NATIONAL COUNCIL OF APPLIED ECONOMIC RESEARCH

*Working Paper No.: WP 152*

# Network Externalities, Strategic Delegation and Optimal Trade Policy

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| January | 2024 |

National Council of Applied Economic Research

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**Abstract**

This paper examines strategic trade policy for differentiated network-goods oligopolies under alternative scenarios when there is export-rivalry between two countries. We demonstrate that, in the absence of managerial delegation, the optimal trade policy entails an export tax (subsidy) if network externalities are weak (strong). However, when price competition is combined with managerial delegation, the opposite is true. Subsidizing exports, on the other hand, is always optimal under quantity competition. We also show that the welfare consequences of strategic trade policy depend not only on the mode of product market competition, but also on firms' internal organizations and the strength of network externalities.

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

**JEL Classifications**: *F12, F13, L13, L22, D21*

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# 1 Introduction

In their seminal paper, Brander and Spencer (1985) demonstrate that, when firms engage 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 than in the case of free trade. Eaton and Grossman (1986) on the other hand, 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 a tax on its exports and achieves a higher level of social welfare than free trade. Das (1997) and Miller and Pazgal (2005) extend the analysis to investigate the implications of separation of ownership and control, a common phenomenon in modern firms, on optimal trade policy under alternate 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 insensitive 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, which help us understand the implications of imperfect competition on optimal trade policy in a variety of scenarios.[2] There is, however, scant evidence on how to design optimal trade policies in managerial exporting firms operating in a horizontally differentiated network goods oligopoly, which is a widespread phenomenon as documented below.

In reality, there are many goods and services for which the 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, positive consumption externalities characterize such network goods industries (Shy, 2001). Examples of network goods include softwares, computers, consumer electronics, telephones, social media applications, and other communication devices and

[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.

services.[3] The opportunities created by the availability of network goods, particularly information and technology (IT) products, are not limited to specific sectors, but benefit many other sectors of the economy (Hogendorn, 2012).

It is well documented that (a) network goods account for a sizable share of international trade. (OECD, 2014; WTO, 2007), (b) volumes of exports and imports of network goods crucially depend on product market regulations in place (Molnar, 2008; Alleman et al., 2000), (c) network goods have been of particular focus in international trade agreements in recent years (Portugal-Perez et al., 2010), and (d) separation of ownership and management is more pronounced in exporting firms compared to non-exporting counterparts (Meagher and Wait, 2014; Navaretti et al., 2013).[4] Motivated by this evidence, this paper aims to (a) analyze optimal trade policy for network goods oligopoly under alternative modes of product market competition, price vis-à-vis quantity, and (b) examine the effect of interplay between managerial delegation in firms and the strength of network externalities on optimal trade policy.

To answer the above questions, we develop a model in which firms in two countries sell their output of differentiated network goods to a third country market. We show that in the case of price competition in nonmanagerial firms (a) it is optimal for exporting countries to subsidize exports, unless network externalities are weak; (b) the stronger the network externalities, the 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 free trade only if network externalities are either weak or very strong; otherwise, the opposite is true. These results contradict the findings of Eaton and Grossman (1986). Conversely, if there is quantity competition and no managerial delegation in firms, the optimal trade policy involves export subsidies, regardless of the strength of network externalities, as in Brander and Spencer (1985). The optimal rate of such an export subsidy is higher in the presence of stronger network externalities. However, in contrast

[3]Many consumer durable goods can also be classified as network goods, because the utility of consumer durables is dependent on the quality of post-sales services, and a larger consumer base often leads to better services.

[4]These trade agreements can be classified as part of the fully integrated industrial model discussed in the paper's concluding remarks, as opposed to the export rivalry model that is the focus of the paper.

to Brander and Spencer (1985), trade policy interventions under quantity competition result in higher social welfare of exporting countries compared to free trade, when network externalities are sufficiently strong. Thus, if governments want to maximize the surplus of nonmanagerial firms and their own income, they might consider facilitating the export of network goods with a sufficiently large user base.

Then, we turn to answer the following questions in the context of exporting firms where managerial decision making is prevalent. What effect does managerial delegation have on optimal trade policy in a network goods oligopoly? Is the equivalence result of Miller and Pazgal (2005) valid in the presence of network externalities? Is free trade preferable to trade policy interventions in network goods oligopoly with managerial firms? For this purpose, we assume that the owner of each firm delegates the task of setting price or quantity to her manager, depending on the mode of product market competition, by offering relative-performance based managerial incentive schemes (Miller and Pazgal, 2001, 2005).[5] Our findings reveal that in the case of price competition among managers, it is optimal for the governments of exporting countries to offer export subsidies (impose export taxes) under weak (strong) network effects. That is, relative performance-based managerial delegation in firms changes the nature of optimal trade policy under price competition compared to no delegation. In contrast, the equilibrium trade policy in quantity competition with delegation involves subsidization of domestic firms regardless of the strength of network externalities, as in the case of no delegation. That is, even when owners offer relative performance-based contracts to their managers, the nature of optimal trade policy depends on the mode of product market competition, unless network externalities are weak. Nonetheless, even when export subsidies are optimal under both price and quantity competition, the optimal rate of export subsidies is always higher under quantity competition than under price competition, regardless of whether managerial

[5]Examining managerial incentive schemes based on relative performance facilitates a direct comparison of the outcomes with the findings of (Miller and Pazgal, 2005). Moreover, providing such incentive schemes is the dominant strategy in a game in which owners can choose not to hire a manager or, if they do, pay their manager a bonus based on relative performance, market share, or sales revenue (Jansen et al., 2007, 2009; Kopel and Lambertini, 2013).

delegation exists. Clearly, Miller and Pazgal (2005)'s equivalence result does not hold true in the case of network goods oligopoly.

The next set of results pertains to the welfare effects of exporting countries composed of managerial firms. These findings suggest that the strength of network externalities has a differential impact on equilibrium outcomes under price and quantity competition in the case of delegation. Trade policy interventions result in lower social welfare for exporting countries under price competition with delegation, but only if network externalities are weak. In contrast, under quantity competition with delegation, regardless of the strength of network externalities, each exporting country obtains lower social welfare with trade policy interventions than with free trade. Clearly, the welfare implications of strategic trade policy are determined not only by the mode of product market competition, but also by the strength of network externalities and the internal organizational structures of firms. In this scenario, if governments are concerned about the well-being of managerial firms, they might think about encouraging the export of network goods with a sufficiently large user base, but only if those firms compete on price.

Overall, our findings have practical implications because they can inform policymakers about the most effective trade policy instruments to adopt when managerial and nonmanagerial firms compete in the downstream market on different variables.

It is important to mention here that Krishna (1988), Klimenko (2009), and Fujiwara (2011a,b) all 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 an import-competing model and quantity competition in bilateral trade, respectively. None of these papers investigate the implications of network externalities on trade policies of competing countries in the export rivalry setting. Additionally, unlike the current paper, these papers only consider pure profit-maximizing firms with no managerial delegation.

Wiese (2002)'s paper is the most similar to ours. They characterize optimal trade policy in a network goods oligopoly with a different trade pattern. In their setup, firms compete solely

on price, selling their output in their respective home and export markets. They find that, for relatively high network effects, it is preferable for one of the countries to impose a subsidy on imports from the other country, yielding a result similar to ours in the alternate setting of the export rivalry model. Beyond their paper, we consider the case of quantity competition between firms and demonstrate the optimality of export subsidies, regardless of the strength of network effects. More importantly, we show that the welfare consequences of exporting countries in a network goods oligopoly differ from those in a non-network goods oligopoly. This highlights the importance of including quantity competition as an additional scenario and comparing the results. The *key distinction*, between our paper and Weise's is that we describe optimal trade policy instruments when exporting firms have owner-delegated managerial decision making. Wiese does not consider this more realistic scenario (Meagher and Wait, 2014; Navaretti et al., 2013). One interesting result from our study is that managerial firms behave differently than nonmanagerial firms when faced with price competition. This implies that the organization of the firm's decision-making process plays a vital role in determining firm-specific outcomes as well as the overall welfare of the countries.

The remainder of the paper is structured as follows. Section 2 describes the model's setup. Section 3 analyzes optimal trade policy in a network goods oligopoly with no managerial delegation, taking price and quantity competition into account separately. In Section 4, we examine the impact of relative-performance-based managerial delegation in firms and its interaction with the strength of network externalities on optimal trade policy. Section 5 offers concluding remarks and a discussion of the implications of network externalities on equilibrium trade policy instruments under alternative trade patterns.

## 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 a 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 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 an 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 $i$; $i = 1, 2$. As a result, the effective marginal cost of a 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), Bhattacharjee and Pal (2013), Pal (2014), and Pal (2015), we consider that the utility function of the representative consumer is as follows.

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

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 consumers' expectation of firm $i$'s total sales, and $\alpha > 0$, $\beta \in (0, 1)$ , and $n \in [0, 1)$ are preference parameters. A lower value of $\beta$ denotes a higher degree of product differentiation. Clearly, there is positive consumption externality and a 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, because the two goods are imperfect substitutes, the effect of $y_j$ on the marginal utility of good $i$ is positive but less so than the effect 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.[6] It is easy

[6]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 consumer's expectations regarding firm

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 demand functions additively and cause parallel outward shifts in demand curves.

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

We analyze optimal trade policy in two alternative scenarios - no delegation and strategic managerial delegation in firms. Firms set price or quantity based on exogenously given mode of product market competition to maximize their respective profits in the absence of delegation. 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 latter case, let $\lambda_i$ 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.

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

$i$'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 do not impose any restriction on the value of the incentive parameter $\lambda_i$. It is easy to observe that $\lambda_1 = \lambda_2 = 0$ corresponds to 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 in the product market than in the absence of delegation. We investigate the potential implications of network externalities on trade policy in each of these two scenarios, no delegation and strategic managerial delegation in firms, under alternative modes of product market competition - price vis-à-vis quantity.

# 3 Trade policy in the 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: The governments of country 1 and country 2 decide their respective export tax rates simultaneously and independently.
>
> Stage 2: Depending on the mode of product market competition, the owners of each firm decide the price or quantity simultaneously and independently.

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.[7]

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

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

It is easy to check that $\frac{\partial p_i}{\partial p_j} > 0$, implying that firms perceive prices to be strategic complements, regardless of the strength of network effects. Also, note that a country can induce its firm to restrict price undercutting by imposing a 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 higher consumer expectations for a firm's sales result in an outward shift of that firm's price reaction curve ($\frac{\partial p_i}{\partial y_i} > 0$) , and this effect is larger in the case of stronger network effects ($\frac{\partial}{\partial n}[\frac{\partial p_i}{\partial y_i}] > 0$). As a result, it appears that the strength of network externalities will have an impact on 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 the following second stage equilibrium prices.

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

From these expressions for equilibrium prices in stage 2, it is easy to check that (a) the 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 $n \in [0,1);\ i, j = 1,\ 2,\ i \neq j$. Furthermore, the marginal effect of a country's tax rate on its own firm's price is always lower when network externalities are stronger: $\frac{\partial}{\partial n}[\frac{\partial p_i}{\partial t_i}] < 0,\ \ \forall n \in [0,1)$. 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 $SW_2 = SW_2(t_1, t_2)$.[8] It can be easily checked

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

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 when network externalities are weak $(n < n_B)$. 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, the 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 consider 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-reaction functions are negatively (positively) sloped in the $t_1 - t_2$ plane, if $n > n_B$ $(n < n_B)$.[9] Solving the governments' problems we get the optimal export-tax rates and corresponding prices, outputs, profits, and social welfares as shown in Lemma 1.

[9]The equation of the tax-reaction function of country $i$ is as follows.

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

**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, in the absence of network externalities, it is optimal for governments to tax exports when firms compete on price. This is consistent with the existing result for 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 an export tax, which increases its tax revenue by more than the corresponding decrease in profit of its own firm. Furthermore, because tax rates are strategic complements, it is optimal for each of the two exporting countries to impose tax on exports. The presence of network externalities complicates this mechanism.

In the case of network goods oligopoly, firms' less aggressive behavior (i.e., setting higher prices) dampens consumers' expectations about total sales and, thus, reduces their willingness to pay. Therefore, export tax has an indirect negative effect 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: $\frac{\partial t^B_{ND}}{\partial n} =$

$-\frac{(\alpha-c)(1-\beta)^2\{(2+\beta)(2-n)^2-2\beta^2(2-n)-\beta^3\}}{(1-n)^2\{4-\beta(\beta+2)-n(2-\beta)\}^2} < 0$. Moreover, if network externalities are strong ($n > n_B$), the negative indirect effect of the 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, the increase in profit of the firm over compensates the loss due to subsidy. As a result, in the case of strong network externalities, it is optimal for both country 1 and country 2 to offer export subsidies: $t^B_{ND} < 0$, 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 levy export taxes if 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 $SW^B_{ND} < SW^{B,(0,0)}_{ND}$, if $n_B < n < n^B_0$; where $SW^{B,(0,0)}_{ND} = \frac{(1-\beta)(\alpha-c)^2}{(\beta+1)(-\beta-n+2)^2}$ is the social welfare in the case of free trade and $n^B_0 = 1+\beta-\beta^2-(1-\beta)\sqrt{1+\beta^2} < 1$. Otherwise, if $n < n_B$ or $n > n^B_0$, we have $SW^B_{ND} > SW^{B,(0,0)}_{ND}$. That is, when export-taxation is the optimal policy, policy intervention increases the social welfare of exporting countries in equilibrium compared to free trade. In contrast, when exporting countries find it optimal to subsidize exports, the equilibrium social welfare of exporting countries is lower than that of 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 equilibrium than 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, while the optimal export tax rate decreases with the strength of network externalities, both the equilibrium price and the equilibrium quantity of each firm increase: $\frac{\partial x^B_{ND}}{\partial n} > \frac{\partial p^B_{ND}}{\partial n} > 0$. The reason is, stronger network externalities shift the demand curve outward. As a result, equilibrium profits of firms and social welfare 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.

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

Firms clearly perceive quantities to be 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 along 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 result in a 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 of its own sales as well as the sales of its rival firm.

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 $t_2$: $SW_i = SW_i(t_i, t_j)$, $i,j = 1,2,\ \ i \neq j$.[10] It follows that $\frac{\partial}{\partial t_j}\left(\frac{\partial SW_i(.)}{\partial t_i}\right) < 0$, $\forall\ \beta \in (0,1)$ and $n \in [0,1)$. As a result, unlike in the case of Bertrand type price competition, exporting countries consistently perceive export tax/subsidy rates as strategic substitutes in the current scenario.

**Corollary 2:** *In the case of Cournot type quantity competition without managerial delegation, the 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, as well as the social welfare of competing countries.

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

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

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

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

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

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

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

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

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 contrasts sharply with the outcome of Bertrand type price competition without delegation. Second, it can be demonstrated that the optimal rate of export subsidy is higher in the presence of stronger network externalities: $\frac{\partial t^C_{ND}}{\partial n} < 0$. The mechanism underlying these findings 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, resulting in higher profit for its own firm at the expense of its rival firm's profit. Furthermore, unless the subsidy rate exceeds a certain level, the profit of the subsidy-receiving firm increases by a larger amount than the amount of subsidy paid to it. 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 holds true regardless of how strong network externalities are. In the case of network goods oligopoly, export subsidy induces a firm to choose higher output, which increases consumers' willingness to pay, resulting 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. As a result, in the equilibrium of 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, regardless of the strength of network externalities. Nonetheless, the optimal rate of export-subsidy is higher when network externalities are stronger.*

From Propositions 1 and 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 significant ($n > n_B$), the optimal trade policy is to subsidize exports regardless of the mode of product market competition. In other words, unlike in the case of usual non-network goods oligopoly, the nature of trade policy in network goods oligopoly does not have to be sensitive to the mode of product market competition.

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 $SW_{ND}^{C,(0,0)} = \frac{(\alpha-c)^2}{\{2+(1-n)\beta-n\}^2}$, where superscript '$C,(0,0)$' indicates 'Cournot type quantity competition in absence of policy interventions'. Comparing social welfare under free trade to that in Lemma 2, it turns out that $SW_{ND}^{C,(0,0)} < (>)\, SW_{ND}^{C}$, if $n > (<) 2 - \frac{1+\sqrt{1+\beta^2}}{1+\beta} = n_0^C$. That is, unless network externalities are sufficiently strong, trade policy intervention reduces social welfare compared to free trade. Because both countries 1 and 2 offer export subsidies in equilibrium, the 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. As a result, in the latter case, each firm's profit increases by more than the amount of subsidy, even 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 benefits from export subsidies in terms of social welfare.

**Proposition 4:** *In the case of network goods Cournot oligopoly without delegation, each exporting country's trade policy intervention does not always result in Pareto inferior equilibrium. If network externalities are sufficiently strong, each exporting country obtains higher social welfare by subsidizing exports than it would under free trade.*

Comparative static analysis reveals that, as in the case of Bertrand type price competition without delegation, (a) the positive effect of network externalities on equilibrium output is larger than the positive effect on equilibrium price, and (b) stronger network externalities lead to higher equilibrium profit of firms and social welfare of exporting countries: $\frac{\partial x^C_{ND}}{\partial n} > \frac{\partial p^C_{ND}}{\partial n} > 0$, $\frac{\partial \pi^C_{ND}}{\partial n} > 0$ and $\frac{\partial SW^C_{ND}}{\partial n} > 0$, $\forall\ \beta \in (0,1)$ 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 than Bertrand type price competition: $x^C_{ND} < x^B_{ND}$, $t^C_{ND} < t^B_{ND}$, $p^C_{ND} > p^B_{ND}$, $\pi^C_{ND} > \pi^B_{ND}$ and $SW^C_{ND} > SW^B_{ND}$. 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 a closed economy and no policy intervention (Pal, 2014). However, because the rate of export subsidy under quantity competition is higher than that under price competition in the current context, the equilibrium profit under quantity competition remains higher than that under price competition even in the presence of strong network externalities.

# 4 Trade policy under strategic managerial delegation

As previously stated, Miller and Pazgal (2005) argues that optimal trade policy does not depend on the mode of product market competition - price or quantity - and that it is always optimal for exporting countries to subsidize exports in the case of usual non-network goods oligopoly with relative performance based managerial delegation contracts in firms. The reason for this is that owners can exercise sufficient control over their managers through these performance based contracts, 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, is optimal trade policy invariant to the nature of product market competition under relative

performance-based managerial delegation, even in the case of network goods oligopoly? To answer these questions, we now consider that the stages of the game involved are as follows.

Stage 1: The governments of country 1 and country 2 decide on export tax rates simultaneously and independently.

Stage 2: The owners of firms 1 and 2 design managerial delegation contracts simultaneously and independently.

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

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 her price reaction functions as follows.

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

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 $i$ raises prices in response to a higher export tax rate in country $j$. Furthermore, if $\lambda_i < -1$, the manager of the firm $i$ considers prices to be strategic substitutes. 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 $\pi_i = \pi_i(\lambda_i, \lambda_j, t_i, t_j)$; $i, j = 1,\ 2,\ i \neq j$. In the current scenario, the effects of tax rates on stage 3 equilibrium prices and profits are clearly dependent on the

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 are 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 than in the case of no-delegation, if network externalities are weak (strong). The reason for this is that, in the case of strong network externalities ($n > n_B$), the positive effect of more aggressive play by a firm on consumers' expectations of its sales leads to a 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 an export tax in the case of strong network externalities, its own (rival country's) firm's gain from being more aggressive reduces (increases) and it is thus 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 than in the case of no-delegation. On the other hand, if a country imposes an 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, causing 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), a country's export tax rate has a negative (positive) effect on the incentive parameter for the manager of its own firm and a positive (negative) effect on the manager of its rival country's firm: (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, trade policy works through an additional channel under managerial delegation, namely 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 in the absence of 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:** *In the case of Bertrand type price competition in firms with strategic managerial delegation, the equilibrium export-tax rates, incentive parameters, prices, quantities, profits, and social welfares are 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 presence of weak (strong) network externalities, as observed in a free trade environment. Needless to mention here that positive (negative) incentive parameters have the same effect on pricing behavior as 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 indirectly through managerial delegation contracts. In the case of weak network externalities, country $i$'s export subsidy makes firm $i$ even less aggressive (by increasing $\lambda_i$) and firm $j$ relatively more aggressive (by reducing $\lambda_j$). As a result, firm $i$'s profit increases by more than the amount of subsidy paid, resulting in greater social welfare for 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 inducing their managers to engage in excessive price undercutting under free trade, resulting in sub-optimal social welfare in equilibrium. In such a scenario, by imposing an export tax, country $i$ can restrict firm $i$'s aggressiveness (by increasing $\lambda_i$) while simultaneously inducing firm $j$ to be even more aggressive (by reducing $\lambda_j$), resulting in higher (lower) social welfare for country $i$ (country $j$). Thus, in the case of significant network externalities, it is optimal for exporting countries to levy an export tax under managerial delegation. Third, unlike in the absence of delegation, the optimal export tax (export subsidy) rate is higher (lower) in the presence of stronger network externalities under managerial delegation: $\frac{\partial t_D^B}{\partial n} > 0$ for all $n \in [0, 1)$. Fourth, if network externalities are weak (strong), exporting countries obtain higher (lower) social welfare under free trade than they do under optimal policy intervention: $SW_D^B(0,0) > (<)\, SW_D^B$, 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 a 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 than 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 compared to no delegation.*

## 4.2 Cournot type quantity competition under delegation

We now consider that there is Cournot type quantity competition in the third-country 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 her 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 her incentive parameter ($\lambda_i$) is less than minus one. The negative effects of the export-tax rate and the positive effects of consumer expectations about firm sales are the same as in the absence of delegation. Solving managers' quantity reaction functions 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 than in the case of no delegation, regardless of the strength of network externalities. This is in contrast to the case of price competition. In fact, if network externalities are stronger, each

owner has a greater incentive to induce her manager to be more aggressive in the case of quantity competition : $\frac{\partial \lambda_i}{\partial n} < 0$. 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, resulting in a larger increase in profit. 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 than in the case of free trade, whereas export tax does the opposite: $\frac{\partial \lambda_i}{\partial t_i} > 0$ 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, resulting in firm $i$ having a competitive advantage (disadvantage) over firm $j$ in the product market.

We derive the social welfare of country $i$ in the case of quantity competition under delegation as a function of $t_i$ and $t_j$ from the expressions for social welfare, stage 2 equilibrium incentive parameters, and stage 3 equilibrium quantities and prices: $SW_i = SW_i(t_i, t_j)$; $i, j = 1, 2$; $i \neq j$.[11] 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 with delegation, the government of each exporting country views tax rates, $t_1$ and $t_2$, as strategic complements, regardless 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, the 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.

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

Solving the 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 social welfares of exporting countries.

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

**Lemma 4:** *In the case of Cournot type quantity competition under strategic managerial delegation in firms, the equilibrium export tax rates, incentive parameters, prices, quantities, profits, and social welfares are, respectively, as follows.*

$$t_{1,D}^C = t_{2,D}^C = t_D^C = -\frac{(\alpha-c)\{\beta^3(1-n)^2+(2-n)n\beta\}}{\{2-n+\beta(1-n)\}\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}},$$

$$\lambda_{1,D}^C = \lambda_{2,D}^C = \lambda_D^C = -\frac{\beta^2+\left(1-\beta^2\right)(2-n)n}{(2-n)\beta+(1-n)\beta^2},$$

$$p_{1,D}^C = p_{2,D}^C = p_D^C = \frac{\alpha(1-\beta)(2-n)+c\{2-n-(1-n)\beta^2\}}{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n},$$

$$x_{1,D}^C = x_{2,D}^C = x_D^C = \frac{(\alpha-c)\{2-n-(1-n)\beta^2\}}{(1-n)(1+\beta)\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}},$$

$$\pi_{1,D}^C = \pi_{2,D}^C = \pi_D^C = \frac{(\alpha-c)^2\{2-n-(1-n)\beta^2\}^2\{2-n(1-\beta)-\beta\}}{(1-n)(1+\beta)\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}^2\{2-n(1+\beta)+\beta\}} \text{ and}$$

$$SW_{1,D}^C = SW_{2,D}^C = SW_D^C = \frac{(\alpha-c)^2\{2-n-(1-n)\beta^2\}(2-n)(1-\beta)}{(1-n)(1+\beta)\{4-\beta(2+\beta)-(2-\beta-\beta^2)\,n\}^2};$$

*where subscript 'D' indicates delegation in firms.*

It is easy to observe that $t_D^C < 0$ and $\frac{\partial t_D^C}{\partial n} < 0$ 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 export subsidization, and the optimal rate of export subsidy is higher when network externalities are stronger. 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 a unilateral incentive to induce her manager to be more aggressive in the product market than under no delegation, irrespective of the strength of network externalities. Export subsidy strengthens such incentive of the owner, as noted before. As a result, the firm's profit increases by more than the amount of the subsidy, resulting in greater social welfare. The stronger the network effect, the greater the positive effect of export subsidy on profit as well as social welfare, because aggressive play increases consumers' willingness to pay to a greater extent when network externalities are stronger. Also, in the current scenario, the optimal incentive parameter is negative, and it is lower in the case of stronger network externalities, $\lambda_D^C < 0$ and $\frac{\partial \lambda_D^C}{\partial n} < 0$ for all $\beta \in (0,1)$ and $n \in [0,1)$, because both the strength of network externalities and export-subsidy have a negative impact on the incentive parameter. Interestingly, even with stronger network externalities, the optimal social welfare of exporting countries in the

present scenario is lower than that under free trade: : $SW_D^C(0,0) > SW_D^C$ 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, whereas in the absence of 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 precludes such a 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, regardless of the strength of network externalities, each exporting country obtains lower social welfare in equilibrium than it would under free trade.*

According to Propositions 5 and 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 imply that the magnitude of a trade policy instrument under quantity competition differs 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 in the case of typical non-network goods oligopoly, the mode of product market competition is critical in determining a country's optimal trade policy, regardless of whether firms have managerial delegation or not.

It is also worth noting that, in the case of quantity competition, the equilibrium rate of export subsidy under delegation is higher than that under no delegation, if the 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, in the case of both network goods and non-network goods oligopolies, the scale of strategic trade policy under relative performance based managerial del-

egation does not have to be smaller than that under no delegation. In contrast, considering a homogeneous non-network goods oligopoly and Fershtman and Judd (1987) type managerial incentive scheme, Das (1997) argues that delegation reduces the scale of strategic trade policy.[12] 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 focus on the optimal trade policy for network goods oligopoly, when two countries sell their output in a third country market. We compare the results of alternative modes of product market competition, price versus quantity, in the presence and absence of strategic managerial delegation in firms. Our findings reveal that in the case of price competition, the nature of optimal trade policy –- export subsidy or tax –- is determined by the strength of network externalities; but not 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 best for exporting countries to subsidize exports in both price and quantity competition. Nonetheless, the optimal rate of export subsidy is higher in the case of quantity competition than in the case of price competition. These findings contradict the predictions of standard non-network goods oligopoly models such as Brander and Spencer (1985) and Eaton and Grossman (1986). Furthermore, unlike in the case of a typical non-network goods oligopoly, policy interventions by exporting countries do not always result in Pareto inferior (superior) equilibrium outcomes when nonmanagerial firms compete on quantity (price) in the product market. More precisely, we show that exporting countries can achieve higher (lower) social welfare through trade policy

[12]This incentive scheme represents a linear combination of firm's own profit and own revenue.

interventions relative to free trade, under quantity (price) competition with nonmanagerial firms, provided network externalities are sufficiently strong (moderate).

We also demonstrate 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. When network externalities are weak (strong) in the case of price competition under managerial delegation, it is optimal for exporting countries to subsidize (tax) exports. In the case of price competition, managerial delegation changes the nature of the optimal trade policy from what it would be in the absence of delegation. However, even with managerial delegation, (a) export subsidization is always optimal in the case of quantity competition, and (b) quantity competition requires a higher rate of export subsidy than 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).

The above findings underscore the importance of considering how product market competition and firm internal organization interact with network externalities when determining the welfare effects of trade policies. Our findings suggest that, from a welfare standpoint, central and state governments may want to consider boosting the exports of network goods and services that have reached a critical user base and are produced by nonmanagerial firms. However, they must exercise caution before providing special incentives for the export of network goods produced by managerial firms. Thus, governments may find it beneficial to target price-based trade policies depending on the managerial structure of firms as well as the type and extent of competition in the product market for network goods.[13]

*Alternative patterns of trade*: So far, we have looked at a specific type of trade pattern: export

[13]Price based trade policy instruments include various types of taxes and subsidies, as opposed to quantity restrictions imposed by governments.

rivalry. What are the implications of network externalities on optimal trade policy under alternate trade patterns? To economize on space, we present the main findings obtained under (i) import-competing network goods oligopoly and (ii) fully integrated markets.

In the case of an 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 occurs between managerial or non managerial firms, and (d) whether the foreign government is active or passive. The optimal trade policy of an active foreign government in this scenario is found to be the same as in the case of export rivalry. In the case of network goods oligopoly, the free trade welfare of the home country does not have to be higher than its autarky welfare in the import competing model, contrary to popular belief. Furthermore, unlike in the case of the export rivalry model, optimal trade policy interventions always result in higher social welfare in the domestic country when compared to free trade. On the contrary, regardless of the strength of network externalities, foreign governments' equilibrium welfare is lower than that of free trade.

Finally, in the case of a fully integrated network goods industry across countries, the optimal import tariff rates obtained under price and quantity competition between non managerial firms are found to be the same as the optimal import tariff rates derived in the case of an import competing industry with a passive foreign government.[14]

Given that countries today are likely to trade both non-network and network goods, optimal trade policy decisions in such a scenario could potentially depend on the composition of export goods (non-network to network) as well as network externalities.

Our results are, of course, partially driven by the simplified modeling approach we adopted in the paper –- that of linear demand functions and symmetric countries. It might be interesting to expand the current analysis to include more general demand functions, asymmetric countries, irrational consumer expectations, and a broader range of policy instruments. However, these are outside the scope of this paper. We leave these for future research.

[14]Details are available on request from the authors.

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