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Abstract

This paper revisits the welfare ranking of tariff revenue maximizing export tariff and welfare maximizing export tariff in an imperfectly substitutable network goods oligopoly. The results are often strikingly different and opposite to the ones obtained from a similar comparison in non-network goods oligopoly.

Keywords: Network externalities, differentiated product, oligopoly, export-rivalry, trade policy

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Welfare Ranking of Alternative Export Tariffs Revisited

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1   Introduction

We revisit the welfare ranking of alternative export tariffs – revenue maximizing vis-à-vis welfare maximizing, but in network goods oligopoly which is characterized by positive consumption externalities. In reality there are many goods and services for which utility derived by a particular consumer increases with the number of other users of that good or service (Shy, 2001). Empirical evidence also suggests that the volume of international trade in network goods has increased by many folds during the last two decades (OECD, 2014; Molnar, 2008). Introducing network externalities in export-rivalry model yields results that are often strikingly different from the ones obtained in the context of non-network goods oligopoly.

In their seminal papers, considering a two-country framework with perfectly competitive market for non-network goods, Johnson (1951, 1954) and Tower (1977) demonstrate that tariff revenue maximizing export tariffs can be higher than welfare maximizing export tariffs, because of strategic interdependence between countries. Extending this analysis to the case of export-rivalry between two countries in a third country's market Panagariya and Schiff (1994, 1995) and Trandel and Skeath (1996) show that, not only are tariff revenue maximizing tariffs higher than welfare maximizing tariffs, each exporting country can obtain higher welfare under tariff revenue maximizing tariffs than under welfare maximizing tariffs. Yilmaz (1999)'s results of computable general equilibrium analysis of the global cocoa market further strengthens this paradoxical result. More recently, consider-

ing a differentiated non-network goods Bertrand duopoly in the third country's market, Clarke and Collie (2008) demonstrate that, though export tariffs are always higher under tariff revenue maximization than under welfare maximization regardless of the degree of product substitutability, each exporting country attains lower (higher) welfare under tariff revenue maximization compared to that under welfare maximization if the degree of product substitutability is low (high). They also argue that the equilibrium of the bigger game, in which each exporting country can choose between tariff revenue maximization and welfare maximization for the purpose of export tariff determination, depends on the degree of product substitutability.

We show that in the case of network goods oligopoly high degree of product substitutability does not necessarily imply that tariff revenue maximizing export tariffs yield higher welfare than welfare maximizing export tariffs, unlike as in the case of non-network goods. In fact, the presence of network externalities reverses the standard welfare ranking of alternative export tariffs over a wide range of parametric configurations. Moreover, when countries can choose between tariff revenue maximization and welfare maximization, the equilibrium depends, not only on the degree of product substitutability, but also on the strength of network externalities. Unlike as in the case of usual non-network goods oligopoly, the possibility of 'tariff revenue maximization by each exporting country' to be the unique Nash equilibrium does not arise, unless the degree of product substitutability is very high and the strength of network externalities is very low.

2 The model

There are two countries, labeled one and two, each with one firm that produces a differentiated network good. Each firm incurs constant marginal(average) cost of production c and sells its entire produce in a third country, where firms engage themselves in Bertrand type price competition. The mode of product market competition is common knowledge.

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The government of country i $(= 1, 2)$ imposes per unit export tariff t_i, which can be positive or negative or zero, before the product market competition takes place. Countries decide their respective export tariffs simultaneously and independently, and there is no other policy instrument available to them. Clearly, the effective marginal cost of firm i is $c_i = c + t_i$, which is more (less) than c in the case of export tax (subsidy).

The utility function of the representative consumer is as follows.[1]

$$U(x_1, x_2, y_1, y_2) = m + \alpha(x_1 + x_2) - \frac{x_1^2 + 2\beta x_1 x_2 + x_2^2}{2} + $$
$$n[(y_1 + \beta y_2)x_1 + (y_2 + \beta y_1)x_2 - \frac{y_1^2 + 2\beta y_1 y_2 + y_2^2}{2}],$$

where m denotes the consumption of all other goods measured in terms of money, x_i denotes the quantity of the good produced by firm i $(= 1, 2)$, y_i denotes the consumers' expectations regarding firm i's total sales, and α $(> c)$, $\beta \in (0, 1)$ and $n \in [0, 1)$ are preference parameters. Higher value of β indicates higher degree of product substitutability.

Note that marginal utility of a good increases at the rate n, due to increase in consumers' expectations regarding total sales of that good: $\frac{\partial}{\partial y_i}[\frac{\partial U}{\partial x_i}] = n > 0$, $i = 1, 2$. That is, there is positive consumption externality and higher value of the parameter n indicates stronger network externalities. Further, since the two goods are imperfect substitutes, the effect of y_j on marginal utility of good i is also positive but less than that of y_i.[2] It follows that, for any given consumption bundle (x_1, x_2), correct expectations (i.e., $y_1 = x_1$ and $y_2 = x_2$) result in highest level of utility.

The demand function of good i corresponding to the above mentioned utility function is as follows.

$$x_i = \frac{\alpha(1 - \beta) - p_i + \beta p_j + n y_i (1 - \beta^2)}{1 - \beta^2}; \quad i, j = 1, 2; i \neq j; \quad (1)$$

where p_i denotes the price of good i. Clearly, as in Economides (1996), network externalities enter additively in demand functions and, thus, cause parallel outward shifts of

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[1] Hoernig (2012), Chirco and Scrimitore (2013), Pal (2014), Bhattacharjee and Pal (2014), Ghosh and Pal (2014) and Pal (2015), to name a few, have also considered a similar form of the utility function.

[2] $0 < \frac{\partial}{\partial y_j}[\frac{\partial U}{\partial x_i}] = n\beta < n$.

demand curves.

Let π_i, R_i and SW_i denote, respectively, profit of firm i, tariff revenue of country i and social welfare of country i. Thus, $\pi_i = (p_i - c)x_i - t_i x_i$, $R_i = t_i x_i$ and $SW_i = \pi_i + R_i = (p_i - c)x_i$; $i = 1, 2$.

Now, for any given export tariffs, t_1 and t_2, the problem of firm i can be written as $\underset{p_i}{Max}\, \pi_i = (p_i - c)x_i - t_i x_i$, which yields firm i's price reaction function as follows.[3]

$$p_i = \frac{1}{2}[\{\alpha(1 - \beta) + c + (1 - \beta^2) n y_i\} + \beta p_j + t_i]; \; i = 1, 2; \; i \neq j. \qquad (2)$$

It is easy to observe that (a) each firm perceives that prices, p_1 and p_2, are strategic complements, regardless of export tariffs and the strength of network externalities, (b) higher consumers' expectations regarding a firm's sales shifts that firm's price reaction function outward and such shift is greater in the case of stronger network externalities, and (c) a positive (negative) export tariff imposed by country i shifts firm i's price reaction function outward (inward).

Following Katz and Shapiro (1985) and Hoernig (2012), we consider that consumers' expectations satisfy 'rational expectations' conditions. That is, $y_1 = x_1$ and $y_2 = x_2$ hold true in the equilibrium. Solving firms' price reaction functions together with the conditions $y_1 = x_1$ and $y_2 = x_2$, we get the equilibrium price and profit of firm i and country i's tariff revenue and social welfare, respectively, as follows.

$$\left.\begin{aligned}
p_i(t_i, t_j) &= \frac{(2 + \beta - n)\{\alpha(1 - \beta) + c(1 - n)\} + \beta(1 - n)t_j + (1 - n)(2 - n)t_i}{(2 - n)^2 - \beta^2}, \\
\pi_i(t_i, t_j) &= \frac{\{(1 - \beta)(2 + \beta - n)(\alpha - c) - (2 - \beta^2 - n)\, t_i + \beta(1 - n)t_j\}^2}{(1 - \beta^2)\{(2 - n)^2 - \beta^2\}^2}, \\
R_i(t_i, t_j) &= \frac{\{(1 - \beta)(2 + \beta - n)(\alpha - c) - (2 - \beta^2 - n)\, t_i + \beta(1 - n)t_j\}t_i}{(1 - \beta^2)\{(2 - n)^2 - \beta^2\}} \;\; \text{and} \\
SW_i(t_i, t_j) &= \pi_i(t_i, t_j) + R_i(t_i, t_j); \; i, j = 1, 2; i \neq j.
\end{aligned}\right\} \qquad (3)$$

Clearly, $0 < \frac{\partial p_i}{\partial t_j} < \frac{\partial p_i}{\partial t_i}$ and $\frac{\partial \pi_i}{\partial t_i} < 0 < \frac{\partial \pi_i}{\partial t_j}$. Also, note that $\frac{\partial}{\partial t_j}[\frac{\partial R_i}{\partial t_i}] = \frac{\beta(1 - n)}{(1 - \beta^2)((2 - n)^2 - \beta^2)} > 0$

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[3]Second order conditions and stability conditions are satisfied in each of the cases considered.

$\forall n \in (0,1)$. However, $\frac{\partial}{\partial t_j}[\frac{\partial SW_i}{\partial t_i}] = -\frac{\beta(1-n)\left((2-n)n-\beta^2\right)}{(1-\beta^2)((2-n)^2-\beta^2)^2} \begin{cases} > 0, & \text{if } 0 < n < 1 - \sqrt{1-\beta^2} = n_w \\ \\ < 0, & \text{if } n_w < n < 1. \end{cases}$

Lemma 1: *If country i chooses revenue maximizing export tariff, it always perceives export tariffs t_i and t_j as strategic complements. However, If country i chooses welfare maximizing export tariff, it perceives export tariffs t_i and t_j as strategic substitutes (complements) in the presence of strong (weak) network externalities, i.e., when $n_w < n < 1$ ($0 < n < n_w$), where $n_w = 1 - \sqrt{1-\beta^2}$.*

Let us now characterize the equilibrium in the tariff setting stage by considering (a) both countries choose tariff revenue maximizing export tariffs (RR-game) and (b) both countries choose welfare maximizing export tariffs (WW-game), separately.

2.1 The RR-game

When both countries choose their respective tariff revenue maximizing export tariffs, the problem of the government of country i can be written as $\underset{t_i}{Max} R_i(t_i, t_j)$; $i, j = 1, 2$ and $i \neq j$. The first-order-condition of this maximization problem yields the following tariff reaction function of country i.

$$t_i = \frac{(1-\beta)(2+\beta-n)(\alpha-c) + \beta(1-n)t_j}{2(2-\beta^2-n)} \tag{4}$$

Solving the above reaction functions, we get the equilibrium export tariffs, which along with the corresponding tariff revenue and social welfare of each exporting country are presented in Lemma 2.

Lemma 2: *When both countries choose tariff revenue maximizing export tariffs, the equilibrium tariff rates, tariff revenues and social welfares are, respectively, as follows.*

$$t_1^{RR} \;=\; t_2^{RR} = t^{RR} = \frac{(\alpha - c)(1 - \beta)(2 - n + \beta)}{4 - n(2 - \beta) - \beta(1 + 2\beta)},$$

$$R_1^{RR} \;=\; R_2^{RR} = R^{RR} = \frac{(\alpha - c)^2(1 - \beta)(2 - n + \beta)\,(2 - n - \beta^2)}{(1 + \beta)(2 - n - \beta)\{4 - n(2 - \beta) - \beta(1 + 2\beta)\}^2} \;\; and$$

$$SW_1^{RR} \;=\; SW_2^{RR} = SW^{RR} = \frac{(\alpha - c)^2(1 - \beta)\,(6 - 5n + n^2 - 2\beta^2)\,(2 - n - \beta^2)}{(1 + \beta)(2 - n - \beta)^2\{4 - n(2 - \beta) - \beta(1 + 2\beta)\}^2},$$

where superscript 'RR' indicates that both countries set tariff revenue maximizing export tariffs.

Remark: From Lemma 2 it follows that $t^{RR} > 0$, $\frac{\partial t^{RR}}{\partial n} > 0$, $\frac{\partial R^{RR}}{\partial n} > 0$ and $\frac{\partial SW^{RR}}{\partial n} > 0$, for all $n \in [0, 1)$ and $\beta \in (0, 1)$.

2.2 The WW-game

When the government of country i chooses welfare maximizing export tariff, its problem can be written as $\underset{t_i}{Max} SW_i(t_i, t_j)$, $i, j = 1, 2$ and $i \neq j$, which yields the following tariff reaction function.

$$t_i = -\frac{(2n - n^2 - \beta^2)\left\{(\alpha - c)(1 - \beta)(2 - n + \beta) + \beta(1 - n)t_j\right\}}{2\,(2 - 3n + n^2)\,(2 - n - \beta^2)} \tag{5}$$

From these tariff reaction functions and the expressions for tariff revenue and social welfare, we get Lemma 3.

Lemma 3: *When both countries choose social welfare maximizing export tariffs, the equilibrium tariff rates, tariff revenues and social welfares are, respectively, as follows.*

$$t_1^{WW} \;=\; t_2^{WW} = t^{WW} = \frac{(\alpha - c)(1 - \beta)\,(n^2 - 2n + \beta^2)}{(1 - n)\{4 - n(2 - \beta) - \beta(2 + \beta)\}},$$

$$R_1^{WW} \;=\; R_2^{WW} = R^{WW} = \frac{(\alpha - c)^2(1 - \beta)(2 - n - \beta^2)\,(n^2 - 2n + \beta^2)}{(1 + \beta)(1 - n)^2\{4 - n(2 - \beta) - \beta(2 + \beta)\}^2} \;\; and$$

$$SW_1^{WW} \;=\; SW_2^{WW} = SW^{WW} = \frac{(\alpha - c)^2(2 - n)(1 - \beta)\,(2 - n - \beta^2)}{(1 - n)(1 + \beta)\{4 - n(2 - \beta) - \beta(2 + \beta)\}^2},$$

where the superscript 'WW' indicates that both countries set social welfare maximizing export tariffs.

Remark: It is straightforward to observe that, unlike as in the RR-game, in the present scenario it is optimal for exporting countries to subsidize (tax) exports in the presence of strong (weak) network externalities a la Ghosh and Pal (2014): $t^{WW} < (>) 0$, if $n > (<) n_w$. The reason is, export subsidy to a firm induces it to behave more aggressively in the product market, which enhances consumers' marginal willingness to pay and, thus, results in higher profit of the firm. In the presence of strong network externalities, increase in firm's profit due to more aggressive play in the product market over compensates the loss due to subsidy. Also, note that $\frac{\partial t^{WW}}{\partial n} < 0$ and $\frac{\partial SW^{WW}}{\partial n} > 0$ for all $n \in [0,1)$ and $\beta \in (0,1)$, while the equilibrium tariff revenue (R^{WW}) may be higher or lower in the presence of stronger network externalities depending on parametric configurations.

2.3 Revenue maximization versus welfare maximization

We now turn to compare the equilibrium tariff, tariff revenue and welfare under revenue maximization with those under welfare maximization. From Lemma 2 and Lemma 3, it is easy to check that $t^{RR} > t^{WW}$ and $R^{RR} > R^{WW}$, $\forall\ n \in [0,1)$ and $\beta \in (0,1)$, as in the case of non-network goods oligopoly $(n = 0)$ a la Clarke and Collie (2008). However, higher rate of export tariff under revenue maximization results in lower output and lower profit. Thus, the equilibrium welfare of an exporting country, which is the sum of its government's tariff revenue and its firm's profit, need not necessarily be higher when both countries set revenue maximizing tariffs compared to that under welfare maximization by both countries.

Comparing SW^{RR} and SW^{WW} from Lemma 2 and Lemma 3, we get $SW^{WW} > (<) SW^{RR}$ iff $f(n,\beta) > (<) 0$, where $f(n,\beta) = 2(2 - n - \beta^2)\{2(2-n)^2 - 2(3-n)(2-n)^2\beta + (6-n)(2-n)(1-n)\beta^2 + 4(2-n)\beta^3 - (5-3n)\beta^4\}$. Since we have $0 \le n < 1$ and $0 < \beta < 1$, it

follows that $f(n, \beta) \gtreqqless 0$, if $\beta \lesseqqgtr \hat{\beta}(n)$, where $\hat{\beta}(0) = 0.46558$, $\hat{\beta}(1) = 1$ and $\frac{\partial \hat{\beta}(n)}{\partial n} > 0$.
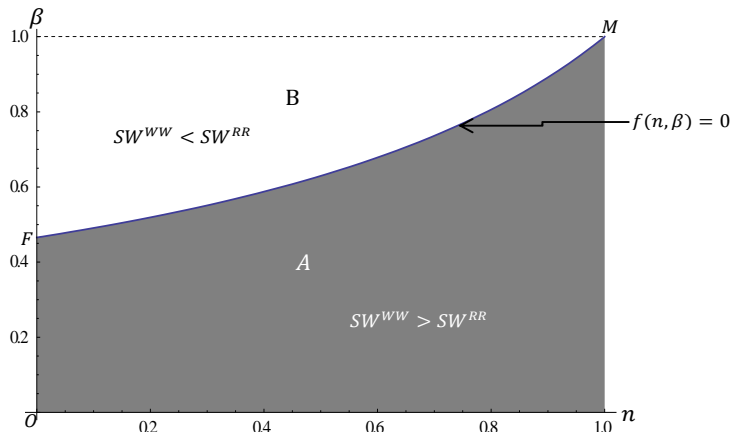

Figure 1: Comparison of social welfare under alternative export tariffs – welfare maximizing vs. revenue maximizing

Figure 1 depicts $f(n, \beta) = 0$, which is denoted by the curve FM. In the shaded region A, which is bounded below the curve FM, we have $f(n, \beta) > 0$ and, thus, $SW^{WW} > SW^{RR}$. The opposite holds true (i.e. $SW^{WW} < SW^{RR}$) in the region bounded above the curve FM (denoted by B). Clearly, we can say the following. When $0 < \beta \leq 0.46558$, $SW^{RR} < SW^{WW}$ for all $n \in [0, 1)$. Further, when $0.46558 < \beta < 1$, then also we have $SW^{RR} < SW^{WW}$ if the strength of network externalities is greater than $\underline{n}(\beta)$; $\underline{n}(\beta) > 0$ and $\frac{\partial \underline{n}(\beta)}{\partial \beta} > 0$. In other words, for any given degree of product substitutability $\beta \in (0, 1)$, there exists a critical value of n, such that $SW^{RR} < SW^{WW}$ holds true unless the strength of network externalities is less than that critical value. This is because, even when products are highly substitutable ($\beta > 0.46558$), in the presence of stronger network externalities, the negative effect of higher export tariff (via its detrimental effect on consumers' expectations) on firm's profit dominates its positive effect on tariff revenue. That is, unlike as in the case of usual non-network goods, in the presence of network externalities high degree of product substitutability does not necessarily imply that welfare under revenue maximization is greater than under welfare maximization. Clearly, the welfare ranking of Clarke and Collie (2008) emerges as a special case in our model.

Proposition 1: *Each exporting country attains higher social welfare when both countries set welfare maximizing export tariffs than when both countries set tariff revenue maximizing export tariffs, unless the degree of product substitutability is high ($\beta > 0.46558$) and the strength of network externalities is less than a critical level ($n < \underline{n}(\beta)$).*

Proposition 1 implies that in the presence of network externalities the scope of obtaining higher welfare by setting revenue maximizing export tariffs is much less than in the case of usual non-network goods oligopoly.

2.4   Endogenous choice

Finally, we turn to answer the following question. Given the choice, should a non-leviathan government set welfare maximizing export tariff or tariff revenue maximizing export tariff in the case of export rivalry? To address this issue of endogenous choice of tariff setting strategies, we solve the following two stage game by backward induction method.

In the first stage, each exporting country's government decides whether to set export tariff based on welfare maximization or tariff revenue maximization, simultaneously and independently, so that the highest possible level of welfare is attained. In the second stage, they set export tariffs, simultaneously and independently.

Let SW_i^{RW} (SW_i^{WR}) denote the second stage equilibrium welfare of country i ($= 1, 2$) when country i sets revenue (welfare) maximizing export tariff and country j sets welfare (revenue) maximizing export tariff. See Appendix A for derivations of SW_i^{RW} and SW_i^{WR}. If both countries set revenue (welfare) maximizing export tariff, each country's second stage equilibrium welfare is SW^{RR} (SW^{WW}), which is as in Lemma 2 (Lemma 3).

Now, in the first stage, each government chooses a strategy from the strategy set $S = \{Revenue, Welfare\}$. Therefore, the first stage of the game can be depicted as the 2×2 normal-form game in Figure 2, where the first (second) entry in each cell denotes the payoff of country 1 (country 2) corresponding to the associated strategy pair.

Country 2

		Welfare	Revenue
	Welfare	$SW^{WW}, \ SW^{WW}$	$SW_1^{WR}, \ SW_2^{WR}$
Country 1	Revenue	$SW_1^{RW}, \ SW_2^{RW}$	$SW^{RR}, \ SW^{RR}$

Figure 2: Choice of tariff setting strategies

Comparing payoffs corresponding to alternative pairs of strategies we get four partitions of the relevant $n\beta$-plane, as shown in Figure 3. See Appendix B for details.

In region A: $SW_2^{RW} = SW_1^{WR} > SW^{WW} > SW^{RR} > SW_2^{WR} = SW_1^{RW}$. Clearly, welfare maximization is the dominant strategy of each exporting country in the region A and the Nash equilibrium pair of payoffs (SW^{WW}, SW^{WW}) is Pareto superior to payoffs under tariff revenue maximization by both countries.

In region C: $SW_2^{RW} = SW_1^{WR} > SW^{RR} > SW^{WW} > SW_2^{WR} = SW_1^{RW}$. It implies that in the equilibrium each country sets welfare maximizing export tariff in region C. However, the strategy pair $(Revenue, Revenue)$ is Pareto superior to the Nash equilibrium strategy pair $(Welfare, Welfare)$. That is, there is Prisoners' Dilemma type of situation in this scenario.

In region D: $SW_2^{WR} = SW_1^{RW} < SW^{WW} < SW_1^{WR} = SW_2^{RW} < SW^{RR}$. It implies that, in this region, both $(Welfare, Welfare)$ and $(Revenue, Revenue)$ emerge as Nash equilibrium pair of strategies, while the later Pareto dominates the former.

In region E: $SW^{WW} < SW_1^{WR} = SW_2^{RW} < SW^{RR}$ and $SW^{WW} < SW_2^{WR} = SW_1^{RW} < SW^{RR}$. It implies that, in this region, revenue maximization is the dominant strategy of each exporting country and the Nash equilibrium pair of payoffs (SW^{RR}, SW^{RR}) is Pareto superior to payoffs under welfare maximization by both countries.
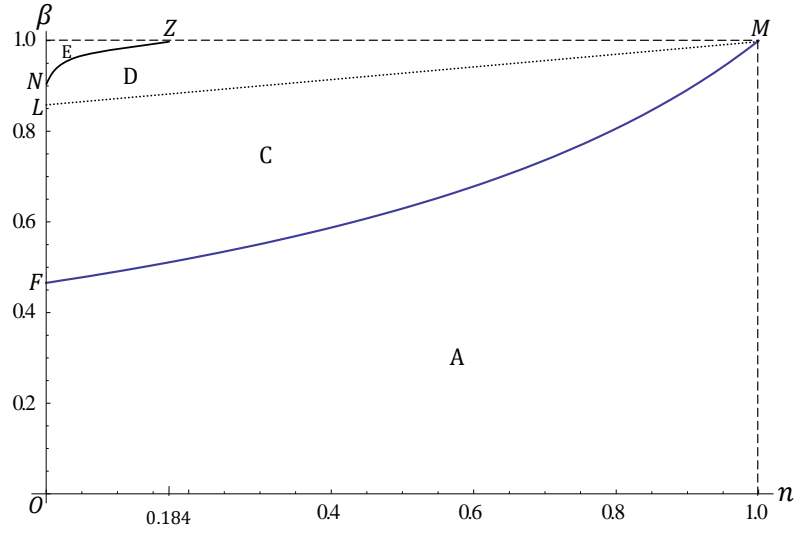
Figure 3: Comparison of welfare under endogenous choice

Proposition 2: $(Welfare, Welfare)$ *is the unique and Pareto superior Nash equilibrium in most of the cases. The possibility of such as equilibrium cannot be ruled out even when products are very close substitutes. In contrast, the possibility of* $(Revenue, Revenue)$ *to be the unique Nash equilibrium does not arise, unless products are very close substitutes and network externalities are very weak. Further, scopes for* $(Revenue, Revenue)$ *to be one of the equilibria and/or to Pareto dominate* $(Welfare, Welfare)$ *are lower in the presence of stronger network externalities.*

It is easy to observe that the equilibrium tariff setting strategies of competing governments can be interpreted as the the equilibrium of the delegation game, in which each government simultaneously and independently delegates the tariff setting decision to a policymaker who maximizes tariff revenue or to a policy maker who maximizes welfare a la Clarke and Collie (2008). Following this line of interpretation of our results, we can say that in network goods oligopoly the need for non-leviathan governments, whose ultimate objective is to maximize social welfare, to delegate tariff setting decisions to policy makers who maximize tariff revenue arises only in special cases.

3   Conclusion

This paper contributes to the literature by extending the analysis of welfare ranking of exporting countries' alternative tariff setting strategies, revenue maximization vs. welfare maximization, to the case of a differentiated network goods oligopoly. It shows that non-leviathan governments' incentives to deviate from welfare maximization to tariff revenue maximization while deciding export tariffs depends, not only on the degree of product substitutability, but also on the strength of network externalities. Thus, the existing results do not hold true except in special cases of the present model. In other words, the optimal strategy for trade policy determination in the presence of network externalities can be opposite to that in the case of usual non-network goods. Overall, results of this paper suggest that 'one size fits all' does not apply to trade policy determination in strategic environment.

Appendix

A. Asymmetric tariff setting

Note that, in the second stage of the game, there are possibilities of asymmetric competition in which one country chooses tariff revenue maximizing export tariff and the other country chooses welfare maximizing export tariff (RW-game or WR-game). It is evident that, when country 1 sets welfare maximizing export tariff and country 2 sets tariff revenue maximizing export tariff (WR-game), the tariff reaction functions of country 1 and country 2 are given by equation (5) and equation (4), respectively. Solving these two equations, we get the equilibrium export tariffs of country 1 and country 2 in the case of WR-game as in (A1) and (A2), respectively, where superscript 'WR' indicates that 'country 1 sets welfare maximizing export tariff and country 2 sets tariff revenue maximizing export tariff'.

$$t_1^{WR} = \frac{(1-\beta)(\alpha-c)(\beta-n+2)\left(\beta^2+n^2-2n\right)\{(1-2\beta)\beta-(\beta+2)n+4\}}{(1-n)\{4(2-n)^3-\beta^2(2-n)\left(n^2-9n+16\right)+\beta^4(7-3n)\}} \quad (A1)$$

$$t_2^{WR} = \frac{(1-\beta)(\alpha-c)(2-\beta-n)(\beta-n+2)\{(2-\beta)\beta-(\beta+2)n+4\}}{4(2-n)^3-\beta^2(2-n)\left(n^2-9n+16\right)+\beta^4(7-3n)} \quad (A2)$$

It is easy to check that (a) $t_2^{WR} > 0$, $\forall n \in (0,1)$ and $\beta \in (0,1)$, but (b) $t_1^{WR} < \ (>) \ 0$, if $n > \ (<) \ n_w$. That is, while tariff revenue maximizing export tariff is always positive, welfare maximizing export tariff is negative (positive) in the presence of strong (weak) network externalities, regardless of whether the rival country chooses welfare maximizing export tariff or not.

Corresponding to tariff rates t_1^{WR} and t_2^{WR}, welfare of country 1 and country 2 are, respectively, as follows.

$$SW_1^{WR} = \frac{(1-\beta)(2-n)(\alpha-c)^2(2+\beta-n)^2\left(2-\beta^2-n\right)\{4+(1-2\beta)\beta-(\beta+2)n\}^2}{(\beta+1)(1-n)[\beta^4(7-3n)-\beta^2(2-n)\{16-(9-n)n\}+4(2-n)^3]^2} \quad (A3)$$

$$SW_2^{WR} = \frac{(1-\beta)(\alpha-c)^2\left(6-2\beta^2+n^2-5n\right)\left(2-\beta^2-n\right)\{4+(2-\beta)\beta-(\beta+2)n\}^2}{(1+\beta)[\beta^4(7-3n)-\beta^2(2-n)\{16-(9-n)n\}+4(2-n)^3]^2} \quad (A4)$$

Since exporting countries are otherwise identical, if country 1 sets tariff revenue maximizing export tariff and country 2 sets welfare maximizing export tariff (RW-game), in

the equilibrium their tariff rates (t_1^{RW} and t_2^{RW}) and welfares (SW_1^{RW} and SW_2^{RW}) always satisfy following conditions.

$$t_1^{RW} = t_2^{WR}, \ t_2^{RW} = t_1^{WR}, \ SW_1^{RW} = SW_2^{WR}, \ \text{and} \ SW_2^{RW} = SW_1^{WR}, \qquad \text{(A5)}$$

where superscript 'RW' indicates that 'country 1 sets tariff revenue maximizing export tariff and country 2 sets welfare maximizing export tariff'. Needless to mention here that equilibrium outcomes under RR-game and WW-game are as in Lemma 2 and Lemma 3, respectively.

B. Social welfare comparisons

Comparing the equilibrium social welfares under alternative pairs of strategies, we obtain the following.

1. $SW_1^{RW} = SW_2^{WR}$ and $SW_2^{RW} = SW_1^{WR}$, by (A5)

2. $SW_1^{WR} > SW^{WW}$ and $SW^{RR} > SW_2^{WR}$ hold true always.

3. $SW^{WW} > (<) SW^{RR} \Leftrightarrow f(n,\beta) > (<) 0$, as seen in Section 2.3. That is, $SW^{WW} > SW^{RR}$ holds true in the region A, which is below the curve FM, in Figure 3. Whereas $SW^{WW} < SW^{RR}$ holds true in regions C, D and E, which are above the curve FM, in Figure 3.

4. $SW^{RR} > (<) SW_1^{WR} \Leftrightarrow g(n,\beta) > (<) 0 \Leftrightarrow \beta > (<) \hat{\beta}_1(n)$, where $\hat{\beta}_1(0) = 0.862454$, $\lim_{n \to 1} \hat{\beta}_1(n) = 1$, $\frac{\partial \hat{\beta}_1(n)}{\partial n} > 0 \ \forall n(0,1)$.[4] Therefore, $SW^{RR} > SW_1^{WR}$ ($SW^{RR} < SW_1^{WR}$) holds true in the region above (below) the curve LM, i.e., in regions D and E (C and A), in Figure 3,

5. $SW^{WW} < (>) SW_2^{WR} \Leftrightarrow h(n,\beta) > (<) 0 \Leftrightarrow$ [both (either) $0 < n < 0.183503$ and (or) $\beta > \hat{\beta}_2(n)$ holds true (is violated)], where $\hat{\beta}_2(0) = 0.983448$, $\hat{\beta}_2(0.183503) = 1$,

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[4]$g(n,\beta) = 2(\alpha-c)^2(1-\beta)(2-n-\beta^2)^2[-8(2-n)^6+4(2-n)^4\{24-19n+(6-n)n^2)\}\beta^2-(2-n)^2\{410-566n+315n^2-n^3(93-15n+n^2)\}\beta^4+2(2-n)\{200-(5-n)n(53-16n+3n^2)\}\beta^6-(3-n)(61-52n+11n^2)\beta^8+8(2-n)\beta^{10}]$.

and $\frac{\partial \hat{\beta}_2(n)}{\partial n} > 0$ whenever $n \in (0,1)$ and $0 < \hat{\beta}_2(n) < 1$.[5] It implies that $SW^{WW} < SW_2^{WR}$ ($SW^{WW} > SW_2^{WR}$) holds true in the region above (below) the curve NZ, i.e., in the region E (in regions D, C and A), in Figure 3.

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[5]$h(n,\beta) = 2(\alpha - c)^2(1 - \beta)(2 - n - \beta^2)^2(4(2 - n)^3(8 - 3n + n^2)\beta^2 - (2 - n)^2(38 - 22n + 9n^2 - n^3)\beta^4 + 2(2 - n)(6 - 3n + n^2)\beta^6 + (1 - n)\beta^8 - 8(2 - n)^4)$.

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