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Abstract

We analyze strategic trade policy for differentiated network goods oligopolies under alternative scenarios, when there is export-rivalry between two countries. We show that, under price competition without managerial delegation, it is optimal to tax (subsidize) exports, if network externalities are weak (strong). But, the opposite is true under price competition with relative-performance based managerial delegation in firms. In contrast, under quantity competition, the optimal trade policy always involves subsidization of exports. Nonetheless, the optimal rate of export-subsidy under quantity competition is always higher than that under price competition. We also show that, under quantity (price) competition without managerial delegation, trade policy interventions in the presence of sufficiently strong (weak or very strong) network externalities lead to higher social welfare of each exporting country compared to that under free-trade. However, under quantity (price) competition with managerial delegation, trade policy interventions result in Pareto-inferior outcomes always (unless network externalities are strong).

Keywords: Strategic trade policy, network goods, relative-performance based managerial delegation, price competition, quantity competition

JEL Code: F12, F13, L13, L22, D21

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1 Introduction

In their seminal paper, Brander and Spencer (1985) demonstrate that, when firms engage themselves in quantity competition in a third country's market, it is optimal for exporting countries to subsidize exports, but such policy interventions result in lower social welfare of exporting countries compared to that in the case of free-trade. On the other hand, Eaton and Grossman (1986) show that these results are reversed in the case of price competition in the third market, i.e. in the equilibrium under price competition, each exporting country imposes tax on its exports and obtains greater than free-trade level of social welfare. Das (1997) and Miller and Pazgal (2005) extend the analysis to examine the implications of separation of ownership and control, which is a common phenomenon in modern firms, on optimal trade policy under alternative modes of product market competition. While Das (1997) argues that managerial delegation in firms reduces the scale of strategic trade policy, Miller and Pazgal (2005) demonstrate that the optimal trade policy is not sensitive to the mode of product market competition under relative-performance based managerial delegation contracts in firms.[1] Following Brander and Spencer (1985) and Eaton and Grossman (1986), the literature on strategic trade theory has been enriched by several other studies as well, which helps us to understand the implications of imperfect competition on optimal trade policy in many different scenarios.[2] However, the existing literature on strategic trade theory has primarily focused on usual non-network goods oligopolies.

[1] Das (1997) considers that managerial incentive schemes are based on a linear combination of own profit and sales revenue a la Vickers (1985), Fershtman (1985), Fershtman and Judd (1987) and Sklivas (1987).

[2] See Helpman and Krugman (1989) and Brander (1995) for surveys of early literature.

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, which are referred to as network goods in the literature. That is, network goods industries are characterized by positive consumption externalities (Shy, 2001).[3] Further, empirical evidence suggests that (a) the volume of international trade of network goods has increased quite significantly in recent years and (b) product market regulations significantly affect exports and imports.[4] Against this backdrop, in this paper we aim to analyze optimal trade policy for network goods oligopoly under alternative modes of product market competition - price vis-à-vis quantity. We also examine the effect of interplay between relative-performance based managerial delegation in firms and the strength of network externalities on optimal trade policy.

Developing a model of export rivalry between two countries for differentiated network goods, we first show that in the case of price competition without managerial delegation (a) it is optimal for exporting countries to subsidize exports, unless network externalities are weak; (b) the stronger the network externalities, greater (smaller) the optimal rate of export subsidy (tax); and (c) exporting countries obtain higher social welfare in the equilibrium under trade policy interventions compared to that under free trade only if network externalities are either weak or very strong, otherwise, the opposite is true. These results are in contrast to the findings of Eaton and Grossman (1986). On the other hand,

[3]Examples of network goods include softwares, computers, consumer electronics and telephone and other communication services. Many consumer durable goods can also be classified in the category of network goods, since utility of consumer durables depends on the quality of post-sales services and higher consumer-base often leads to better post-sales services.

[4]For example, the value of exports of 'Information and Communication Technologies' (ICT) industries of India has increased from 211831.536 ('000 USD) in 1991 to 5332811.776 ('000 USD) in 2013 (OECD, 2014). Portugal-Perez et al. (2010) document spurt in growth of imports of electronic components, consumer electronics and information technologies by European Union countries during the period 1990-2006, which has been primarily contributed by imports from east Asian and Pacific countries. Analyzing data from 30 OECD countries for the period 1998-2007, Molnar (2008) argues that product market regulation has a statistically significant effect on trade flows of telecommunication services.

if there is quantity competition and no managerial delegation in firms, the optimal trade policy involves subsidization of exports, regardless of the strength of network externalities, as in Brander and Spencer (1985). The optimal rate of export-subsidy is higher in the presence of stronger network externalities under quantity competition without managerial delegation as well. However, in contrast to Brander and Spencer (1985), trade policy interventions under quantity competition without managerial delegation result in higher social welfare of exporting countries in the equilibrium compared to that under free trade, when network externalities are sufficiently strong. Clearly, welfare implications of strategic trade policy depends on both (a) the mode of product market competition and (b) the strength of network externalities. The intuitions behind these results are as follows.

First, in the case of usual non-network goods oligopoly under price competition without managerial delegation, price undercutting by firms leads to low levels of profits and social welfare of exporting countries. Therefore, imposition of export-tax by an exporting country's government restricts price undercutting, which results in higher social welfare. However, in the presence of network externalities, less aggressive behaviour (i.e., setting higher price) by a firm dampens consumers' expectations regarding its sales and hence their willingness to pay. Thus, in the case of network goods oligopoly, there are indirect negative effects of export-tax on firms' profits and exporting countries' social welfares, via consumers' expectations. If network externalities are weak (strong), the direct positive effect dominates (is dominated by) the indirect negative effect of export-tax on social welfare. Thus, in the presence of weak network externalities Eaton and Grossman (1986)'s results go through. But, in the presence of strong network externalities, the nature of the optimal trade policy reverses. In the later case, each exporting country has an incentive to intensify price competition by offering export-subsidy to its firm, since due to export-subsidy firm's profit increases by a larger amount than the amount of subsidy. However, since each exporting country offers export-subsidy in the equilibrium, the strength of network externalities needs to be sufficiently strong in order to realize higher social welfare compared to that under free-trade. Second, in the case of usual non-network goods oligopoly under quantity competition without managerial delegation, due to profit shift-

ing effect of export-subsidy, each country has a unilateral incentive to subsidize exports. Presence of network externalities further strengthens the incentive to subsidize exports. This is because, in the case of network goods oligopoly export-subsidy induces a firm to choose higher output, which enhances consumers' willingness to pay and, thus, results in sufficiently higher profits. If network externalities are sufficiently strong, demand curves shift sufficiently outward due to export-subsidies, which result in higher social welfare of each exporting country compared to that under free-trade.

Next, we turn to answer the following questions. What is the implication of managerial delegation on optimal trade policy for network goods oligopoly? Does Miller and Pazgal (2005)'s equivalence result hold true in the presence of network externalities? For this purpose, we consider that the owner of each firm delegates the task to set price or quantity, depending on the mode of product market competition, to her manager by offering appropriately designed relative performance based managerial incentive schemes, after export-tax/subsidy has been determined by governments, à la Miller and Pazgal (2001, 2005). It turns out that in the case of price competition between the managers, it is optimal for the exporting countries' governments to offer export-subsidy (impose export-tax) under weak (strong) network effects. That is, under price competition, relative performance based managerial delegation in firms alters the nature of optimal trade policy compared to that under no delegation. In contrast, under quantity competition with delegation, the equilibrium trade policy involves subsidization of domestic firm regardless of the strength of network externalities, as in the case of no delegation. That is, the nature of optimal trade policy remains sensitive to the mode of product market competition even when owners offer relative performance based delegation contracts to their managers, unless network externalities are weak. The reason is, in absence of trade policy interventions under price competition, owners induce their managers to be less (excessively) aggressive in the case of weak (strong) network externalities. Moreover, in the case of weak (strong) network externalities, export-tax by a country makes the owner of its own firm to induce her manager to be relatively more (less) aggressive compared to that in the case of free trade. Thus, optimal trade policy involves subsidization of (taxing) domestic firm in the case of price

competition under delegation, if the strength of network externalities is weak (strong). On the other hand, in the case of quantity competition under delegation, exporting countries have an additional incentive to offer export-subsidy compared to that in the case of no delegation, since export-subsidy leads to higher gain from more aggressive play in the case of quantity competition. Moreover, even when subsidization of exports is optimal under both price and quantity competition, the optimal rate of export-subsidy is always higher under quantity competition compared to that under price competition, regardless of whether there is managerial delegation or not. Clearly, Miller and Pazgal (2005)'s equivalence result does not hold true in the case of network goods oligopoly. In other words, the optimal trade policy under quantity competition is equivalent to that under price competition, only if (a) there is no network externality and (b) firms' owners offer relative-performance based managerial delegation contracts to their respective managers.

We also demonstrate that in the case of delegation the strength of network externalities has differential impact on equilibrium outcomes under price and quantity competition. Further, we show that (a) under price competition with delegation, trade policy interventions result in lower social welfare for exporting countries compared to that under free-trade, only if network externalities are weak; and (b) under quantity competition with delegation, in equilibrium each exporting country obtains lower social welfare in the case of trade policy interventions compared to that under free-trade, regardless of the strength of network externalities.

We mention here that Krishna (1988), Klimenko (2009) and Fujiwara (2011a,b) also attempt to analyze optimal trade policy for network goods oligopoly. While Krishna (1988) considers only unilateral trade policy of a single country, Klimenko (2009) and Fujiwara (2011a,b) exclusively focus on price competition in a import-competing model and quantity competition in the case of bilateral trade, respectively. None of these papers examine the implications of network externalities on strategic trade policies of competing countries in the case of export rivalry. Moreover, unlike the present paper, these papers consider only the case of pure profit maximizing firms without managerial delegation.

The rest of the paper is organized as follows. Section 2 presents the setup of the model.

Section 3 analyzes optimal trade policy in network goods oligopoly without managerial delegation, considering price and quantity competition separately. Interplay between relative-performance based managerial delegation in firms and the strength of network externalities on optimal trade policy is analyzed in Section 4. Section 5 offers concluding remarks along with a discussion on the implications of network externalities on the equilibrium outcomes under alternative trade patterns in the present context.

2 Setup of the model

We consider that two firms, firm 1 and firm 2, are located in country 1 and country 2 respectively. They produce imperfectly substitutable goods that have positive consumption externalities. In other words, we consider that firms produce differentiated network goods. Each firm incurs constant marginal (average) cost of production c and sells its produce only in a third country, where firms engage themselves either in Bertrand type price competition or in Cournot type quantity competition in order to maximize their respective profits. The mode of competition in the product market is exogenously determined and is common knowledge.

The objective of the government of country i $(= 1, 2)$ is to maximize its social welfare (SW_i) and we consider that export-tax/subsidy is the only policy instrument available to the government. Let t_i be the per unit export tax or subsidy, depending on whether t_i is positive or negative, imposed by government i; $i = 1, 2$. Therefore, effective marginal cost of firm i is given by $c_i = c + t_i$, which is more (less) than c in the case of tax (subsidy).

Following Hoernig (2012), Pal (2014) and Bhattacharjee and Pal (2014), we consider that the utility function of the representative consumer is as follows.

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

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'

expectation regarding firm i's total sales, and $\alpha > 0$, $\beta \in (0,1)$ and $n \in [0,1)$ are preference parameters. Lower value of β denotes higher degree of product differentiation. Clearly, there is positive consumption externality and higher value of the parameter n indicates stronger network effects, since $\frac{\partial}{\partial y_i}[\frac{\partial U}{\partial x_i}] = n > 0$, $i = 1,\ 2$. Also, 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. Needless to mention here that $n = 0$ corresponds to the case of usual non-network goods, and in that case the above mentioned quasi-linear utility function is comparable to Singh and Vives (1984)'s utility function.[5] It is easy to check that, for any given consumption bundle (x_1, x_2), utility is maximum when consumers' expectations are fulfilled, i.e., when $y_1 = x_1$ and $y_2 = x_2$. We assume that $0 < c < \alpha$, which ensures that equilibrium quantities and prices are always positive. From the above mentioned utility function of the representative consumer, the inverse demand function for good i can be derived as follows.

$$p_i = \alpha - x_i - \beta x_j + n(y_i + \beta y_j) \quad i, j = 1, 2, i \neq j; \tag{1a}$$

where p_i is the price of good i. The corresponding direct demand function is given by

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

Note that, as in Economides (1996), network externalities enter additively in demand functions and, thus, cause parallel outward shifts of demand curves.

Clearly, total tax collection (T_i) and profit (π_i) expressions are $T_i = t_i x_i$ and $\pi_i = (p_i - c)x_i - t_i x_i$, respectively. Therefore, social welfare of country i is given by $SW_i = \pi_i + T_i = (p_i - c)x_i$; $i = 1, 2$.

[5]Qualitative results of this analysis go through, if we consider (a) alternative forms of the representative consumer's utility function or (b) Hotelling's linear city model with a continuum of consumers uniformly distributed over the unit interval $[0,1]$ and the utility function of a consumer as $u_x = a - p_i - \tau x_i^2 + n x_i^e$; where p_i is the price charged by firm i, x_i is the distance of the consumer from firm i, x_i^e is the consumers' expectations regarding firm i's total sales, $a\,(> 0)$ denotes the utility in the case of no purchase, $\tau\,(> 0)$ is the transport-cost parameter and $n\,(> 0)$ denotes the strength of network externalities.

We analyze optimal trade policy in two alternative scenarios - no delegation and strategic managerial delegation in firms. In the case of no delegation, firms set price or quantity depending on exogenously given mode of product market competition in order to maximize their respective profits. On the other hand, in the case of strategic managerial delegation in firms, owners design relative performance based incentive schemes for their managers and delegate tasks to set prices or quantities so that respective profits are maximized à la Miller and Pazgal (2001, 2005). In the later case, let λ_i be the weight on the rival firm j's profit in the firm i's manager's incentive scheme. Following the literature on strategic managerial delegation, we also assume that mangers are risk neutral and the market for managers is perfectly competitive. Thus, the objective function of the manager of firm i can be written as follows.

$$O_i = \pi_i + \lambda_i \pi_j;\ i, j = 1, 2;\ i \neq j. \tag{2}$$

We do not impose any restriction on the value of the incentive parameter λ_i. It is easy to observe that $\lambda_1 = \lambda_2 = 0$ corresponds to the case of no delegation. However, if a firm chooses a positive (negative) value of the incentive parameter, her manager is rewarded (penalized) for the rival firm's profit and, thus, the manager behaves less (more) aggressively, i.e., set higher (lower) price, in the product market compared to that in the case of no delegation. We examine possible implications of network externalities to trade policy in each of these two scenarios, no delegation and strategic delegation, under alternative modes of product market competition - price vis-à-vis quantity.

3 Trade policy in absence of delegation

We begin with the scenario in which there is no delegation in firms. In this case, stages of the game involved are as follows.

> Stage 1: Governments of country 1 and country 2 simultaneously and independently decide their respective tax rates on exports.

Stage 2: Owners of each firm simultaneously and independently decide the price or quantity, depending on the mode of product market competition.

We solve this game by the standard backward induction method.

3.1 Bertrand type price competition

Let us first consider that firms are engaged in Bertrand type price competition in the third country's product market. In this case firm i's problem in stage 2 is to maximize its profit $\pi_i = (p_i - c)x_i - t_i x_i$ by choosing its price (p_i), where x_i is given by equation (1b), taking the tax rate (t_i), the rival firm's price (p_j) and consumers' expectations regarding sales (y_i and y_j) as given. From the first order condition of firm i's problem, we obtain its price reaction function as follows.[6]

$$p_i = \frac{\alpha(1-\beta) + c + t_i + \beta p_j + n y_i(1-\beta^2)}{2}, \; i, j = 1, 2, \; i \neq j, \tag{3}$$

It is easy to check that $\frac{\partial p_i}{\partial p_j} > 0$, i.e., firms perceive that prices are strategic complements, regardless of the strength of network effects. Also note that a country can induce its firm to restrict price undercutting by imposing higher rate of tax on exports ($\frac{\partial p_i}{\partial t_i} > 0$), as in the case of usual non-network goods oligopoly. It is interesting to observe that greater expectations of consumers regarding a firm's sales lead to outward shift of that firm's price reaction curve ($\frac{\partial p_i}{\partial y_i} > 0$) and such effect is higher in the case of stronger network effects ($\frac{\partial}{\partial n}[\frac{\partial p_i}{\partial y_i}] > 0$). Therefore, it seems that the strength of network externalities will have implications to optimal trade policy.

Following Katz and Shapiro (1985) and Hoernig (2012), we consider the 'fulfilled expectations' equilibrium. In other words, we consider that consumers' expectations satisfy 'rational expectations' conditions, $y_1 = x_1$ and $y_2 = x_2$, in equilibrium. Now, solving the price reaction functions of firms, as given by equation (3), together with the conditions $y_1 = x_1$ and $y_2 = x_2$, we get second stage equilibrium prices as follows.

[6]Second order conditions for maximization and stability conditions are satisfied in each stage and in all the cases considered in this paper.

$$p_i = p_i(t_i, t_j) = \frac{(2+\beta-n)\{\alpha(1-\beta)+c(1-n)\}+\beta(1-n)t_j+(1-n)(2-n)t_i}{(2-n)^2-\beta^2},\ i, j = 1,\ 2,\ i \neq j.$$

From these expressions for equilibrium prices in stage 2, it is easy to check that (a) marginal effects of a country's tax rate on prices set by firm 1 and firm 2 are positive and (b) the marginal effect of a country's tax rate on the price set by its own firm is larger than that on its rival country's firms' price: $\frac{\partial p_i}{\partial t_i} > \frac{\partial p_j}{\partial t_i} > 0;\ \forall \beta \in (0,1)$ and $n \in [0,1);\ i, j = 1,\ 2,\ i \neq j$. Further, the marginal effect of a country's tax rate on its own firm's price is always lower in the case of stronger network externalities: $\frac{\partial}{\partial n}[\frac{\partial p_i}{\partial t_i}] < 0,\ \ \forall n \in [0,1)$. However, stronger network externalities lead to lower marginal effect of a country's tax rate on its rival country's firm's price, if the strength of network externalities is greater than a critical value: $\frac{\partial}{\partial n}[\frac{\partial p_j}{\partial t_i}] < 0$, if $n > 1 - \sqrt{1-\beta^2} = n_B$, say.

Now, substituting the stage 2 equilibrium prices and corresponding quantities in the expression for social welfare, we get $SW_1 = SW_1(t_1, t_2)$ and $SW_2 = SW_2(t_1, t_2)$.[7] It can be easily cheked that, for all $\beta \in (0,1)$,

$$\frac{\partial}{\partial t_j}\left(\frac{\partial SW_i(.)}{\partial t_i}\right) = \frac{\beta(1-n)\{(2-n)n-\beta^2\}}{(1-\beta^2)\{(n+2)^2-\beta^2\}^2} \begin{cases} > 0 & \text{if } 0 \leq n < 1-\sqrt{1-\beta^2} = n_B \\ < 0 & \text{if } n_B < n < 1. \end{cases}$$

It implies that, unlike as in usual non-network goods oligopoly models, strategic nature of export-tax rates (t_1, t_2) crucially depends on the strength of network externalities. Countries perceive that export-tax rates are strategic complements only in the case of weak network externalities ($n < n_B$). Otherwise, if network externalities are strong ($n > n_B$), export-tax rates are strategic substitutes.

Corollary 1: *In the case of Bertrand type price competition without managerial delegation, export-tax/subsidy rates of two competing countries are strategic substitutes (complements), if network externalities are strong (weak), i.e., if $n > n_B$ ($n < n_B$).*

Let us now turn to the problem of the government of country i in the first stage of the game, which can be written as $\underset{t_i}{Max}\ SW_i(t_i, t_j)$. From Corollary 1, it follows that tax-

[7] $SW_i(t_i, t_j) = \frac{\{((1-\beta)(\beta-n+2)(\alpha-c)+\beta(1-n)t_j+(1-n)(2-n)t_i\}\{((1-\beta)(\beta-n+2)(\alpha-c)+\beta(1-n)t_j-\left(2-\beta^2-n\right)t_i\}}{(1-\beta^2)\{(2-n)^2-\beta^2\}^2}$; $i, j = 1,\ 2$ and $i \neq j$.

reaction functions are negatively (positively) sloped in the t_1-t_2 plane, if $n > n_B$ ($n < n_B$).[8] Solving governments' problems we get the optimal export-tax rates and corresponding prices, outputs, profits and social welfares as in Lemma 1.

Lemma 1: *The equilibrium export-tax rates, prices, quantities, profits and social welfares under Bertrand type price competition without managerial delegation are, respectively, as follows.*

$$t^B_{1,ND} = t^B_{2,ND} = t^B_{ND} = \frac{(\alpha-c)(1-\beta)\{\beta^2-n(2-n)\}}{(1-n)\{4-\beta(2+\beta)-n(2-\beta)\}},$$
$$p^B_{1,ND} = p^B_{2,ND} = p^B_{ND} = \frac{\alpha(1-\beta)(2-n)+c\left(2-\beta^2-n\right)}{4-\beta(2+\beta)-n(2-\beta)},$$
$$x^B_{1,ND} = x^B_{2,ND} = x^B_{ND} = \frac{(\alpha-c)\left(2-n-\beta^2\right)}{(1+\beta)(1-n)\{4-\beta(2+\beta)-n(2-\beta)\}},$$
$$\pi^B_{1,ND} = \pi^B_{2,ND} = \pi^B_{ND} = \frac{(\alpha-c)^2(1-\beta)\left(2-n-\beta^2\right)^2}{(1+\beta)(1-n)^2\{4-\beta(2+\beta)-n(2-\beta)\}^2} \text{ and}$$
$$SW^B_{1,ND} = SW^B_{2,ND} = SW^B_{ND} = \frac{(\alpha-c)^2(1-\beta)(2-n)\left(2-n-\beta^2\right)}{(1+\beta)(1-n)\{4-\beta(2+\beta)-n(2-\beta)\}^2};$$

where subscript 'ND' indicates no-delegation and superscript 'B' indicates Bertrand type price competition.

It is easy to observe that, if $n = 0$, the equilibrium export-tax rate is positive: $t^B_{ND}|_{n=0} > 0$. That is, when firms compete in terms of price, it is optimal for governments to impose tax on exports in absence of network externalities. This is in line with the existing result in the case of usual non-network goods oligopoly under Bertrand type price competition (see, for example, Eaton and Grossman, 1986). The intuition behind this result is as follows. In the case of usual non-network goods oligopoly with Bertrand type price competition, price under cutting by firms results in low levels of profits and social welfares of exporting countries. The government of an exporting country can restrict price undercutting by imposing export-tax, which increases its tax revenue by a larger amount than the corresponding decrease in profit of its own firm. Further, since tax rates are strategic complements, it

[8] The equation of the tax-reaction function of country i is as follows.
$t_i = -\frac{\left(2n-\beta^2-n^2\right)\{(1-\beta)(\alpha-c)(2+\beta-n)+\beta(1-n)t_j\}}{2(2+n^2-3n)(2-\beta^2-n)}$; $i, j = 1, 2$; $i \neq j$.

is optimal for each of the two exporting countries to impose tax on exports. Presence of network externalities adds twist to this mechanism.

In the case of network goods oligopoly, less aggressive play (i.e., setting higher prices) by firms dampens consumers' expectations regarding total sales and, thus, reduces their willingness to pay. Therefore, export-tax has indirect negative effects on both profit and tax revenue, via consumers' expectations, in the case of network goods oligopoly. The stronger the network externalities, the larger the indirect negative effect of export-tax on social welfare. As a result, the optimal export-tax is decreasing in the strength of network externalities: $\frac{\partial t_{ND}^B}{\partial n} = -\frac{(\alpha-c)(1-\beta)^2\{(2+\beta)(2-n)^2-2\beta^2(2-n)-\beta^3\}}{(1-n)^2\{4-\beta(\beta+2)-n(2-\beta)\}^2} < 0$. Moreover, if network externalities are strong ($n > n_B$), negative indirect effect of export-tax dominates its positive direct effect on social welfare. This is because, less (more) aggressive play by a firm reduces (enhances) consumers' willingness to pay for its product to a large extent in the case of strong network externalities. In such scenario, if a country induces its firm to behave more aggressively by subsidizing exports, increase in profit of its firm over compensates the loss due to subsidy. Therefore, in the case of strong network externalities, it is optimal for both country 1 and country 2 to offer export-subsidy: $t_{ND}^B < 0$, if $n > n_B$. We summarize these results in the following proposition.

Proposition 1: *In the case of network goods oligopoly under Bertrand type price competition without managerial delegation, the nature of the optimal trade policy depends on the strength of network externalities. It is optimal for exporting countries to impose tax on exports, provided that network externalities are weak ($0 \leq n < n_B$). Otherwise, if network externalities are strong ($n_B < n < 1$), it is optimal to subsidize exports. The stronger the network externalities, the smaller (greater) the rate of export-tax (export-subsidy).*

Comparing the equilibrium social welfare from Lemma 1 with that in absence of policy interventions ($t_1 = t_2 = 0$) by exporting countries, we get $S_{ND}^B < S_{ND}^{B,(0,0)}$, if $n_B < n < n_0^B$; where $S_{ND}^{B,(0,0)} = \frac{(1-\beta)(\alpha-c)^2}{(\beta+1)(-\beta-n+2)^2}$ is the social welfare in the case of free-trade and $n_0^B = 1+\beta-\beta^2-(1-\beta)\sqrt{1+\beta^2} < 1$. Otherwise, if $n < n_B$ or $n > n_0^B$, we have $S_{ND}^B > S_{ND}^{B,(0,0)}$.

That is, policy intervention leads to higher social welfare of exporting countries in the equilibrium compared to that under free-trade, whenever export-tax is optimal policy. In contrast, when exporting countries find it optimal to subsidize exports, the equilibrium social welfare of exporting countries is lower than that under free-trade unless network externalities are sufficiently strong.

Proposition 2: *When non managerial firms engage in Bertrand type price competition, trade policy interventions result in higher social welfare of each exporting country in the equilibrium than that under free trade, if network externalities are either weak or very strong; otherwise, free trade results in higher social welfare.*

Comparative static analysis also reveals that, though the optimal export-tax rate decreases with the strength of network externalities, both the equilibrium price and the equilibrium quantity of each firm increase with the strength of network externalities: $\frac{\partial x^B_{ND}}{\partial n} > \frac{\partial p^B_{ND}}{\partial n} > 0$. The reason is, stronger network externalities shifts the demand curve outward. As a result, equilibrium profits of firms and social welfares of exporting countries are also higher in the case of stronger network externalities: $\frac{\partial \pi^B_{ND}}{\partial n} > 0$ and $\frac{\partial SW^B_{ND}}{\partial n} > 0$.

3.2 Cournot type quantity competition

Let us now consider that firms are engaged in Cournot type quantity competition. Thus, in stage 2, firm i sets its quantity x_i, taking x_j, y_i, y_j, t_i and t_j as given, to maximize its profit $\pi_i = (p_i - c)x_i - t_i x_i$, where p_i is given by equation 1(a). Solving firm i's problem, we get its quantity reaction function as follows.

$$x_i = \frac{\alpha - c - t_i - \beta x_j + n y_i + n\beta y_j}{2} \qquad i, j = 1, 2, \;\; i \neq j \tag{4}$$

Clearly, firms perceive that quantities are strategic substitutes ($\frac{\partial x_i}{\partial x_j} < 0$) and by subsidizing exports a country can induce its firm to be more aggressive in the product market, as in the case of usual non-network goods oligopoly. Also, note that higher y_i and/or y_j shift the quantity reaction function outward in the presence of network externalities and the extent of such outward shift is larger in the case of stronger network externalities, ceteris paribus.

From the above mentioned quantity reaction functions of firm 1 and firm 2 together with the 'rational expectations conditions', $y_1 = x_1$ and $y_2 = x_2$, we get the stage 2 equilibrium quantities as follows.

$$x_i = x_i(t_i, t_j) = \frac{(\alpha-c)\{2-n-\beta(1-n)\}-(2-n)t_i+\beta(1-n)t_j}{(2-n)^2-\beta^2(1-n)^2},\ i,j = 1,2,\ \ i \neq j.$$

It is evident that $\frac{\partial x_i(t_i,t_j)}{\partial t_i} < 0 < \frac{\partial x_i(t_i,t_j)}{\partial t_j}$ and $|\frac{\partial x_i(t_i,t_j)}{\partial t_i}| > |\frac{\partial x_i(t_i,t_j)}{\partial t_j}|$, $i,j = 1,2,\ \ i \neq j$, $\forall n \in [0,1)$ and $\beta \in (0,1)$. That is, the magnitude of the negative (positive) effect of a country's tax (subsidy) rate on its own firm's output is larger than the magnitude of the positive (negative) effect of a country's tax (subsidy) rate on rival country's firms' output. Interestingly, stronger network externalities lead to larger (smaller) effect of a country's tax/subsidy rate on its own (rival country's) firm's output: $\frac{\partial}{\partial n}(|\frac{\partial x_i(t_i,t_j)}{\partial t_i}|) > 0$ and $\frac{\partial}{\partial n}(|\frac{\partial x_i(t_i,t_j)}{\partial t_j}|) < 0$, $i,j = 1,2,\ \ i \neq j$, $\forall n \in [0,1)$ and $\beta \in (0,1)$. This is because, a firm's optimal output choice is positively affected by consumers' expectations regarding its own sales as well as regarding its rival firm's sales.

Now, substituting the stage 2 equilibrium quantities and corresponding prices in the expression for social welfare, we obtain social welfares in terms of t_1 and t_2: $SW_i = SW_i(t_i, t_j)$, $i,j = 1,2,\ \ i \neq j$.[9] It follows that $\frac{\partial}{\partial t_j}\left(\frac{\partial SW_i(.)}{\partial t_i}\right) < 0$, $\forall\ \beta \in (0,1)$ and $n \in [0,1)$. Therefore, unlike as in the case of Bertrand type price competition, exporting countries always perceive that export-tax/subsidy rates are strategic substuitutes in the present scenario.

Corollary 2: *In the case of Cournot type quantity competition without managerial delegation, export-tax/subsidy rates of two competing countries are strategic substitutes, irrespective of the strength of network externalities.*

Solving the governments' problems in stage 1 of the game, $\underset{t_i}{Max}\ SW_i(t_i, t_j)$, we get the optimal export-tax/subsidy rates. In Lemma 2, we report these optimal export-tax/subsidy rates along with the equilibrium quantities, prices and profits of firms and social welfares of competing countries.

[9] $SW_i(t_i,t_j) = \frac{[(\alpha-c)\{2-n-\beta(1-n)\}-(2-n)t_i+\beta(1-n)t_j][(\alpha-c)\{2-n-\beta(1-n)\}+(1-n)\{(2-n-\beta^2(1-n)\}t_i+\beta(1-n)t_j]}{\{(2-n)^2-\beta^2(1-n)^2\}^2}$.

Lemma 2: *When non-managerial firms are engaged in Cournot type quantity competition in a third country's market, the equilibrium export-tax rates, prices, quantities, profits and social welfares are, respectively, as follows.*

$$t^C_{1,ND} = t^C_{2,ND} = t^C_{ND} = -\frac{(\alpha-c)\{\beta^2(1-n)^2+(2-n)n\}}{(1-n)\{4+(2-\beta)\beta-(2-\beta)(1+\beta)n\}},$$

$$p^C_{1,ND} = p^C_{2,ND} = p^C_{ND} = \frac{\alpha\{2-n-\beta^2(1-n)\}+c(1+\beta)(2-n)}{4+(2-\beta)\beta-(2-\beta)(1+\beta)n},$$

$$x^C_{1,ND} = x^C_{2,ND} = x^C_{ND} = \frac{(\alpha-c)(2-n)}{(1-n)\{4+(2-\beta)\beta-(2-\beta)(1+\beta)n\}},$$

$$\pi^C_{1,ND} = \pi^C_{2,ND} = \pi^C_{ND} = \frac{(\alpha-c)^2(2-n)^2}{(1-n)^2\{4+(2-\beta)\beta-(2-\beta)(1+\beta)n\}^2} \text{ and}$$

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

where subscript 'ND' indicates no-delegation and superscript 'C' indicates Cournot type quantity competition.

A few observations regarding the optimal trade policy in the present context are in order. First, $t^C_{ND} < 0$, $\forall\ \beta \in (0,1)$ and $n \in [0,1)$. That is, it is always optimal for exporting countries to subsidize exports in the case of Cournot type quantity competition under no delegation, as in the case of usual non-network goods oligopoly (Brander and Spencer, 1985). This result is in sharp contrast to that in the case of Bertrand type price competition without delegation. Second, it can be checked that the optimal rate of export-subsidy is higher in the case of stronger network externalities: $\frac{\partial t^C_{ND}}{\partial n} < 0$. The mechanism behind these results is as follows. If only one country offers per unit export-subsidy, the quantity reaction curve of its own firm shifts to the right without affecting the rival firm's quantity reaction curve, which leads to higher profit of its own firm at the expense of its rival firm's profit. Further, the subsidy-receiving firm's profit increases by a larger amount than the amount of subsidy paid to it, unless the rate of subsidy exceeds a certain level. It implies that, due to *profit shifting effect* of export-subsidy in the case of Cournot type quantity competition, each country has unilateral incentive to offer per unit export-subsidy to its firm. This is true regardless of the strength of network externalities. In the case of network goods oligopoly, export-subsidy induces a firm to choose higher

output and that in turn enhances consumers' willingness to pay, which results in higher profits. The stronger the network externalities, the greater the positive effect of export-subsidy on firms' profits through its effect on consumers' willingness to pay. It implies that, in network goods oligopoly with Cournot type quantity competition, countries have an additional incentive to subsidize exports and such incentive is larger in the case of stronger network externalities. Therefore, in the equilibrium under Cournot type quantity competition without delegation, each country offers export-subsidy and the rate of subsidy is higher in the case of stronger network externalities.

Proposition 3: *Under Cournot type quantity competition without managerial delegation, it is optimal for exporting countries to subsidize exports, irrespective of the strength of network externalities. Nonetheless, the optimal rate of export-subsidy is higher in the case of stronger network externalities.*

From Proposition 1 and Proposition 2, it follows that the nature of the optimal trade policy under price competition without delegation is opposite to that under quantity competition without delegation, provided that network externalities are weak ($n < n_B$). Otherwise, if network externalities are strong ($n > n_B$), the optimal trade policy is to subsidize exports regardless of the mode of product market competition. In other words, unlike as in the case of usual non-network goods oligopoly, the nature of trade policy need not necessarily be sensitive to the mode of product market competition in network goods oligopoly.

It can be checked that, in the case of free-trade ($t_1 = t_2 = 0$), each exporting country's social welfare under quantity competition without managerial delegation is given by $S_{ND}^{C,(0,0)} = \frac{(\alpha-c)^2}{\{2+(1-n)\beta-n\}^2}$, where superscript '$C,(0,0)$' indicates 'Cournot type quantity competition in absence of policy interventions'. Comparing social welfare under free-trade with that in Lemma 2, it turns out that $S_{ND}^{C,(0,0)} < (>)\, S_{ND}^{C}$, if $n > (<) 2 - \frac{1+\sqrt{1+\beta^2}}{1+\beta} = n_0^C$. That is, trade policy intervention brings about lower social welfare compared to that in the case of free-trade, unless network externalities are sufficiently strong. Note that, since both country 1 and country 2 offers export-subsidy in equilibrium, quantity reaction function of each firm shifts to the right. As a result, if network externalities are not sufficiently strong

($n < n_0^C$), each firm's profit increases due to export-subsidy from that under free-trade, but by a lesser amount than the amount of subsidy paid to it. However, in the presence of sufficiently strong network externalities ($n > n_0^C$), firms' more aggressive play shifts demand curves outwards to a large extent. Therefore, in the later case, each firm's profit increases by a larger amount than the amount of subsidy, though both the rate of subsidy and the volume of exports are higher in the case of stronger network externalities. Therefore, if network externalities are sufficiently strong ($n > n_0^C$), each of the two exporting countries gains in terms of social welfare by subsidizing exports.

Proposition 4: *In the case of network goods Cournot oligopoly without delegation, trade policy intervention by each exporting-country does not necessarily lead to Pareto inferior equilibrium. If network externalities are sufficiently strong, each exporting country obtains higher social welfare by subsidizing exports compared to that in the case of free-trade.*

Comparative static analysis reveals that, as in the case of Bertrand type price competition without delegation, (a) positive effect of the strength of network externalities on the equilibrium output is larger than that on the equilibrium price and (b) stronger network externalities leads to higher equilibrium profit of firms and social welfare of exporting countries: $\frac{\partial x_{ND}^C}{\partial n} > \frac{\partial p_{ND}^C}{\partial n} > 0$, $\frac{\partial \pi_{ND}^C}{\partial n} > 0$ and $\frac{\partial SW_{ND}^C}{\partial n} > 0$, $\forall\ \beta \in (0,1)$ and $n \in [0,1)$.

Finally, comparing equilibrium outcomes from Lemma 1 and Lemma 2, we find that, in the case of network goods oligopoly without delegation, Cournot type quantity competition leads to lower output and higher export-subsidy rate, price, profit and exporting countries' social welfare compared to that under Bertrand type price competition: $x_{ND}^C < x_{ND}^B$, $t_{ND}^C < t_{ND}^B$, $p_{ND}^C > p_{ND}^B$, $\pi_{ND}^C > \pi_{ND}^B$ and $SW_{ND}^C > SW_{ND}^B$. Clearly, Singh and Vives (1984)'s ranking of profits under Cournot and Bertrand competition holds true in the present context. We note here that, if the strength of network externalities exceeds a critical level, this profit-ranking is reversed in the case of closed economy and no policy intervention Pal (2014). However, since in the present context the rate of export-subsidy under quantity competition is higher than that under price competition, the equilibrium

profit under quantity competition remains higher compared to that under price competition even in the case of strong network externalities.

4 Trade policy under strategic managerial delegation

As mentioned before, considering usual non-network goods oligopoly with relative performance based managerial delegation contracts in firms, Miller and Pazgal (2005) argue that optimal trade policy does not depend on the mode of product market competition - price or quantity - it is always optimal for exporting countries to subsidize exports. The reason is, through relative performance based managerial delegation contracts owners can exercise sufficient control over their managers and, thus, equilibrium outcomes under price and quantity competition are equivalent in the case of usual non-network goods oligopoly (Miller and Pazgal, 2001). The question is, does optimal trade policy remain invariant to the mode of product market competition under relative performance based managerial delegation even in the case of network goods oligopoly? Recently, Bhattacharjee and Pal (2013) demonstrate that in the case of network goods oligopoly Miller and Pazgal (2001)'s equivalence result does not hold true, rather quantity competition leads to lower outputs, higher prices and higher profits compared to that under price competition à la Singh and Vives (1984). It seems to indicate that the mode of product market competition is likely to play important role in determining optimal trade policy in network goods oligopoly with relative performance based managerial delegation as well. Nonetheless, it seems important to examine the implications of interplay between managerial delegation and network externalities to optimal trade policy under alternative modes of product market competition. For this purpose, we now consider that the stages of the game involved are as follows.

> Stage 1: Governments of country 1 and country 2 simultaneously and independently decide export-tax rates.
> Stage 2: Owners of firm 1 and firm 2 simultaneously and independently design managerial delegation contracts.

Stage 3: Managers engage themselves either in Bertrand type price competition or Cournot type quantity competition, depending on the exogenously given mode of competition, in a third country.

As before, we solve this game by backward induction method considering price competition and quantity competition separately.

4.1 Bertrand type price competition under delegation

Let us begin with the scenario in which there is Bertrand type price competition in the product market. From the first order condition of manager i's problem in stage 3, $\underset{p_i}{Max}\ O_i(p_i, p_j) = \pi_i + \lambda_i \pi_j = (p_i - c - t_i)x_i + \lambda_i(p_j - c - t_j)x_j$, where x_i is given by equation 1(b), we obtain his price reaction functions as follows.

$$p_i = \frac{\alpha(1-\beta) + c + t_i - \lambda_i\beta(c + t_j) + \beta(1 + \lambda_i)p_j + ny_i(1 - \beta^2)}{2}\ , i, j = 1,\ 2,\ i \neq j, \quad (5)$$

It is interesting to note that, if $\lambda_i < 0$, i.e., if the owner of firm i induces its manager to be more aggressive, the manager of firm i sets higher price in response to higher export-tax rate in country j. Further, if $\lambda_i < -1$, prices are considered to be strategic substitutes by the firm i's manager. Also, note that we have $\frac{\partial p_i}{\partial y_i} > 0$ and $\frac{\partial}{\partial n}\left(\frac{\partial p_i}{\partial y_i}\right) > 0$. Now, solving managers' price reaction functions along with 'rational expectations' conditions ($y_1 = x_1$ and $y_2 = x_2$), we obtain the stage 3 equilibrium prices and corresponding profits of firms as functions of incentive parameters and tax rates: $p_i = p_i(\lambda_i, \lambda_j, t_i, t_j)$ and $\pi_i = \pi_i(\lambda_i, \lambda_j, t_i, t_j)$; $i, j = 1,\ 2,\ i \neq j$. It is evident that, in the present scenario, effects of tax rates on stage 3 equilibrium prices and profits will depend on values of incentive parameters in managerial delegation contracts. Also note that we can write the problem of the owner of firm i in stage 2 of the game as $\underset{\lambda_i}{Max}\ \pi_i(\lambda_i, \lambda_j; t_i, t_j)$, where $i, j = 1,\ 2$ and $i \neq j$.

Solving the owners' problems in stage 2, we get the following expression for manager i's incentive parameter.

$$\lambda_i(t_i, t_j) = -\frac{\{(2-n)n - \beta^2\}(\alpha - c - t_i)}{\beta(1-n)\{(\alpha - c)(2 - \beta - n) - (2-n)t_j + \beta t_i\}}; i, j = 1,\ 2 \text{ and } i \neq j.$$

From the above expression, it can be checked that in the case of free trade ($t_1 = t_2 = 0$) the stage 2 equilibrium incentive parameter is positive (negative), if there is weak (strong) network externalities: $\lambda_i(0,0) > 0$, if $0 \leq n < 1 - \sqrt{1-\beta^2} = n_B$; otherwise, $\lambda_i(0,0) < 0$. That is, under free trade it is optimal for each owner to reward (penalize) her manager for rival firm's profit in order to induce her manager to be less (more) aggressive in the product market compared to that in the case of no-delegation, if network externalities are weak (strong). The reason is, in the case of strong network externalities ($n > n_B$), positive effect of more aggressive play by a firm on consumers' expectations regarding its sales leads to more than proportionate increase in its demand. Therefore, if network externalities are strong, price undercutting results in higher profit. The opposite is true in the case of weak network externalities ($n < n_B$).

Now, if a country imposes export-tax in the case of strong network externalities, its own (rival country's) firm's gain from being more aggressive reduces (increases) and, thus, it is optimal for the owner of its own (rival country's) firm to choose a higher (lower) value of the incentive parameter in order to induce her manager to behave less (more) aggressively compared to that in the case of no-delegation. On the other hand, if a country imposes export-tax in the case of weak network externalities, the gain of its rival country's firm from less aggressive behavior in the product market rises at the expense of its own firm, which induces the owner of its own (rival country's) firm to set a lower (higher) value of the incentive parameter for her manager. It implies that, if network externalities are weak (strong), the effect of a country's export-tax rate on the incentive parameter for the manager of its own firm is negative (positive) and that of its rival country's firm is positive (negative): (a) $\frac{\partial \lambda_i}{\partial t_i} < 0$ and $\frac{\partial \lambda_j}{\partial t_i} > 0$, if $0 \leq n < n_B = 1 - \sqrt{1-\beta^2}$, and (b) $\frac{\partial \lambda_i}{\partial t_i} > 0$ and $\frac{\partial \lambda_j}{\partial t_i} < 0$, if $n_B < n < 1$; $i, j = 1, 2$ and $i \neq j$.

Clearly, under managerial delegation trade policy works through an additional channel, i.e., through its influence on managerial delegation contracts. However, it is easy to observe that, $\frac{\partial}{\partial t_j}\left(\frac{\partial SW_i(t_i,t_j)}{\partial t_i}\right) = -\frac{\beta(2-n)n-\beta^3}{4(1-\beta^2)(1-n)(2-n)^2} > (<)\, 0$, if $n < (>)\, n_B$. That is, for any given strength of network externalities, the strategic nature of export-tax rates under managerial delegation remains the same as that in the case of no delegation (Corollary 1).

Finally, solving the governments' problems in stage 1 of the game, $\underset{t_i}{Max}\ SW_i(t_i, t_j)$, where $i, j = 1, 2$ and $i \neq j$, we get the subgame perfect Nash equilibrium export-tax rates and corresponding quantities, prices, profits and social welfares as follows.

Lemma 3: *The equilibrium export-tax rates, incentive parameters, prices, quantities, profits and social welfares in the case of Bertrand type price competition under strategic managerial delegation in firms are, respectively, as follows.*

$$t^B_{1,D} = t^B_{2,D} = t^B_D = \frac{\beta(\alpha - c)\{(2-n)n - \beta^2\}}{(2+\beta-n)\{4 - \beta(2+\beta) - n(2-\beta)\}},$$

$$\lambda^B_{1,D} = \lambda^B_{2,D} = t^B_D = -\frac{(2-n)n - \beta^2}{\beta(1-n)(2-\beta-n)},$$

$$p^B_{1,D} = p^B_{2,D} = p^B_D = \frac{\alpha(1-\beta)(2-n) + c\left(2 - \beta^2 - n\right)}{4 - \beta(\beta+2) - n(2-\beta)},$$

$$x^B_{1,D} = x^B_{2,D} = x^B_D = \frac{(\alpha - c)\left(2 - \beta^2 - n\right)}{(1-n)(1+\beta)\{4 - \beta(2+\beta) - n(2-\beta)},$$

$$\pi^B_{1,D} = \pi^B_{2,D} = \pi^B_D = \frac{(\alpha - c)^2(2-\beta-n)\left(2 - \beta^2 - n\right)^2}{(1-n)(1+\beta)(2-n+\beta)\{4 - \beta(2+\beta) - n(2-\beta)\}^2} \text{ and}$$

$$SW^B_{1,D} = SW^B_{2,D} = SW^B_D = \frac{(\alpha - c)^2(1-\beta)(2-n)\left(2 - \beta^2 - n\right)}{(1-n)(1+\beta)\{4 - \beta(2+\beta) - n(2-\beta)\}^2};$$

where subscript 'D' indicates delegation in firms.

First, note that the equilibrium incentive parameter is positive (negative) in the case of weak (strong) network externalities, as observed under free trade environment. Needless to mention here that positive (negative) incentive parameter has similar effect on pricing behavior as that of export-tax (export-subsidy). Second, the optimal export-tax rate is negative (positive), if network externalities are weak (strong): $t^B_D <\ (>)\, 0$, if $0 \leq n < n_B$ ($n > n_B$). That is, the nature of optimal trade policy under managerial delegation is exactly opposite to that under no delegation. The intuition behind this result is as follows. Under strategic managerial delegation, trade policy interventions affect firms' pricing behavior both directly and through influencing managerial delegation contracts. In the case of weak network externalities, export-subsidy offered by country i makes firm i even less aggressive (by increasing λ_i) and firm j relatively more aggressive (by reducing λ_j). As a result, firm i's profit increases by a larger amount than the amount of subsidy paid,

which leads to higher social welfare of country i. Therefore, it is optimal to subsidize exports under strategic managerial delegation, if network externalities are weak. On the other hand, if network externalities are strong, owners end up by inducing their managers to engage in excessive price undercutting under free-trade, which results in sub-optimum social welfare in equilibrium. In such a scenario, by imposing export-tax country i can restrict firm i's aggressiveness and (by increasing λ_i) and at the same time induce firm j to be even more aggressive (by reducing λ_j), which results in higher (lower) social welfare of country i (country j). Thus, in the case of strong network externalities, it is optimal for exporting countries to impose export-tax under managerial delegation. Third, unlike as in the case of no delegation, optimal export-tax (export-subsidy) rate is higher (lower) in the case of stronger network externalities under managerial delegation: $\frac{\partial t_D^B}{\partial n} > 0$ for all $n \in [0, 1)$. Fourth, in the case of managerial delegation exporting countries obtain higher (lower) social welfare under free-trade compared to that under optimal policy intervention, if network externalities are weak (strong): $SW_D^B(0,0) > (<) SW_D^B$, if $n < (>) n_B$, where $SW_D^B(0,0) = \frac{(\alpha-c)^2(2-\beta-n)(2+\beta-n)}{4(1+\beta)(1-n)(2-n)^2}$ is the equilibrium social welfare of each exporting country in the case of managerial delegation under free-trade.

Proposition 5: *In the case of Bertrand type price competition in network goods oligopoly under strategic managerial delegation, the following is true.*

(a) *It is optimal for each exporting country to subsidize (tax) exports, if network externalities are weak (strong). The stronger the network externalities, the higher (lower) the rate of export-tax (export-subsidy).*

(b) *Trade policy interventions result in lower social welfare for exporting countries compared to that under free-trade, unless network externalities are strong.*

From Proposition 1 and Proposition 5, it is evident that in the case of price competition the nature of optimal trade policy under managerial delegation is exactly opposite to that under no delegation, for any given strength of network externalities.

Corollary 3: *Managerial delegation alters the nature of optimal trade policy under Bertrand type price competition from that in the case of no delegation.*

4.2 Cournot type quantity competition under delegation

Now, we consider that there is Cournot type quantity competition in the third country's product market. In this scenario, from the first order condition of manager i's problem in the third stage, $\underset{x_i}{Max}\ O_i = \pi_i + \lambda_i \pi_j$, we obtain his quantity reaction function as follows.

$$x_i = \frac{\alpha - c - t_i - x_j\beta\,(1+\lambda_i) + ny_i + n\beta y_j}{2}; i, j = 1, 2,\ i \neq j \tag{6}$$

From equation (6) it follows that manager i perceives quantities, x_i and x_j, as strategic substitutes, unless his incentive parameter (λ_i) is less than minus one. The negative effect of export-tax rate and positive effects of consumers' expectations regarding firms' sales are same as in the case of no delegation. Solving managers' quantity reaction function along with 'rational expectations' conditions ($y_1 = x_1$ and $y_2 = x_2$), we get the stage 3 equilibrium outputs and corresponding profits of firms. Next, solving owners' problems we get the following stage 2 equilibrium incentive parameters.

$$\lambda_i(t_i, t_j) = \frac{-\{(\alpha-c)(1-\beta) - t_1 + \beta t_2\}\{(\beta^2 + n(2-n)(1-\beta^2)\}}{\beta\left[(\alpha-c)(1-\beta)\{2-n+\beta(1-n)\} + \beta t_1 - t_2\{2-n-(1-n)\beta^2\}\right]};$$
$$i, j = 1, 2; i \neq j.$$

Note that, if $t_1 = t_2 = 0$, i.e., in the case of free trade, $\lambda_i(0,0) = -\frac{\beta^2 + n(2-n)\left(1-\beta^2\right)}{\beta\{2-n+(1-n)\beta\}} < 0$ for all $\beta \in (0,1)$ and $n \in [0,1)$. That is, under free trade in the case of quantity competition it is optimal for owners to induce their respective managers to be more aggressive in the product market compared to that in the case of no delegation, regardless of the strength of network externalities. This is in contrast to that in the case of price competition. In fact, if network externalities are stronger, in the case of quantity competition each owner has higher incentive to induce his manager to be more aggressive : $\frac{\partial \lambda_i}{\partial n} < 0$. The reason is, in the case of stronger network externalities, aggressive play by a firm enhances consumers'

willingness to pay for its product to a greater extent, which leads to increase in profit by a larger amount. Moreover, it can be checked that export-subsidy to a firm enhances (reduces) its (rival firm's) owner's incentive to induce her manager to be more aggressive compared to that in the case of free trade, while the opposite is true for export-tax: $\frac{\partial \lambda_i}{\partial t_i} > 0$ and $\frac{\partial \lambda_j}{\partial t_i} < 0$ for all $\beta \in (0,1)$ and $n \in [0,1)$. This is because, export-subsidy (export-tax) to firm i reduces (increases) firm i's effective marginal cost and that results in competitive advantage (disadvantage) of firm i over firm j in the product market.

From the expressions for social welfare, stage 2 equilibrium incentive parameters and stage 3 equilibrium quantities and prices, we obtain the social welfare of country i in the case of quantity competition under delegation as functions of t_i and t_j: $SW_i = SW_i(t_i, t_j)$; $i, j = 1, 2;\ i \neq j$.[10] It turns out that $\frac{\partial}{\partial t_j}\left(\frac{\partial SW_i(t_i,t_j)}{\partial t_i}\right) = \frac{\beta^3+\left(1-\beta^2\right)\beta(2-n)n}{4(1-\beta^2)(1-n)(2-n)^2} > 0$, since $0 < \beta < 1$ and $0 \leq n < 1$. It implies that in the case of quantity competition under delegation the government of each exporting country perceives tax rates, t_1 and t_2, as strategic complements, irrespective of the strength of network externalities, which is exactly opposite to that in the case of quantity competition without delegation. In other words, strategic managerial delegation in firms alters the strategic nature of trade policy instruments under quantity competition. Therefore, following tax-reaction functions of governments, which we derive from the first order conditions of governments' problems $\underset{t_i}{Max}\, SW_i(t_i, t_j)$ in stage 1 of the game, are positively sloped in t_1-t_2 plane.

$$t_i = \frac{-(a-c-t_j)\{\beta^3 + (1-\beta^2)\,\beta(2-n)n\}}{2(2-n)\{2-n-(1-n)\beta^2\}},\ i, j = 1, 2,\ i \neq j$$

Solving above mentioned tax-reaction functions of governments, we get the equilibrium tax rates in the case of quantity competition under delegation, which are reported in Lemma 4 along with the equilibrium incentive parameters, prices, quantities, profits and exporting countries' social welfares.

Lemma 4: *In the case of Cournot type quantity competition under strategic managerial delegation in firms, the equilibrium export-tax rates, incentive parameters, prices,*

[10] $SW_i(t_i, t_j) = \frac{\left[(\alpha-c)(1-\beta)\{2-n+\beta(1-n)\}-\{2-n-(1-n)\beta^2\}t_1+\beta t_2\right]\left[(\alpha-c)\{2-n-\beta(1-n)\}+\beta(1-n)t_2+(2-n)t_1\right]}{4(1-\beta^2)(1-n)(2-n)^2}$.

quantities, profits and social welfares are, respectively, as follows.

$$t^C_{1,D} = t^C_{2,D} = t^C_D = -\frac{(\alpha-c)\{\beta^3(1-n)^2+(2-n)n\beta\}}{\{2-n+\beta(1-n)\}\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}},$$

$$\lambda^C_{1,D} = \lambda^C_{2,D} = \lambda^C_D = -\frac{\beta^2+\left(1-\beta^2\right)(2-n)n}{(2-n)\beta+(1-n)\beta^2},$$

$$p^C_{1,D} = p^C_{2,D} = p^C_D = \frac{\alpha(1-\beta)(2-n)+c\{2-n-(1-n)\beta^2\}}{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n},$$

$$x^C_{1,D} = x^C_{2,D} = x^C_D = \frac{(\alpha-c)\{2-n-(1-n)\beta^2\}}{(1-n)(1+\beta)\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}},$$

$$\pi^C_{1,D} = \pi^C_{2,D} = \pi^C_D = \frac{(\alpha-c)^2\{2-n-(1-n)\beta^2\}^2\{2-n(1-\beta)-\beta\}}{(1-n)(1+\beta)\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}^2\{2-n(1+\beta)+\beta\}} \text{ and}$$

$$SW^C_{1,D} = SW^C_{2,D} = SW^C_D = \frac{(\alpha-c)^2\{2-n-(1-n)\beta^2\}(2-n)(1-\beta)}{(1-n)(1+\beta)\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}^2};$$

where subscript 'D' indicates delegation in firms.

It is easy to observe that $t^C_D < 0$ and $\frac{\partial t^C_D}{\partial n} < 0$ for all $\beta \in (0,1)$ and $n \in [0,1)$. That is, in the case of quantity competition under strategic managerial delegation, regardless of the strength of network externalities, the equilibrium trade policy involves subsidization of exports and the optimal rate of export-subsidy is higher under stronger network externalities. The intuition behind this result is as follows. In the case of Cournot type quantity competition under strategic managerial delegation, each firm's owner has unilateral incentive to induce her manager to be more aggressive in the product market compared to that under no delegation, no matter what is the strength of network externalities. Export-subsidy strengthens such incentive of the owner, as noted before. As a result, firm's profit increases by a larger amount than the amount of subsidy, which leads to higher social welfare. The stronger the network effect, the higher the positive effect of export-subsidy on profit as well as on social welfare, since aggressive play enhances consumers' willingness to pay to a greater extent in the case of stronger network externalities. Also note that, in the present scenario, optimal incentive parameter is negative and it is lower in the case of stronger network externalities, $\lambda^C_D < 0$ and $\frac{\partial \lambda^C_D}{\partial n} < 0$ for all $\beta \in (0,1)$ and $n \in [0,1)$, because both the strength of network externalities and export-subsidy have negative impact on the incentive parameter. Interestingly, it turns out that the optimal social welfare of exporting countries in the present scenario is lower than that under free-trade, even

in the case of stronger network externalities: $SW_D^C(0,0) > SW_D^C$ for all $\beta \in (0,1)$ and $n \in [0,1)$, where the equilibrium social welfare in the case of free-trade under quantity competition with delegation is given by $SW_D^C(0,0) = \frac{(\alpha-c)^2\{2-\beta-n(1-\beta)\}(2+\beta-n(1+\beta)\}}{4(1+\beta)(1-n)(2-n)^2}$. That is, while in the case of no delegation exporting countries obtain higher social welfare by subsidizing exports under sufficiently strong network externalities ($n > n_0^C$), under managerial delegation the second order effect of export-subsidy through delegation contracts on firms' product market behavior thwarts such possibility. We summarize these results in the following Proposition.

Proposition 6: *In the case of Cournot type quantity competition under strategic managerial delegation, it is always optimal for an exporting country to subsidize its exports and the optimal rate of subsidy is higher in the case of stronger network externalities. However, in equilibrium each exporting country obtains lower social welfare compared to that under free-trade, regardless of the strength of network externalities.*

From Proposition 5 and Proposition 6, it is evident that in the case of network goods oligopoly the nature of optimal trade policy under relative performance based strategic managerial delegation in firms is sensitive to the mode of product market competition - price vis-à-vis quantity, unless network externalities are weak ($n < n_B$). Moreover, Lemma 3 and Lemma 4 implies that the magnitude of trade policy instrument under quantity competition is different from that under price competition ($t_C^D < t_B^D$ for all $n \in (0,1)$). Clearly, Miller and Pazgal (2005)'s equivalence result does not go through in the case of network goods oligopoly. In other words, unlike as in the case of usual non-network goods oligopoly, the mode of product market competition plays a crucial role in determining the optimal trade policy of a country regardless of whether there are managerial delegations in firms or not.

It is also interesting to note that, in the case of quantity competition, the equilibrium rate of export-subsidy under delegation is higher than that under no delegation, if products are close substitutes ($0.869 < \beta \leq 1$) and the strength of network externalities is less than a critical value ($0 \leq n < \frac{4-2\beta-3\beta^2}{2-\beta-3\beta^2}$). It implies that the scale of strategic trade

policy under relative performance based managerial delegation need not necessarily be lower compared to that under no delegation, in the case of both network goods and non-network goods oligopolies. In contrast, considering a homogeneous non-network goods oligopoly and Fershtman and Judd (1987) type managerial incentive scheme, which is a linear combination of firm's own profit and own revenue, Das (1997) argues that delegation reduces the scale of strategic trade policy. Therefore, we can say the following.

Corollary 4: *Under Cournot type quantity competition, the effect of managerial delegation on the scale of strategic trade policy depends on the form of managerial incentive scheme, degree of product differentiation and the strength of network externalities.*

5 Concluding remarks

In this paper we have examined the optimal trade policy for network goods oligopoly, when there is international market share rivalry between two countries. We have considered alternative modes of product market competition, price vis-*à*-vis quantity, both in the presence and absence of strategic managerial delegation in firms, and compared the results. We have shown that the nature of optimal trade policy, i.e. export subsidy or tax, depends on the strength of network externalities in the case of price competition, regardless of whether there is managerial delegation or not; but, not so in the case of quantity competition. If network externalities are weak, export-tax (export-subsidy) is optimal in the case of price (quantity) competition without managerial delegation in firms. However, if network externalities are strong and there is no managerial delegation, it is optimal for exporting countries to subsidize exports both in the case of price competition and in the case of quantity competition. Nonetheless, the optimal rate of export-subsidy is higher in the case of quantity competition compared to that in the case of price competition. These results are contradictory to the predictions of usual non-network goods oligopoly models a la Brander and Spencer (1985) and Eaton and Grossman (1986). Further, unlike as in the case of usual non-network goods oligopoly, policy interventions by exporting countries do

not necessarily result in Pareto inferior (superior) equilibrium outcomes, when non managerial firms compete in terms of quantity (price) in the product market. Under quantity (price) competition without managerial delegation in the presence of sufficiently strong (moderate) network externalities, exporting countries obtain higher (lower) social welfare through policy intervention in the equilibrium compared to that in the case of free-trade.

We have also demonstrated that, contrary to Miller and Pazgal (2005)'s finding, the optimal trade policy remains sensitive to the mode of product market competition in a network goods oligopoly under relative performance based managerial delegation contracts. In the case of price competition under managerial delegation, it is optimal for exporting countries to subsidize (tax) exports, when network externalities are weak (strong). That is, in the case of price competition, managerial delegation alters the nature of the optimal trade policy from that under no delegation. However, even under managerial delegation, (a) subsidization of exports remains always optimal in the case of quantity competition and (b) quantity competition calls for a higher rate of export-subsidy than that in the case of price competition. Interestingly, when there is managerial delegation, trade policy interventions under price (quantity) competition reduce exporting countries' social welfare from the free-trade level, unless network externalities are strong (regardless of the strength of network externalities). Clearly, welfare implications of strategic trade policy not only depend on the mode of product market competition and internal organization of firms, the strength of network externalities also plays a crucial role.

Alternative patterns of trade: So far, we have considered a particular pattern of trade, i.e., export rivalry. The question is, what are the implications of network externalities on optimal trade policy under alternative trade patterns? In order to economize on space, here we present the main results obtained under (i) import-competing network goods oligopoly and (ii) fully integrated markets. In the case of import-competing network goods oligopoly, domestic country's optimal policy is to impose an import tariff, regardless of (a) the strength of network externalities, (b) whether firms compete in terms of price or quantity, (c) whether product market competition takes place between managerial or non managerial firms and (d) whether the foreign government is active or passive. The nature

of active foreign government's optimal trade policy in this scenario is found to be the same as that in the case of export rivalry. Interestingly, in the import competing model, free trade welfare of home country need not necessarily be higher than its autarky welfare in the case of network goods oligopoly, which is in contrast to the existing result. Further, unlike as in the case of export rivalry model, the domestic country always obtains higher social welfare in case of optimal trade policy intervention(s) compared to that under free trade. On the contrary, foreign government's equilibrium welfare is lower as compared to that under free trade, irrespective of the strength of network externalities. Finally, in the case of fully integrated network goods industry across countries, the optimal import tariff rates obtained under price and quantity competition between non managerial firms found to be the same as the optimal import tariff rates derived in case of import competing industry with a passive foreign government.[11]

For simplicity, in this paper we have considered that demand functions are linear and countries are symmetric. It might be be interesting to extend the present analysis to allow for more general demand functions and asymmetric countries. It also seems to be interesting to consider a larger set of policy instruments. However, these are beyond the scope of the present paper. We leave these for future research.

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