA}^2 = \frac{1}{6(a + b)} (A + B - 2\tau_A - 2\tau_B - 2r_T),
\]

\[
x_{AA}^2 = \frac{1}{12a(a + b)} (2a\tau_A + 2a\tau_B + 2ar_T + 5Aa + 6Ab - Ba),
\]

\[
x_{BB}^2 = \frac{1}{12b(a + b)} (2b\tau_A - 2b\tau_B + 2br_T - Ab + 6Ba + 5Bb).
\]
An increase in $\tau_i$ 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

$$\hat{T}_{AB}^\tau = \frac{1}{4} B - \frac{1}{2} \tau_B,$$

$$\hat{T}_{BA}^\tau = \frac{1}{4} A - \frac{1}{2} \tau_A + \frac{1}{2} r_T.$$ 

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

$$T_{AB}^{\tau_3} = \frac{1}{4} B - \frac{1}{2} \tau_B, T_{BA}^{\tau_3} = \frac{1}{4} A - \frac{1}{2} \tau_A + \frac{1}{2} r_T,$$

$$x_{AA}^{\tau_3} = \frac{1}{12a} (5A + 2\tau_A + 2r_T), x_{BA}^{\tau_3} = \frac{1}{6a} (A - 2\tau_A - 2r_T),$$

$$x_{BB}^{\tau_3} = \frac{1}{12b} (5B + 2\tau_B), x_{AB}^{\tau_3} = \frac{1}{6b} (B - 2\tau_B).$$

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 $\tau_B$ ($\tau_A$) 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 $\tau_B$ increases, $x_{AB}$ decreases. Both with $\tau_B < \frac{1}{2a} (Ba - Ab - 2ar_T)$ and with $\tau_B > \frac{1}{2a} (Ba - Ab + 2br_T)$, $x_{BA}$ is independent of $\tau_B$. With $\frac{1}{2a} (Ba - Ab - 2ar_T) \leq \tau_B \leq \frac{1}{2a} (Ba - Ab + 2br_T)$, $x_{AB} = x_{BA}$ holds and an increase in $\tau_B$ decreases both $x_{AB}$ and $x_{BA}$. In Figure 3 (b), with $0 \leq \tau_B \leq \frac{1}{2a} (Ba - Ab + 2br_T)$, both $x_{AB}$ and $x_{BA}$ decrease together as $\tau_B$ increases. With $\tau_B > \frac{1}{2a} (Ba - Ab + 2br_T)$,

\(^{18}\)If $x_{AB}(\hat{T}_{AB}) \geq x_{BA}(\hat{T}_{BA})$ holds, firm $T$ maximizes its profits subject to $x_{AB} = x_{BA}$. We have already obtained this case.
when $\tau_B$ 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
$$\max\{0, \frac{1}{2a}(Ba - Ab - 2ar_T)\} \leq \tau_B \leq \frac{1}{2a}(Ba - Ab + 2br_T),$$
and type-3 equilibrium arises if $\tau_B > \frac{1}{2a}(Ba - Ab + 2br_T)$.

In Figure 4 (a), an increase in $\tau_A$ decreases $x_{BA}$ but does not affect $x_{AB}$. In Figure 4 (b), with $0 \leq \tau_A \leq \frac{1}{2b}(Ab - Ba + 2ar_T)$, both $x_{AB}$ and $x_{BA}$ decrease together as $\tau_A$ increases. With $\tau_A > \frac{1}{2b}(Ab - Ba + 2ar_T)$, when $\tau_A$ 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
$$0 < \tau_A \leq \frac{1}{2b}(Ab - Ba + 2ar_T).$$

The above results are summarized in the following proposition.

Proposition 5 If country $i$ imposes a tariff, $\tau_i$, 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
$$\max\{0, \frac{1}{2a}(Ba - Ab - 2ar_T)\} < \tau_B < \frac{1}{2a}(Ba - Ab + 2br_T),$$
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
$$0 < \tau_A \leq \frac{1}{2b}(Ab - Ba + 2ar_T),$$
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. The profits of firm $B$ in type-2 equilibrium with $\tau_A = 0$ are
$$\Pi_B^2 = \frac{1}{144b(a + b)^2}(2b\tau_B + 2br_T - Ab + 6Ba + 5Bb)^2 + \frac{a}{36(a + b)^2}(A + B - 2\tau_B - 2r_T)^2.$$

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

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

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

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

Suppose $a = 2b$. Then we check if $\frac{d\Pi^2_B}{d\tau_B} \big|_{\tau_B=0} = -\frac{1}{36b} (A - B - 2r_T) < 0$ 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

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

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

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

Supposing $a = 2b$, we check if $\frac{d\Pi^2_A}{d\tau_B} \big|_{\tau_B=0} = \frac{1}{54b} (2A - B + 2r_T) > 0$ 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

$$W_B^T = CS_B^T + \Pi_B^T + TR_B^T + \Pi_T^T$$

The profits of firm $T$ in type-1 and in type-3 equilibria are, respectively,

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

$$\Pi_T^3 = \frac{1}{24} \left( \frac{B - 2\tau_B}{b} \right)^2 + \frac{1}{24} \left( \frac{A - 2\tau_A - 2r_T}{a} \right)^2 - f_T.$$

Then we obtain

$$\frac{d\Pi_T^3}{d\tau_B} = -\frac{1}{6} \left( \frac{B - 2\tau_B - 2r_T}{b} \right) < 0, \quad \frac{d\Pi_T^1}{d\tau_B} \bigg|_{\tau_B=0} = -\frac{1}{6} \left( \frac{B - 2r_T}{b} \right) < 0$$

$$\frac{d\Pi_T^3}{d\tau_B} = -\frac{1}{6} \left( \frac{B - 2\tau_B}{b} \right) < 0, \quad \frac{d\Pi_T^1}{d\tau_B} \bigg|_{\tau_B=0} = -\frac{B}{6b} < 0,$$

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
\[
\frac{dW^\tau_1_B}{d\tau_B} = \frac{-1}{72} \left(7B - 2\tau_B - 2r_T\right) + \frac{1}{36} \frac{b}{b} - \frac{1}{6} \frac{(B - 2\tau_B - 2r_T)}{b} + \frac{1}{6} \frac{(B - 4\tau_B - 2r_T)}{b}
\]
\[
= \frac{1}{24} \frac{B - 6\tau_B + 2r_T}{b}; \quad \left. \frac{dW^\tau_1_B}{d\tau_B} \right|_{\tau_B = 0} = \frac{1}{24} \frac{B + 2r_T}{b} > 0
\]
\[
\frac{dW^\tau_3_B}{d\tau_B} = \frac{-1}{72} \left(7B - 2\tau_B\right) + \frac{1}{36} \frac{(5B + 2\tau_B)}{b} - \frac{1}{6} \frac{(B - 2\tau_B)}{b} + \frac{1}{6} \frac{(B - 4\tau_B)}{b}
\]
\[
= \frac{1}{24} \frac{B - 6\tau_B}{b}; \quad \left. \frac{dW^\tau_3_B}{d\tau_B} \right|_{\tau_B = 0} = \frac{B}{24b} > 0.
\]

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
\[
\frac{dW^\tau_2_B}{d\tau_B} = \frac{-2b\tau_A - 2b\tau_B - 2br_T + Ab + 6Ba + 7Bb}{72(a + b)^2}
\]
\[
+ \frac{(8a\tau_A + 8a\tau_B + 2b\tau_A + 2b\tau_B + 8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb)}{36(a + b)^2}
\]
\[
+ \frac{A + B - 2\tau_A - 4\tau_B - 2r_T}{6(a + b)}
\]
\[
= \frac{-8a\tau_A - 32a\tau_B - 18b\tau_A - 42b\tau_B - 8ar_T - 18br_T + 4Aa + 9Ab + 10Ba + 15Bb}{72(a + b)^2}
\]
\[
\left. \frac{dW^\tau_2_B}{d\tau_B} \right|_{\tau_A = \tau_B = 0} = \frac{-8ar_T - 18br_T + 4Aa + 9Ab + 10Ba + 15Bb}{72(a + b)^2} > 0,
\]
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
\[
\frac{dW^\tau_2_B}{d\tau_B} = \frac{-2b\tau_A - 2b\tau_B - 2br_T + Ab + 6Ba + 7Bb}{72(a + b)^2}
\]
\[
+ \frac{(8a\tau_A + 8a\tau_B + 2b\tau_A + 2b\tau_B + 8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb)}{36(a + b)^2}
\]
\[
- \frac{(A + B - 2\tau_A - 2r_T)}{6(a + b)} + \frac{A + B - 2\tau_A - 4\tau_B - 2r_T}{6(a + b)}
\]
\[
= \frac{16a\tau_A - 8a\tau_B + 6b\tau_A - 18b\tau_B + 16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb}{72(a + b)^2}
\]
\[
\left. \frac{dW^\tau_2_B}{d\tau_B} \right|_{\tau_A = \tau_B = 0} = \frac{16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb}{72(a + b)^2}.
\]
Thus, a small tariff may make country B worse off. \(^\text{21}\)

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

\[
\frac{dW^\tau_B}{d\tau_A} = -\frac{-2b\tau_A - 2b\tau_B - 2br_T + Ab + 6Ba + 7Bb}{72(a + b)^2} + \frac{8a\tau_A + 8a\tau_B + 2b\tau_A + 2b\tau_B + 8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb}{36(a + b)^2} = \frac{(16a\tau_A + 16a\tau_B + 6b\tau_A + 6b\tau_B + 16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb)}{72(a + b)^2},
\]

\[
\frac{dW^\tau_B}{d\tau_A} |_{\tau_A=\tau_B=0} = \frac{16ar_T + 6br_T - 8Aa - 3Ab - 2Ba + 3Bb}{72(a + b)^2},
\]

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

\[
\frac{dW^\tau_B}{d\tau_A} = -\frac{-2b\tau_A - 2b\tau_B - 2br_T + Ab + 6Ba + 7Bb}{72(a + b)^2} + \frac{8a\tau_A + 8a\tau_B + 2b\tau_A + 2b\tau_B + 8ar_T + 2br_T - 4Aa - Ab + 2Ba + 5Bb}{36(a + b)^2} - \frac{4(A + B - 2\tau_A - 2\tau_B - 2r_T)}{24(a + b)} = \frac{40a\tau_A + 40a\tau_B + 30b\tau_A + 30b\tau_B + 40ar_T + 30br_T - 20Aa - 15Ab - 14Ba - 9Bb}{72(a + b)^2},
\]

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

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

\(\text{Table 1 here}\)

\(^{21}\)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, \(\Omega_i\). 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, \(q_B^{\text{min}}\), at which firm \(A\) is indifferent between exports and FDI. That is, with \(q_B < q_B^{\text{min}}\), 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 $q_1 < q_B < q_B^{\min}$ where $q_1$ is the quota level at which $T_{AB} = r_B$ holds. At $q_B = q_1$, firm $T$ sets $k_T = \frac{A}{6a}(= x_{BA}^{Q})$, because firm $T$ cannot cover the MC, $r_B$, for the capacity beyond the level of $\frac{A}{6a}(= x_{BA}^{Q})$. 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 $q_B < q_1$ and becomes binding again at $q_B = \frac{A}{6a}$. Now suppose $q_2$ is the quota level at which $T_{AB} + T_{BA}^{Q} = r_B$ holds. Then, at $q_B = q_2$, firm $T$ sets $k_T = \frac{1}{6a}(A - 2r_T) (= x_{BA}^{Q})$ and $T_{BA} = T_{BA}^{Q} = \frac{1}{4}A + \frac{1}{2}r_T$. In the figure, both $x_{AB}$ and $x_{BA}$ shift from $Q_2$ to $Q'_2$ at $q_B = q_2$. 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

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 $\tau_B$. 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 $A$

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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 $\tau_B > \tau_B^{\text{max}}$, 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 $\tau_B^{\text{max}} + T_{AB}(\tau_B^{\text{max}})$. As long as the trade cost remains the level of $\tau_B^{\text{max}} + T_{AB}(\tau_B^{\text{max}})$, firm $A$ has no incentive for FDI. Thus, government $B$ can raise the tariff without increasing the consumer price when $\tau_B \geq \tau_B^{\text{max}}$. 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 $B$.\footnote{A similar argument is valid when country $A$ imposes a tariff.}

It should be noted that $x_{AB}$ and $x_{BA}$ may drop at some tariff levels. Figure 6 shows a possible case. When $\tau_B > \tau_B^{\text{max}}$, an increase in $\tau_B$ decreases $T_{AB}$. The trade cost is constant at $\tau_B^{\text{max}} + T_{AB}(\tau_B^{\text{max}})$. Suppose that $\tau_1$ 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 $\tau_B > \tau_1$.\footnote{With $\tau_1 < \tau_B < \tau_2$, $\frac{A}{B}(A - 2r_T) < x_{AB} = x_{BA} < \frac{A}{B}$ holds.} Now suppose that $\tau_2$ 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 $\tau_B > \tau_2$.\footnote{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.}

We obtain the following proposition.

**Proposition 8** Suppose $\tau_B \geq \tau_B^{\text{max}}$. Then an increase in $\tau_B$ leads firm $T$ to lower the freight rate. Even if $\tau_B$ 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-
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

\[
\begin{align*}
P_{Aj} &= A_j - a_j X_{Aj}, \\
P_{Bj} &= B_j - b_j X_{Bj}.
\end{align*}
\]

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

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

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 \( \alpha \) 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

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

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

\[
\begin{align*}
P_{zA} &= A_z - z_{AA} - \phi (x_{AA} + x_{BA}), \\
P_{zB} &= B_z - z_{AB} - \phi (x_{AB} + x_{BB}).
\end{align*}
\]
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 $\alpha$, $\Pi_\alpha$, are given by

$$\Pi_\alpha = P_z A z_{AA} + (P_z B - \tau_z B - T_{AB})z_{AB}.$$  

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

$$x_{AB} = -\frac{1}{2(\phi^2 - 3)} \left( \begin{array}{c} 2B_x - 4\tau_z x - 4T_{AB} + \phi \tau_z B \\ -\phi B_x + \phi T_{AB} + \phi^2 \tau_z x + \phi^3 T_{AB} \end{array} \right),$$

$$x_{BB} = -\frac{1}{2(\phi^2 - 3)} \left( \begin{array}{c} 2\tau_z B + 2B_x + 2T_{AB} + \phi \tau_z B \\ -\phi B_x + \phi T_{AB} - \phi^2 \tau_z B - \phi^3 T_{AB} \end{array} \right),$$

$$z_{AB} = \frac{1}{2(\phi^2 - 3)} (3\tau_z B - 3B_z + 3T_{AB} - \phi \tau_z B + 2\phi B_z - \phi T_{AB}),$$

$$x_{BA} = -\frac{1}{2(\phi^2 - 3)} \left( \begin{array}{c} 2A_x - 4\tau_z x - 4T_{BA} - \phi A_x + \phi^2 \tau_z x + \phi^3 T_{BA} \end{array} \right),$$

$$x_{AA} = -\frac{1}{2(\phi^2 - 3)} \left( \begin{array}{c} 2\tau_z A + 2A_x + 2T_{BA} - \phi A_x - \phi^2 \tau_z x - \phi^3 T_{BA} \end{array} \right),$$

$$z_{AA} = -\frac{1}{2(\phi^2 - 3)} (3A_x + \phi \tau_x A - 2\phi A_x + \phi T_{BA}).$$

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

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

Solving this, we have

$$\tilde{T}_{AB} = \frac{1}{4\phi + 2\phi^2 - 14} \left( \begin{array}{c} -2B_x - 3B_z + r_T (2\phi + \phi^2 - 7) \\ -(\phi^2 + \phi - 4) \tau_x B + 2\phi B_x + \phi B_z - \phi \tau_z B + 3\tau_z B \end{array} \right),$$

$$\tilde{T}_{BA} = -\frac{1}{2\phi^2 - 8} \left( 2A_x - \phi A_x - 4T_{BA} + \phi^2 T_{BA} \right).$$

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

\[ \tilde{T}_{AB}^{M_3} = -\frac{1}{4\phi + 2\phi^2 - 14} (2B_x + 3B_z + \phi\tau_zB - 2\phi B_x - \phi B_z - 3\tau_zB + (\phi^2 + \phi - 4) \tau_xB), \]
\[ \tilde{T}_{BA}^{M_3} = \frac{1}{2\phi^2 - 8} (-2A_x + r (\phi^2 - 4) + \phi A_z + 4\tau_xA - \phi^2 \tau_xA). \]

In both cases, therefore, an increase in \( \tau_xB \) or \( \tau_zB \) decreases \( T_{AB} \), while an increase in \( \tau_xA \) decreases \( T_{BA} \). Thus, an increase in \( \tau_xB \) (\( \tau_zB \)) harms firm A (firm \( \alpha \)) but benefits firm \( \alpha \) (firm A).

If \( x_{AB} + z_{AB} = x_{BA} \) holds, there do exist spillover effects. That is, an increase in \( \tau_xB \) or \( \tau_zB \) not only decreases \( T_{AB} \) but also increases \( T_{BA} \) and an increase in \( \tau_xA \) 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

\[
\max \Pi_T = \max \{T_{AB}(x_{AB} + z_{AB}) + T_{BA}x_{BA} - (f_T + r_T(x_{AB} + z_{AB}))\}
\]
\[
s.t. x_{BA} = x_{AB} + z_{AB}
\]

With \( \phi = 0 \), we obtain\(^{27}\)

\[
\tilde{T}_{AB}^{M_2}\big|_{\phi=0} = \frac{1}{17} (14r - 7A_x + 18B_x + 27B_z + 14\tau_xA - 36\tau_xB - 27\tau_zB),
\]
\[
\tilde{T}_{BA}^{M_2}\big|_{\phi=0} = \frac{1}{44} (14r + 15A_x - 4B_x - 6B_z - 30\tau_xA + 8\tau_xB + 6\tau_zB).
\]

The economic intuition behind the spillover effects are as follows. When \( \tau_xB \) or \( \tau_zB \) 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 \( \tau_xA \), 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 \( A (\alpha) \) necessarily gains from an increase in \( \tau_zB \) (\( \tau_xB \)). However, the gain for firm A is magnified, because \( \tau_zB \) also increases \( T_{BA} \).\(^\text{28}\)

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 \( \alpha \) unless \( \phi = 0 \).
Proposition 9 If \( x_{AB} + z_{AB} \neq x_{BA} \), then an increase in \( \tau_{xB} \) or \( \tau_{zB} \) decreases \( T_{AB} \). An increase in \( \tau_{xB} \) (\( \tau_{zB} \)) harms firm A (firm \( \alpha \)) and benefits firm \( \alpha \) (firm A) even if \( \phi = 0 \). If \( x_{AB} + z_{AB} = x_{BA} \), then an increase in \( \tau_{xB} \) or \( \tau_{zB} \) decreases \( T_{AB} \) and increases \( T_{BA} \). An increase in \( \tau_{xB} \) (\( \tau_{zB} \)) benefits firm \( \alpha \) (firm A) even if \( \phi = 0 \). Firm B loses from an increase in \( \tau_{zB} \) 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 (\( \alpha \)) when \( \tau_{xB} \) (\( \tau_{zB} \)) 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.\(^{20}\) Then we have

\[
\begin{align*}
x_{AB}^{M3}_{\phi=0, \tau_{zB}=0} &= \frac{1}{3} (B_x - 2T_{AB} - 2\tau_{xB}), \\
z_{AB}^{M3}_{\phi=0, \tau_{zB}=0} &= \frac{1}{2} (B_z - T_{AB}), \\
T_{AB}^{M3}_{\phi=0, \tau_{zB}=0} &= \frac{1}{14} (2B_x + 3B_z - 4\tau_{xB}).
\end{align*}
\]

The profits of firm T from serving both firms A and \( \alpha \) are \( \frac{1}{168} (2B_x + 3B_z - 4\tau_{xB})^2 \). When firm T serves only firm \( \alpha \), we have \( T_{AB} = \frac{1}{2} B_z \) and the profits from serving only firm \( \alpha \) 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 \( \alpha \) are greater than those from serving both firms A and \( \alpha \).

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 \( \tau_{xB} \) (\( \tau_{zB} \)) may lead firm T to stop serving firm X (Z).

This may increase \( T_{BA} \).

\(^{20}\) 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

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

where $\Gamma_{AB}$ is the freight rate for firm $\alpha$. Firm $T$ sets three freight rates, $T_{AB}$, $T_{BA}$ and $\Gamma_{AB}$.

The profits of firm $\alpha$, $\Pi_\alpha$, 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

$$x_{AB} = -\frac{1}{2(\phi^2 - 3)} \left( \begin{array}{c} 2B_x - 4\tau_{xB} - 4T_{AB} + \phi \tau_{zB} \\ -\phi B_z + \phi \Gamma_{AB} + \phi^2 \tau_{xB} + \phi^2 T_{AB} \end{array} \right),$$

$$x_{BB} = -\frac{1}{2(\phi^2 - 3)} \left( \begin{array}{c} 2\tau_{xB} + 2B_x + 2T_{AB} + \phi \tau_{zB} \\ -\phi B_z + \phi \Gamma_{AB} - \phi^2 \tau_{xB} - \phi^2 T_{AB} \end{array} \right),$$

$$z_{AB} = \frac{1}{2(\phi^2 - 3)} \left( 3\tau_{zB} - 3B_z + 3\Gamma_{AB} - \phi \tau_{xB} + 2\phi B_z - \phi T_{AB} \right),$$

$$x_{BA} = -\frac{1}{2(\phi^2 - 3)} \left( 2A_x - 4\tau_{xA} - 4T_{BA} - \phi A_z + \phi^2 \tau_{xA} + \phi^2 T_{BA} \right),$$

$$x_{AA} = -\frac{1}{2(\phi^2 - 3)} \left( 2\tau_{xA} + 2A_x + 2T_{BA} - \phi A_z - \phi^2 \tau_{xA} - \phi^2 T_{BA} \right),$$

$$z_{AA} = -\frac{1}{2(\phi^2 - 3)} \left( 3A_z + \phi \tau_{xA} - 2\phi A_x + \phi T_{BA} \right).$$

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

$$\tilde{T}_{AB}^{m1} = \frac{1}{13\phi^2 - 48} \left( \begin{array}{c} (24 - 7\phi^2) \tau_{xB} - 3\phi \tau_{zB} \\ -12B_x - 24\tau_T + 3\phi B_z + 3\phi \tau_T + 2\phi^2 B_x + 7\phi^2 \tau_T \end{array} \right),$$

$$\tilde{T}_{AB}^{m1} = \frac{1}{13\phi^2 - 48} \left( \begin{array}{c} (24 - 7\phi^2) \tau_{zB} + \phi (-4 + \phi^2) \tau_{xB} - 24B_z - 24\tau_T \\ +14\phi B_x + 4\phi \tau_T - 4\phi^3 B_x + 7\phi^2 B_z + 7\phi^2 \tau_T - 3\phi \tau_T \end{array} \right),$$

$$\tilde{T}_{BA}^{m1} = \frac{1}{2\phi^2 - 8} \left( 4\tau_{xA} - 2A_x + \phi A_z - 2\phi^2 \tau_{xA} \right).$$
These imply that an increase in $\tau_{xB}$ ($\tau_{zB}$) lowers $T_{AB}$ ($\Gamma_{AB}$) and raises $\Gamma_{AB}$ ($T_{AB}$) unless the two goods are independent (i.e., $\phi = 0$). If the two goods are independent (i.e., $\phi = 0$), a change in $\tau_{xB}$ ($\tau_{zB}$) does not affect $\Gamma_{AB}$ ($T_{AB}$). When $\tau_{xB}$ ($\tau_{zB}$) 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 $\Gamma_{AB}$ to restore the balance between $x_{AB}$ and $z_{AB}$. We should note that an increase in $\tau_{xB}$ increases the effective marginal cost for firm $A$ (i.e., $\tau_{xB} + T_{AB}$) and an increase in $\tau_{zB}$ increases the effective marginal cost for firm $\alpha$ (i.e., $\tau_{zB} + \Gamma_{AB}$). Thus, the effective marginal costs of both firms increase when $\tau_{xB}$ or $\tau_{zB}$ rises, implying that firms $A$ and $\alpha$ lose and firm $B$ gains.

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

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

Solving this, we have

$$\tilde{T}_{m3}^{AB} = \frac{1}{13\phi^2 - 48} \left( (24 - 7\phi^2) \tau_{xB} - 3\phi \tau_{zB} - 12B_x + 3\phi B_x + 2\phi^2 B_x \right),$$

$$\tilde{\Gamma}_{m3}^{AB} = \frac{1}{13\phi^2 - 48} \left( \phi \left( \phi^2 - 4 \right) \tau_{xB} + (24 - 7\phi^2) \tau_{zB} - 24B_x + 14\phi B_x - 4\phi^3 B_x + 7\phi^2 B_x \right),$$

$$\tilde{T}_{m3}^{BA} = \frac{1}{2\phi^2 - 8} \left( -4r_T + 4\tau_{xA} - 2A_x + \phi A_z + r_T\phi^2 - \phi^2 \tau_{xA} \right).$$

Again, an increase in $\tau_{xB}$ ($\tau_{zB}$) leads firm $T$ to lower $T_{AB}$ ($\Gamma_{AB}$) and raise $\Gamma_{AB}$ ($T_{AB}$).

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 $\phi = 0$.

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

subject to $x_{BA} = x_{AB} + z_{AB}$.
If $\phi = 0$ holds, we obtain

$$\tilde{T}_{AB}^{m2}\bigg|_{\phi=0} = \frac{1}{44} (8r - 30\tau_{xB} + 8\tau_{xA} - 6\tau_{zB} - 4A_X + 15B_X + 6B_Z),$$

$$\tilde{\Gamma}_{AB}^{m2}\bigg|_{\phi=0} = \frac{1}{11} (2r - 2\tau_{xB} + 2\tau_{xA} - 7\tau_{zB} - A_X + B_X + 7B_Z),$$

$$\tilde{T}_{AB}^{m2}\bigg|_{\phi=0} = \frac{1}{44} (14r + 8\tau_{xB} - 30\tau_{xA} + 6\tau_{zB} + 15A_X - 4B_X - 6B_Z).$$

An increase in $\tau_{xB}$ or $\tau_{zB}$ decreases both $T_{AB}$ and $\Gamma_{AB}$ and increases $T_{BA}$ while an increase in $\tau_{xA}$ increases both $T_{AB}$ and $\Gamma_{AB}$ 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 $\Gamma_{AB}$ to keep a full load in both directions. When $\tau_{xB}$ ($\tau_{zB}$) rises, firm $T$ avoids the reduction of the load from country $A$ to country $B$ by lowering $\Gamma_{AB}$ ($T_{AB}$) 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 $\tau_{xA}$, firm $T$ increases both $T_{AB}$ and $\Gamma_{AB}$ 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 $\alpha$ ($A$) necessarily gains from an increase in $\tau_{xB}$ ($\tau_{zB}$).

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 $\tau_{xB}$ ($\tau_{zB}$) decreases $T_{AB}$ ($\Gamma_{AB}$) but increases $\Gamma_{AB}$ ($T_{AB}$). An increase in $\tau_{xB}$ or $\tau_{zB}$ harms both firms $A$ and $\alpha$ and benefits firm $B$. If $x_{AB} + z_{AB} \neq x_{BA}$ and $\phi = 0$, then the effect of an increase in $\tau_{xB}$ ($\tau_{zB}$) is just to decrease $T_{AB}$ ($\Gamma_{AB}$). An increase in $\tau_{xB}$ harms firm $A$ and benefits firm $B$ while an increase in $\tau_{zB}$ harms firm $\alpha$. If $x_{AB} + z_{AB} = x_{BA}$, then an increase in $\tau_{xB}$ or $\tau_{zB}$ decreases both $T_{AB}$ and $\Gamma_{AB}$ but increases $T_{BA}$. Even if $\phi = 0$, an increase in $\tau_{xB}$ benefits firm $\alpha$ and an increase in $\tau_{zB}$ 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

$$x_{C1}^{1AB} = \frac{1}{9b} (B - 2\tau_B - 4r_1 + 2r_2), x_{C2}^{1AB} = \frac{1}{9b} (B - 2\tau_B + 2r_1 - 4r_2),$$ $$x_{C1}^{1BA} = x_{C2}^{1BA} = \frac{1}{9a} (A - 2\tau_A),$$ $$T_{C1}^{AB} = \frac{1}{6} (B - 2\tau_B + 2r_1 + 2r_2), T_{C1}^{BA} = \frac{1}{6} (A - 2\tau_A),$$ $$\Pi_{C1}^{T1} = \frac{1}{81b} (B - 2\tau_B - 4r_1 + 2r_2)^2 + \frac{1}{81a} (A - 2\tau_A)^2 - f_{T1},$$ $$\Pi_{C1}^{T2} = \frac{1}{81b} (B - 2\tau_B + 2r_1 - 4r_2)^2 + \frac{1}{81a} (A - 2\tau_A)^2 - f_{T2}.$$ 

The following should be noted. First, $(B - 2\tau_B)a - (A - 2\tau_A)b > 2(2ar_1 - ar_2)$ with $x_{1AB} > x_{1BA}$ and $(B - 2\tau_B)a - (A - 2\tau_A)b > 2(-ar_1 + 2ar_2)$ 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

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

\[
\Pi_{A}^{C_{1mon}} = \frac{4}{81b} (B - r_1 - r_2)^2 + \frac{49A^2}{324a}.
\]

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

\[
\Pi_{A}^{C_{1mon}} - \Pi_{A}^{\tau_1} = -\frac{1}{1296ab} (29bA^2 + 180bA\tau_A - 28aB^2 - 16aBr_1 + 128aBr_2 + 36b\tau_A^2 + 80a^2 - 128ar_1r_2 - 64a^2),
\]

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.

References


Figure 1 (a): Import quotas set by country \( B \) 
\( (x_{AB} > x_{BA} \text{ with free trade}) \)
Figure 1 (b): Import quotas set by country B  
\( x_{AB} = x_{BA} \) with free trade

\[ x_{AB}, x_{BA} \]

\[ B_0 \quad B_2 \quad F \]

\[ \frac{(A-2r_T)}{6a} \quad \frac{(A+B-2r_T)}{6(a+b)} \]
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 $B$

$\left( x_{AB} > x_{BA} \text{ with free trade} \right)$

$\chi_{AB}, \chi_{BA}$

$\frac{(B-2r_T)}{6b} F_A$

$\frac{(A-2r_T)}{6a} F_B$

$\frac{(Ba-Ab-2ar_T)}{2a}$

Type 1B, Type 2B, Type 3B
Figure 3 (b): Tariffs set by country $B$

\( (x_{AB} = x_{BA} \text{ with free trade}) \)

\[
\begin{align*}
\left( A + B - 2r_T \right) / 6(a + b) & \quad \text{(Type 2B)} \\
(A - 2r_T) / 6a & \quad (B - A - b + 2br_T) / 2a
\end{align*}
\]
Figure 4 (a): Tariffs set by country A

\((x_{AB} > x_{BA} \text{ with free trade})\)
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

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<td><strong>Country $A$’s tariff</strong></td>
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Table 2: Effects of $\tau_{xB} \uparrow$ on freight rates with price discrimination

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<td>$\phi \neq 0$</td>
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- $T_{AB}$  
- $\Gamma_{AB}$  
- $T_{BA}$