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# TARIFFS AND TRADE LIBERALIZATION
# WITH NETWORK EXTERNALITIES

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# TARIFFS AND TRADE LIBERALIZATION WITH NETWORK EXTERNALITIES*

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### Abstract

This paper constructs a reciprocal market model of intra-industry trade in network goods to consider the implications of network externalities for an optimal tariff policy and the welfare effects of bilateral tariff reductions. We show that the degree of network externalities nontrivially affects the sign of the Nash equilibrium tariff. Then, we prove that network externalities amplify the gains from tariff reductions. These results help better understand the implications of trade-related issues in network industries.

## I. INTRODUCTION

During the last decades, world trade has dramatically grown. As to the driving forces of such growth of trade flows, Baier and Bergstrand (2001) provide evidences suggesting that 'income growth, tariff rate reductions, and transport-cost declines all contributed nontrivially to the real growth of world trade' (p. 19) and that 'the relative contribution of trade liberalization was three times that of transport costs.' (p. 23) Moreover, recent growth in trade of network goods, e.g., personal computers and computer-related products, has made both domestic and foreign brands available around the world.[1] These facts motivate us to consider welfare implications of trade in network goods because a change in trade flows possibly has a significant effect on welfare through network externalities. Network externalities refer to the situation in which 'the utility derived from the consumption of these goods is affected by the number of other people using similar or compatible products.' (Shy, 2001, p. 3)[2]

Taking into account these facts, this paper theoretically addresses some implications of network externalities on trade policies and trade liberalization. For this purpose, we formulate a two-country reciprocal market model of international oligopoly in which consumption of the oligopolized good exhibits an network externality. We show two results. First, we compute and characterize the Nash equilibrium tariff. An intriguing finding is that the sign of the equilibrium tariff is highly sensitive to the degree of network externalities. Second, we consider the welfare effect of bilateral tariff reductions. It is shown that the presence of network externalities amplifies positive gains from freer trade.

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[1]Suh and Poon (2006) empirically attribute export growth of the Korean computer industry to tariff reductions under Information Technology Agreement (ITA) of the WTO. Portugal-Perez et al. (2009, p. 13) also find an evidence that 'East Asian & Pacific countries are clearly the major source of EU imports' of information technology products.

[2]In the literature, 'network effects' and 'network externalities' are sometimes distinguished. For example, Liebowitz and Margolis (1994, p. 135) define the network effect as 'the circumstance in which the net value of an action (consuming a good, subscribing to telephone service) is affected by the number of agents taking equivalent actions.' According to them, a network externality is one special case of such network effects.

The relevance of network industries has long been recognized and a body of literature has been accumulated in industrial organization. Among others, Katz and Shapiro (1985) present an oligopoly model of network externalities and explore effects of a change from incompatibility to compatibility. In a similar model, Economides (1996) shows that new entry can benefit the incumbents under network externalities. While these papers assume a closed economy, some recent studies apply them to open economies. Extending the Katz-Shapiro model to accommodate a foreign firm, Barrett and Yang (2001) examine a rational choice of incompatibility. Kikuchi (2005, 2007) and Kikuchi and Kobayashi (2006, 2007) extend the models of Katz and Shapiro (1985) and Economides (1996) to consider how network externalities affect the determinants and impacts of trade. Yano and Dei (2005, 2006) find an intriguing role of network externalities according to which the monopolistic firm prices below marginal cost under network externalities and discrete demand shifts. More recently, Ji and Daitoh (2008) compute the optimal subsidy to interconnection investments. Klimenko and Saggi (2007) develop a duopoly model with network externalities to explore the effects of foreign direct investment. Note however that these predecessors develop few arguments on trade policies and welfare.

On the other hand, Krishna (1988) and Klimenko (2009) address trade policy issues in a model of oligopolistic network industries and our interests partly overlap theirs. Hence, it should be made clear what is differentiated between this paper and these two works. Krishna (1988) considers the effects of trade policies, focusing on a unilateral choice by a country. Therefore, she a priori rules out the possibility that 'foreign governments may well retaliate with consequent possible losses for all parties.' (p. 304) Relaxing Krishna's (1988) assumption of no retaliation, we characterize the Nash equilibrium in which both countries noncooperatively choose the tariff.

The differences between Klimenko (2009) and us are as follows. First, his result hinges on the assumption that firms play a Bertrand game by choosing price. In contrast, we focus on the case in which strategic substitutes hold

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by extending a Cournot model of Katz and Shapiro (1985). Second, in his Footnote 11, Klimenko (2009, p. 542) suggests that it suffices to exclusively focus on the market of one country. However, we demonstrate that a parallel no longer survives our model and thus taking into account two segmented markets is crucial. Third, we address bilateral tariff reductions affect welfare, which is left an open question in Klimenko (2009).[3] With these differences in mind, we will complement the arguments of Krishna (1988) and Klimenko (2009). Hence, one should not conclude that our contribution is marginal and small.

This paper is organized as follows. Section 2 presents a model. Section 3 solves a noncooperative tariff-setting game and characterizes the Nash equilibrium tariff. Section 4 considers welfare effects of bilateral trade liberalization. Section 5 concludes the paper. Appendix shows the validity of our core results by relaxing the assumption of the 'fulfilled expectations equilibrium'.

## II. A MODEL

Consider two identical countries (Home and Foreign), two tradable goods (Goods 1 and 2) and one factor (labor). All the Foreign variables are asterisked. Good 2 (numeraire) is competitively supplied with a unitary input coefficient so that the wage rate is one in both countries. The market of Good 1 is segmented and duopolized by a Home firm (firm X) and a Foreign firm (firm Y). Each firm incurs a constant marginal cost $c \geq 0$. Imports are subject to a specific tariff $\tau$ and $\tau^*$.[4]

Consumption of Good 1 exhibits a network externality and we employ Katz and Shapiro's (1985) formulation. In Home, there is a mass of consumers uniformly distributed in $[0, a]$ each of whom buys either one unit of

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[3]On the other hand, we consider no compatibility standard policy to which Klimenko (2009) pays special attention.

[4]Negativity of $\tau$ and $\tau^*$ corresponds to an import subsidy. Throughout this paper, we assume that each country's government taxes only the firm of the other country. This assumption is justified invoking that export subsidies are in principle prohibited under the GATT/WTO rule.

Good 1 or nothing. We assume that both firms supply a fully compatible product.[5] When consumer $r \in [0, a]$ purchases Good 1 from the Home firm (resp. Foreign firm), her consumer surplus is $r + bZ - p$ (resp. $r + bZ - p^*$), where $r > 0$ is consumer $r$'s intrinsic utility, $Z$ is the worldwide network size and the parameter $b \geq 0$ measures the degree of network externality. Hence, if both firms are active, we have $r + bZ - p = r + bZ - p^*$. Letting $p - bZ = p^* - bZ = \widetilde{p}$, consumer $r$ buys Good 1 if and only if $r - \widetilde{p} \geq 0$ since purchasing nothing yields zero utility. Thus, any consumer $r \geq \widetilde{p}$ purchases Good 1 and aggregate demand in Home becomes $\int_{\widetilde{p}}^{a} 1 dr = a - \widetilde{p}$. Since the total supply in Home is $x + y$, the market-clearing condition in Home is $a - \widetilde{p} = x + y$ which is inverted to get Home's inverse demand function: $p = a + bZ - x - y$. Foreign's counterpart is similarly obtained as $p^* = a + bZ - x^* - y^*$. Therefore, consumer surplus in Home is computed as

$$\int_{\widetilde{p}}^{a} (r - \widetilde{p}) \, dr = \frac{a^2}{2} - a\widetilde{p} + \frac{\widetilde{p}^2}{2} = \frac{a^2}{2} - a(a - x - y) + \frac{(a - x - y)^2}{2} = \frac{(x+y)^2}{2},$$

(1)

where the second equality comes from the market-clearing condition. In a parallel way, Foreign's consumer surplus is $(x^* + y^*)^2/2$.

Under the underlying assumptions, the profit of firms X and Y is respectively defined by

$$\pi = (a + bZ - c - x - y)x + (a + bZ - c - \tau^* - x^* - y^*)x^*$$
$$\pi^* = (a + bZ - c - \tau - x - y)y + (a + bZ - c - x^* - y^*)y^*$$

Our model comprises three stages. The Home and Foreign governments noncooperatively choose tariffs in the first stage. In the second stage, consumers form expectations about the size of the network. Taking the tariffs and consumer expectations, firms play a duopoly game in the third stage. To solve the game with backward induction, we begin by finding a Cournot-Nash equilibrium. Note that in choosing outputs each firm takes $Z$ as given while

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[5]Mobile communication services are a typical example of a network good which has internationally full compatibility.

it holds that $Z = x + x^* + y + y^*$ ex post.[6] Then, the first-order conditions are

$$\frac{\partial \pi}{\partial x} = a + bZ - c - 2x - y = 0$$

$$\frac{\partial \pi}{\partial x^*} = a + bZ - c - \tau^* - 2x^* - y^* = 0$$

$$\frac{\partial \pi^*}{\partial y} = a + bZ - c - \tau - x - 2y = 0$$

$$\frac{\partial \pi^*}{\partial y^*} = a + bZ - c - x^* - 2y^* = 0.$$

In the fulfilled expectations equilibrium, we have $Z = x + x^* + y + y^*$. Substituting this into the above system of equations and solving for outputs, the equilibrium outputs are

$$x = \frac{3(a - c) + (3 - 5b)\tau - b\tau^*}{3(3 - 4b)} \tag{2}$$

$$x^* = \frac{3(a - c) - b\tau + (7b - 6)\tau^*}{3(3 - 4b)} \tag{3}$$

$$y = \frac{3(a - c) + (7b - 6)\tau - b\tau^*}{3(3 - 4b)} \tag{4}$$

$$y^* = \frac{3(a - c) - b\tau + (3 - 5b)\tau^*}{3(3 - 4b)}. \tag{5}$$

In order to guarantee the stability of Cournot-Nash equilibrium, we make:

**Assumption 1:** $3 - 4b > 0$ or equivalently $b < 3/4$.

It is easy to find that the maximized profit of firm X (resp. firm Y) equals $x^2 + x^{*2}$ (resp. $y^2 + y^{*2}$). Hence, each country's welfare $U$ and $U^*$, which consists of consumer surplus, profits and tariff revenue, is obtained as

$$U = \frac{(x + y)^2}{2} + x^2 + x^{*2} + \tau y \tag{6}$$

$$U^* = \frac{(x^* + y^*)^2}{2} + y^2 + y^{*2} + \tau^* x^*. \tag{7}$$

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[6]Economides (1996) and Barrett and Yang (2001) make the same assumption while Ji and Daitoh (2008) alternatively assume that consumers make expectations *after* a duopoly game. Appendix shows that our results are valid in both cases.

Substituting (2)-(5) into (6), it becomes a function of $\tau$ and $\tau^*$:

$$
\begin{aligned}
U(\tau, \tau^*) &= \frac{1}{2}\left[\frac{6(a-c)+(2b-3)\tau-2b\tau^*}{3(3-4b)}\right]^2 + \left[\frac{3(a-c)+(3-5b)\tau-b\tau^*}{3(3-4b)}\right]^2 \\
&\quad + \left[\frac{3(a-c)-b\tau+(7b-6)\tau^*}{3(3-4b)}\right]^2 + \frac{\tau\left[3(a-c)+(7b-6)\tau-b\tau^*\right]}{3(3-4b)}.
\end{aligned}
$$

$$(8)$$

This defines the Home government's payoff function in the trade policy game. Note that Foreign's counterpart can be defined by $U(\tau^*, \tau)$ since both countries are symmetric.

<h3 style="text-align:center">III. NASH EQUILIBRIUM TARIFFS</h3>

Turning to the first stage of our game, this section characterizes the subgame perfect Nash equilibrium tariff. The government of Home (resp. Foreign) chooses $\tau$ (resp. $\tau^*$) to maximize $U(\tau, \tau^*)$ (resp. $U(\tau^*, \tau)$). The resulting first-order condition for welfare maximization is

$$
\begin{aligned}
U_\tau &\equiv \frac{\partial U(\tau, \tau^*)}{\partial \tau} = \frac{3(9-20b)(a-c)+(-112b^2+198b-81)\tau+b(4b+3)\tau^*}{9(3-4b)^2} = 0 \\
U_{\tau^*}^* &\equiv \frac{\partial U(\tau^*, \tau)}{\partial \tau^*} = \frac{3(9-20b)(a-c)+b(4b+3)\tau+(-112b^2+198b-81)\tau^*}{9(3-4b)^2} = 0.
\end{aligned}
$$

At this stage, we require two more technical assumptions. The first is the second-order condition for welfare maximization. This is given by $-112b^2 + 198b - 81 < 0$ or equivalently $b < 9/14 \approx 0.64$. The second is the stability condition, which is

$$
\begin{vmatrix} U_{\tau\tau} & U_{\tau\tau^*} \\ U_{\tau^*\tau}^* & U_{\tau^*\tau^*}^* \end{vmatrix} = \frac{\left(-108b^2+201b-81\right)\left(-116b^2+195b-81\right)}{81(3-4b)^4} > 0.
$$

Noting that the second-order condition implies that $-116b^2 + 195b - 81 < 0$, the stability condition is equivalent to $-108b^2 + 201b - 81 < 0$, i.e., $b < \left(67 - \sqrt{601}\right)/72 \approx 0.59$. Consequently, in order to ensure (i) the second-order condition for profit maximization, (ii) the stability of the second-stage

game, (iii) the second-order condition for welfare maximization and (iv) the stability of the first-stage game, let us make:

**Assumption 2:** $-108b^2 + 201b - 81 < 0$ or equivalently $b < \left(67 - \sqrt{601}\right)/72 \approx 0.59$.

Solving the above system of the first-order condition for welfare maximization, the tariff rate in the subgame perfect Nash equilibrium is computed as

$$\tau^N = \frac{(9 - 20b)(a - c)}{36b^2 - 67b + 27},$$ (9)

where superscript $N$ indicates the subgame perfect Nash equilibrium. Because the denominator is positive from Assumption 2, (9) immediately leads to:

*Proposition 1: The subgame perfect Nash equilibrium tariff is positive (resp. negative, zero) according as $b < 9/20 = 0.45$ (resp. $b > 9/20$, $b = 9/20$).*

The intuitions behind Proposition 1 are as follows. As Brander and Spencer (1984) show in a reciprocal market model without network externalities, tariff protection shifts profits from the Foreign firm to the Home firm. In the presence of network externalities, we have another effect of protection. Imposing a positive tariff encourages domestic supply of the home firm, discourages import, and decreases total consumption. This decrease in consumption has a direct effect of decreasing consumer surplus and an indirect effect of lowering the network size, both of which are welfare-reducing. What deserves special attention is that the indirect effect through network sizes crucially affects the firm profit as well as the consumer. As Economides (1996) shows in a closed economy context, firms can make a larger profit under network externalities, which implies that the profit-shifting motive of protection is weakened. Therefore, under a sufficiently strong network externality, it is each government's interest to subsidize import. In contrast,

when the network externality is small enough, the rent-shifting motive still plays a dominant role, resulting in an import tariff as shown by Brander and Spencer (1984).

While Proposition 1 concerns whether the Nash equilibrium tax is either an import tariff or an import subsidy, it is of another interest to address how it responds to expansion of network externalities. The result, the proof of which is left in Appendix, is formalized in:

*Proposition 2: The subgame perfect Nash equilibrium tariff is increasing (resp. decreasing) in $b$ according as $b < \left(36 - \sqrt{736}\right)/80 \approx 0.1108$ (resp. $b > \left(36 - \sqrt{736}\right)/80$).*

**(Figure 1 around here)**

The intuitive explanations behind Proposition 1 are also helpful in considering Proposition 2. Suppose first that $b$ is small enough and hence the rent-shifting motive plays a dominant role. Then, an increase in $b$ amplifies the rent-shifting motive and the resulting tariff level. If, on the other hand, $b$ is large, the negative effect on consumer surplus and network externality becomes larger than the positive effect on the firm profit. Therefore, the government is motivated either to reduce an import tariff or to impose a negative tariff (import subsidy) to enjoy gains from network externalities. However, if $b$ is much larger, $\partial \tau^N / \partial b$ turns to a positive sign. This is because the rent-shifting motive once again dominates.[7] Accordingly, a higher tariff is called for as $b$ increases sufficiently.

Figure 1 diagrammatically depicts these considerations. The sign of $\partial \tau^N / \partial b$ is positive if $b$ is either sufficiently small or sufficiently large. This is because in both cases the profit-shifting is a major motive for tariff protection. In contrast, when $b$ falls in an intermediate interval, the negative effect on consumers plays a key role in determining the tariff level. Thus, we have

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[7]Recall that an increase in $b$ has a positive effect both on consumer utility and the firm profit.

$\partial \tau^N / \partial b < 0$, i.e., a strengthened network externality reduces the equilibrium tariff level.

## IV. BILATERAL TRADE LIBERALIZATION

The previous section assumes that the Home and Foreign governments non-cooperatively choose a tariff. While trade policies are still determined non-cooperatively depending on commodities, tariffs are cooperatively reduced mainly by the WTO participants as Baier and Bergstrand's (2001) evidence suggests. This section turns to the case in which both governments impose a common tariff and considers welfare effects of bilateral reductions in such common tariffs.

For this purpose, let us define welfare of each country under the common tariff. Substituting $\tau = \tau^*$ in (8), we have

$$U(\tau, \tau) = \frac{1}{2} \left[ \frac{2(a-c) - \tau}{3 - 4b} \right]^2 + \left[ \frac{a - c + (1 - 2b)\tau}{3 - 4b} \right]^2 + \frac{[a - c + (1 - 2b)\tau][a - c + 2(b-1)\tau]}{(3 - 4b)^2}$$

$$= \frac{(4b - 1)\tau^2 - 2(4b + 1)(a - c)\tau + 8(a - c)^2}{2(3 - 4b)^2} \equiv W(\tau).$$

Carefully looking at $W(\cdot)$ above, the presence of network externalities provides us with two possibilities on the dependence of $W$ on $\tau$. The first case is that $W(\cdot)$ is strictly convex, which holds if network externalities are strong enough to have $b > 1/4$ and the second is that $W(\cdot)$ is strictly concave under $b < 1/4$. Since the second case is a mere reestablishment of the well-known result in the literature assuming away network externalities, let us first address the first case in which network externalities are relevant. In this case, we can establish:[8]

*Proposition 3: Under $3/4 > b > 1/4$, bilateral trade liberalization, i.e., simultaneous tariff reductions of both countries, monotonically improves welfare.*

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[8]The proof is given in Appendix. Note that Assumption 2 is not needed in the argument in this section.

*Moreover, an increase in b enhances gains from trade liberalization.*[9]

**(Figure 2 around here)**

The intuitions behind Proposition 3 are as follows. From Eqs. (2)-(5), a bilateral tariff reduction leads to an increase in imports and total supply while domestic supply can both increase and decrease. Therefore, the profit from exporting necessarily increases and the profit from domestic supply may or may not increase. However, the former is larger than the latter even if the latter is negative. As a result, bilateral tariff reductions favorably affect the monopolistic firm. On the other hand, the consumer necessarily gains from reduces tariffs because both consumer surplus and network externality are enhanced.

Proposition 3, which is diagrammatically shown in Figure 2, tells us that trade liberalization in the form of cooperative tariff reductions is Pareto-improving in the sense that neither the consumer nor the firm loses from it. Furthermore, welfare gains are larger as network externalities are stronger. The underlying reason is the same as that of Propositions 1 and 2. In the presence of network externalities, trade liberalization benefits not only the consumer but also the oligopolistic firm since network size expansion positively affects the firm profit.

**(Figure 3 around here)**

We close this section by briefly addressing the case of $b < 1/4$, namely, $W(\cdot)$ is strictly concave. It immediately follows from (11) that $W'(\cdot) < 0$ for any $\tau \in [0, \overline{\tau}]$. However, when we allow for import subsidies, $W(\cdot)$ reaches a maximum at

$$\widetilde{\tau} = \frac{(4b+1)(a-c)}{4b-1} < 0,$$

---

[9]In this section, we need Assumption 1 but not Assumption 2.

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by solving $W'(\tau) = 0$. In other words, welfare of each country and the world is maximized if both countries cooperatively choose $\tilde{\tau}$. Summarizing the findings so far, one can depicts Figure 3 as a locus of $W(\cdot)$ under $b < 1/4$. While world welfare maximization is achieved at $\tilde{\tau}$, we can conclude that bilateral tariff reductions monotonically benefit all countries in this case as well. In addition, we see that an increase in $b$ shifts up the locus of $W$ upward as in the case of convex $W$. Therefore, network externalities can serve as a driving force for mutually beneficial trade liberalization.[10]

## V. CONCLUDING REMARKS

We have made clear some implications of network externalities for optimal trade policies and welfare effects of trade liberalization. First, the Nash equilibrium tariff is computed and some of its properties are characterized. Second, gains from bilateral trade liberalization are enhanced by network externalities, which complements the result of Economides (1996) and Kikuchi and Kobayashi (2007).

While our results help better understanding of trade liberalization and trade policies in the contemporary world, all of them are based on many simplifying assumptions. It is our future research agenda to extend the present attempt to a more general framework and to consider the robustness of them.

## APPENDIX

*Proof of Proposition 2*
Differentiating (9) with respect to $b$ yields

$$\frac{\partial \tau^N}{\partial b} = \frac{9(80b^2 - 72b + 7)(a - c)}{(36b^2 - 67b + 27)^2},$$

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[10]Note again that this conclusion hinges on the assumption that each government taxes the other country's firm only. In addition, it naturally follows that increased $b$ leads to further import subsidies, i.e., $d\tilde{\tau}/db < 0$.

the sign of which depends on that of the quadratic polynomial on the numerator. As Figure 1 depicts, it is positive (resp. negative) when $b < \left(36 - \sqrt{736}\right)/80 \approx 0.1108$ (resp. $b > \left(36 - \sqrt{736}\right)/80$).[11]

*Proof of Proposition 3* The proof consists of two steps. The first step is to show that $W(\tau)$ defined monotonically increases with $b$. To show this, let us differentiate $W(\tau)$ with respect to $b$:

$$\frac{dW(\tau)}{db} = \frac{2[\tau - 2(a-c)][(4b+1)\tau - 8(a-c)]}{(3-4b)^3},$$

which takes zero under either $\tau = 8(a-c)/(4b+1)$ or $\tau = 2(a-c)$. What we show is that $dW/db > 0$ for any $\tau \leq \bar{\tau}$, where $\bar{\tau}$ is a prohibitive tariff defined by

$$\bar{\tau} = \frac{a-c}{2(1-b)} > 0, \tag{10}$$

by setting exports to zero.[12] Comparing $8(a-c)/(4b+1)$ with $\bar{\tau}$ yields

$$\frac{8(a-c)}{4b+1} - \bar{\tau} = \frac{5(3-4b)(a-c)}{2(4b+1)(1-b)} > 0,$$

which in turn implies that $dW/db$ is always positive for any $\tau \leq \bar{\tau}$. In other words, an increase in $b$ unambiguously raises welfare for any tariff level.

The second step is to show that the locus of $W(\tau)$ is always negatively-sloped and becomes steeper as $b$ increases. Differentiating $W(\tau)$ yields

$$W'(\tau) = \frac{(4b-1)\tau - (4b+1)(a-c)}{(3-4b)^2}, \tag{11}$$

which is always negative for any $\tau \leq \bar{\tau}$. Furthermore, differentiating $W'(\tau)$ with respect to $b$, the effect of $b$ on $W'(\cdot)$ becomes

$$\frac{dW'(\tau)}{db} = \frac{4\left[(4b+1)\tau - (4b+5)(a-c)\right]}{(3-4b)^3},$$

---

[11]Note that the larger root of $80b^2 - 72b + 7 = 0$, i.e., $b = \left(36 + \sqrt{736}\right)/80$ is ruled out from Assumption 2.

[12]Substituting $\tau = \tau^*$ into (3) and (4) and setting the resulting expression to zero, (10) is obtained.

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which becomes zero at $\tau = (4b+5)(a-c)/(4b+1)$. Subtracting this from $\bar{\tau}$, we have

$$\frac{(4b+5)(a-c)}{4b+1} - \bar{\tau} = \frac{(2b+3)(3-4b)(a-c)}{2(1-b)(4b+1)} > 0.$$

This inequality implies that $dW'(\tau)/db$ becomes negative for any $\tau \leq \bar{\tau}$, i.e., the bigger $b$, the steeper the slope becomes. Summarizing these results, the relationship between $W$ and $\tau$ is depicted as Figure 1 and we can conclude that $W'(\cdot) < 0$ for any $\tau \in [0, \bar{\tau}]$.

*Consumers' expectations before output decision* The main text has assumed that firms' output decision is made *after* consumers form expectations about the size of the network. This appendix shows the validity of the core results even by relaxing this assumption. The proof completely parallels that of the text, it suffices to sketch the core argument.

When consumers' expectations about $Z$ are made after output decisions, each firm chooses outputs by taking into account their effect on $Z$. In this situation, the Cournot-Nash equilibrium outputs are

$$x = \frac{a - c + (1-b)\tau - 2b\tau^*}{3(1-2b)}, \quad x^* = \frac{a - c + b\tau - 2(1-b)\tau^*}{3(1-2b)}$$

$$y = \frac{a - c - 2(1-b)\tau + b\tau^*}{3(1-2b)}, \quad y^* = \frac{a - c - 2b\tau + (1-b\tau^*)}{3(1-2b)}.$$

Using these, the Home government's payoff function becomes

$$
\begin{aligned}
U(\tau, \tau^*) &= \frac{1}{2}\left[\frac{2(a-c) - (1-b)\tau - b\tau^*}{3(1-2b)}\right]^2 + \frac{a - c + \tau}{3} \cdot \frac{a - c + (1-b)\tau - 2b\tau^*}{3(1-2b)} \\
&\quad + \frac{a - c - 2\tau^*}{3} \cdot \frac{a - c + b\tau - 2(a-b)\tau^*}{3(1-2b)} + \frac{\tau\left[a - c - 2(1-b)\tau + b\tau^*\right]}{3(1-2b)}.
\end{aligned}
$$
(12)

Similarly, the Foreign government's welfare is defined by $U(\tau^*, \tau)$.

In the first stage, each government noncooperatively determines the tariff. Thus, solving the system of the first-order conditions $U_\tau = U^*_{\tau^*} = 0$ yields the subgame perfect Nash equilibrium tariff:

$$\tau^N = \frac{(3 - 8b)(a - c)}{18b^2 - 28b + 9}.$$

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In order to satisfy (i) the second-order condition for profit maximization, (ii) the stability of the second-stage game, (iii) the second-order condition for welfare maximization and (iv) the stability of the first-stage game, we require the denominator to be positive. Consequently, the sign of $\tau^N$ is determined depending on whether $b$ is larger than $3/8$. If $b$ is so large (resp. small) that $b > 3/8$ (resp. $b < 3/8$), an import subsidy (resp. an import tariff) is optimal.

Let us turn to the welfare effects of bilateral tariff reductions. Substituting $\tau = \tau^*$ into (12) yields

$$U(\tau, \tau) \equiv W(\tau) = \frac{(4b-1)\tau^2 - 2(2b+1)(a-c)\tau + 8(1-b)(a-c)^2}{18(1-2b)^2}.$$

Differentiating $W(\cdot)$, we have

$$W'(\tau) = \frac{(4b-1)\tau - (2b+1)(a-c)}{9(1-2b)^2}, \quad W''(\tau) = \frac{4b-1}{9(1-2b)^2}.$$

Thus, $W(\cdot)$ is negatively sloped at $\tau = 0$. Setting the exports to zero, the prohibitive tariff is obtained as $\overline{\tau} = (a-c)/(2-3b) > 0$. Substituting this into $W'(\cdot)$, we have

$$W'(\overline{\tau}) = \frac{-(b+1)(a-c)}{3(1-2b)(2-3b)} < 0,$$

namely, the slope of $W(\cdot)$ is also negative at $\tau = \overline{\tau}$.

The second derivative computed above provides two possibilities on the shape of $W(\cdot)$. If $b > 1/4$ (network externalities are strong enough), $W(\cdot)$ becomes strictly convex and a figure similar to Figure 2 follows. In a parallel way, we can depict a strictly concave locus of $W(\cdot)$ if $b$ is small enough (see Figure 3).

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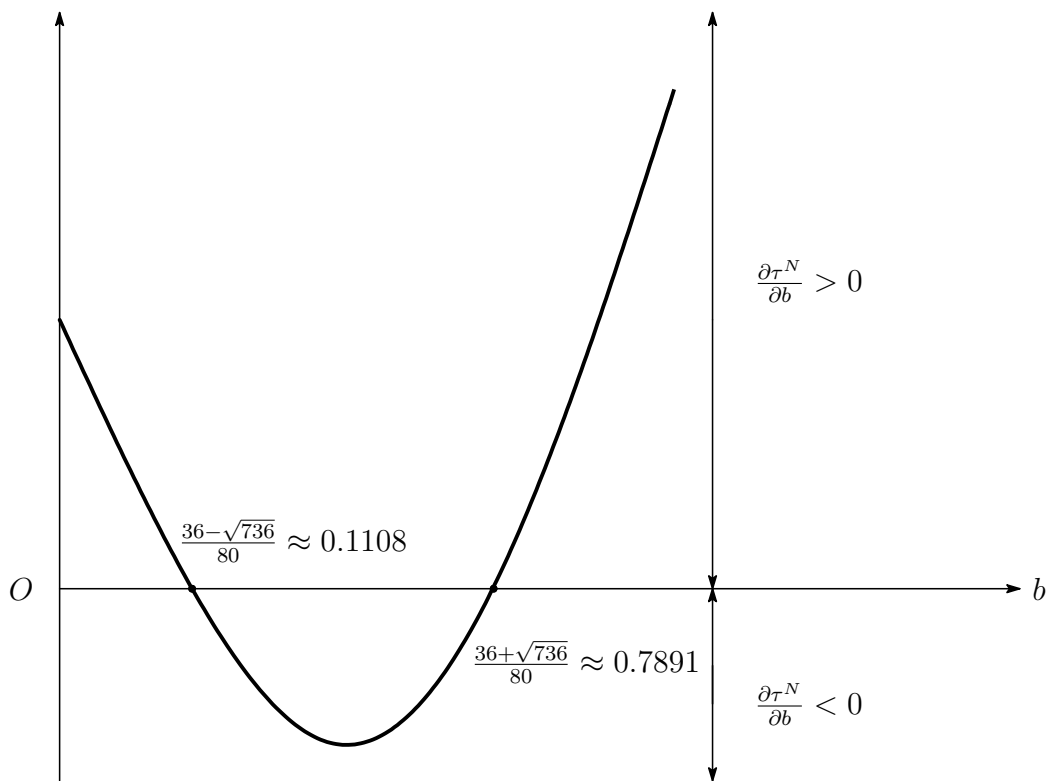
Figure 1: The effect of the expanding network externality on the Nash tariff
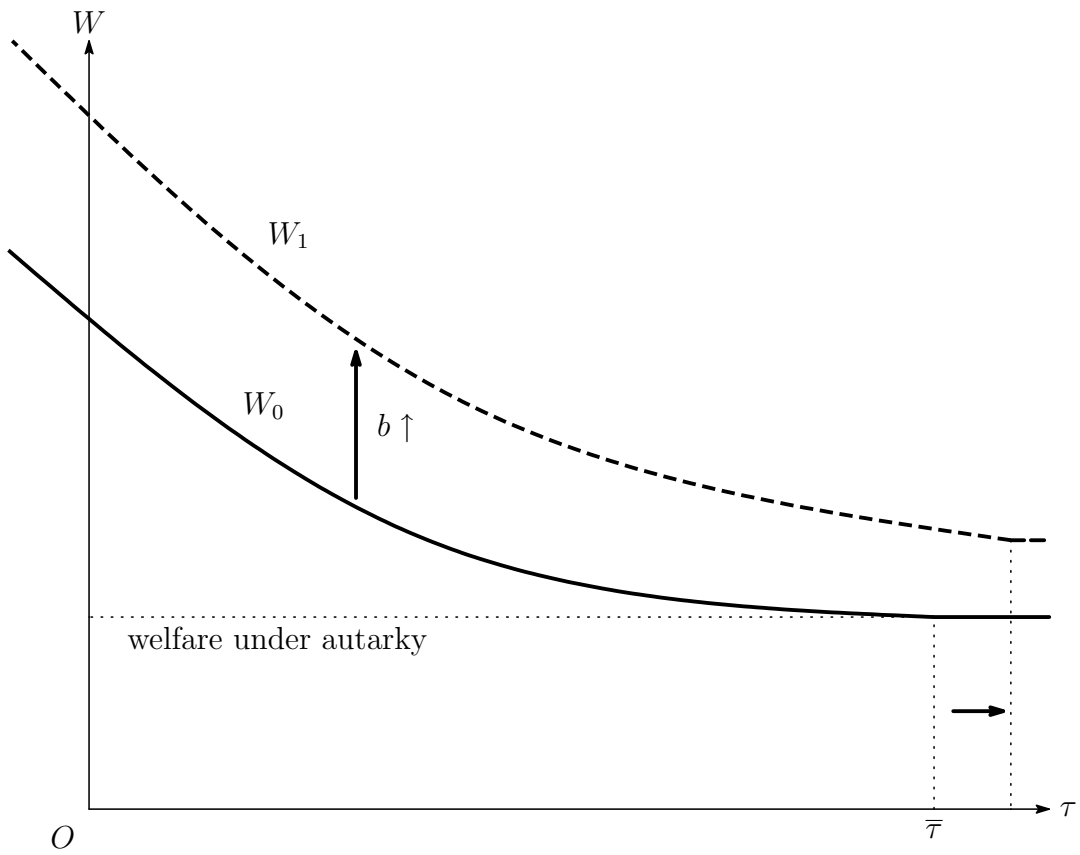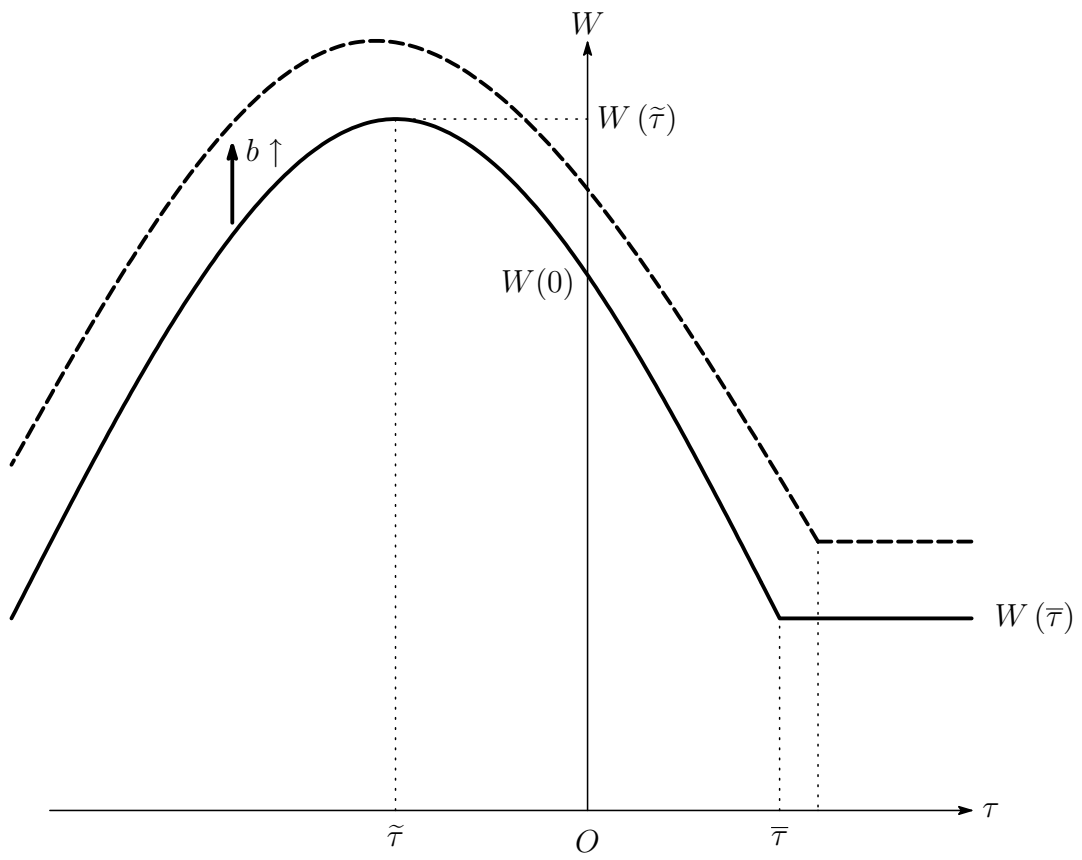
Figure 2: Gains from trade (1): the case of convex $W(\tau)$

Figure 3: Gains from trade (2): the case of concave $W(\tau)$