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Subsidies and countervailing tariffs in vertically related markets*

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Abstract

This paper analyzes a foreign production subsidy to the intermediate good and domestic countervailing tariffs imposed on the intermediate good and on the final good incorporating the subsidized intermediate good in vertically related markets that are characterized by Cournot competition. It is shown that the optimal domestic response to a foreign production subsidy is a partially countervailing tariff on the intermediate and final goods. Retaliation with countervailing tariffs on the intermediate and final goods deters the foreign country from subsidizing its intermediate-good production. In contrast, retaliation with only a countervailing tariff on the intermediate good fails to deter foreign subsidization.

Keywords: Countervailing tariffs; Production subsidies; Vertically related markets; Cournot competition

1. Introduction

Elpida Memory, Inc. and Micron Japan, Ltd. submitted a petition to the Japanese government on June 16, 2004, requesting the imposition of countervailing duties on imports of Dynamic Random Access Memories (DRAMs) manufactured by Hynix Semiconductor, Inc. in Korea. The Japanese government initiated an investigation of countervailing duties on August 4, 2004. The investigation revealed that the assistance provided to Hynix constituted subsidies and that the import of subsidized Hynix DRAMs caused injury to the Japanese DRAMs industry. As a result, on January 27, 2006, the Japanese government issued a final determination to impose countervailing duties on the import of DRAMs produced by Hynix. This was the first imposition of countervailing duties in Japan.

The United States issued a provisional determination on April 7, 2003, and a final one on June 23, 2003, to impose countervailing duties on Hynix. The Korean government requested the establishment of a WTO dispute settlement panel, alleging that the United States determinations were inconsistent with the WTO rules. On June 27, 2005, the WTO Appellate Body reversed the panel that had concluded that the United States countervailing duties on Hynix were inappropriate and favored the United States.[1]

Dixit (1988) and Collie (1991, 1992, 1994) analyze export subsidies and countervailing duties under international oligopoly. In their studies, there exist no intermediate goods, and only a final good is considered. Japanese consumer electronics makers import DRAMs from Hynix and produce items such as DVD recorders, plasma televisions, and car navigation systems. In the case of countervailing duties on Hynix DRAMs, subsidies and countervailing duties applied to intermediate goods have to be

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[1] The EU issued a provisional determination on April 23, 2003, and a final determination on August 22, 2003, to impose countervailing duties against Hynix. The Korean government requested the establishment of a WTO panel, alleging that the EU's measures were inconsistent with the WTO rules. A panel was established on January 23, 2004 and on June 17, 2005, it rejected most of Korea's claims.

considered explicitly. In the decision regarding the imposition of countervailing duties against subsidized intermediate goods, the importing country will take into account not only the protection of the domestic intermediate-good industry but also the impact on the domestic final-good industry.

This paper examines a foreign production subsidy to the intermediate good and domestic countervailing tariffs imposed on the intermediate good and on the final good incorporating the subsidized intermediate good in a model of vertically related markets. We consider whether and to what extent a foreign subsidy granted to intermediate-good production should be offset by countervailing tariffs on the intermediate and final goods; we also examine whether retaliation by imposing countervailing tariffs deters the foreign country from subsidizing its intermediate-good production.

We incorporate a vertical industry structure into the model of strategic trade policy.[2] In our model, the domestic intermediate-good and final-good markets are both characterized by Cournot competition between domestic and foreign firms.[3] Domestic and foreign policies are modeled as a multistage game. At the first stage, the foreign government sets its production subsidy to the intermediate good. Then, at the second stage, the domestic government sets its import tariffs. We specifically consider two cases. The first is a case where the domestic government uses tariffs on the intermediate and final goods in response to a foreign production subsidy to the intermediate good.[4] The second is a case where the domestic government only uses a tariff on the intermediate good to countervail a foreign subsidy.[5]

We obtain three main results. First, if the domestic country sets its tariffs on the intermediate and final goods optimally, it will benefit from a foreign production subsidy to the intermediate good. However, if the domestic country sets its tariff on the intermediate good optimally, it may be harmed by a foreign subsidy. In Collie (1991, 1994), a country that pursues an optimal trade policy cannot be harmed by a foreign export subsidy.

Secondly, the optimal domestic response to a subsidy granted to foreign intermediate-good production is a less than fully countervailing tariff imposed on the intermediate and final goods. This result is similar to the result in Dixit (1988) and Collie (1991, 1992, 1994) that the optimal domestic response to a foreign export subsidy is a partially countervailing tariff.

Thirdly, when the domestic country retaliates with countervailing tariffs on the intermediate and final goods, the optimal foreign policy would be to impose a production tax on the intermediate good. On the other hand, when the foreign country faces retaliation with only a countervailing tariff on the intermediate good, its optimal policy would be to grant a production subsidy. The latter contrasts sharply with the result obtained by Collie (1991, 1994), in which the domestic country's retaliation with a countervailing tariff is expected to deter the foreign country from subsidizing exports.

The paper is organized as follows. The structure of the model is described in Section 2. The comparative static results for the effects of domestic and foreign policies are derived in Section 3. Section 4 considers the welfare effects of a foreign production subsidy to the intermediate good when there is no

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[2] See Spencer and Jones (1991, 1992), Bernhofen (1997), Ishikawa and Lee (1997), Ishikawa and Spencer (1999), and Chang and Sugeta (2004) for strategic trade policy in vertically related markets.

[3] The model of vertical Cournot oligopolies is familiar in the theory of industrial organization. See, for example, Greenhut and Ohta (1979), Salinger (1988), and Lin (2006). Papers on trade that use this framework include Bernhofen (1995), Spencer and Raubitschek (1996), Ishikawa and Lee (1997), Ishikawa (1999), and Ishikawa and Spencer (1999).

[4] Countervailing duties may be imposed on a product to offset subsidies granted with respect to its input product. This is referred to as "upstream subsidy."

[5] In the case of countervailing duties on Hynix DRAMs, the Japanese government did not impose countervailing duties against imports of consumer electronics incorporating Hynix DRAMs.

retaliation. Section 5 examines the policy game with a foreign production subsidy to the intermediate good and domestic import tariffs on the intermediate and final goods. Section 6 analyzes the policy game with a foreign production subsidy and a domestic import tariff on the intermediate good. Concluding remarks are presented in Section 7.

2. The model

The model setting is illustrated in Fig. 1. There are two vertically related activities in two countries: the domestic country and the foreign country. In the upstream stage, a homogeneous intermediate good is produced, while in the downstream stage, a homogeneous final good is produced. In the domestic country, there exist m identical domestic final-good firms and n identical domestic intermediate-good firms. In the foreign country, there exist a single foreign final-good firm and a single foreign intermediate-good firm.[6] The numbers of firms are given and constant. The domestic intermediate-good market is supplied by both domestic and foreign intermediate-good firms, while a foreign final-good firm purchases the intermediate good exclusively from a foreign intermediate-good firm.[7] The domestic final-good market is supplied by both domestic and foreign final-good firms. The domestic intermediate-good and final-good markets are both characterized by Cournot competition. The foreign government grants a production subsidy to the intermediate good. The domestic government imposes import tariffs on the intermediate and final goods.

The model involves four stages of decision. In stage 1, the foreign government sets its production subsidy to the intermediate good. In stage 2, the domestic government sets its tariffs on the intermediate and final goods in response to the foreign production subsidy. In stage 3, the domestic intermediate-good firms decide their supplies of the intermediate good to the domestic market. The foreign intermediate-good firm decides its supplies to the domestic market and the foreign final-good firm. In stage 4, taking the domestic and foreign prices of the intermediate good as given, the domestic and the foreign final-good firms decide their supplies of the final good.[8] The domestic price of the intermediate good is the market-clearing price at which the demand by the domestic final-good firms equals the supply to the domestic country. The foreign price of the intermediate good is the market-clearing price in the foreign country. The solution concept adopted is the

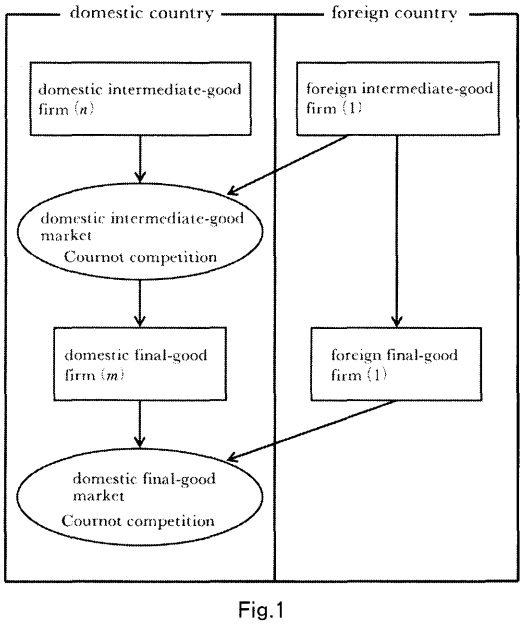

Fig.1

[6] We concentrate on the case where in the absence of retaliation the optimal foreign policy is a production subsidy to the intermediate good. It can be shown that the foreign country has a unilateral incentive to subsidize intermediate-good production if the numbers of foreign intermediate-good and final-good firms are small relative to the numbers of domestic intermediate-good and final-good firms. For simplicity, we assume that there exist a foreign intermediate-good firm and a foreign final-good firm.

[7] We assume that the domestic and foreign intermediate-good markets are segmented.

[8] In our model, it is assumed that the final-good firms have market power as sellers of the final good, but taking the intermediate-good price as given, they have no market power as buyers of the intermediate good. As the number of final-good firms increase, their market power decreases. Thus, if there exist a large number of domestic final-good firms (i.e., m is large), the assumption that these firms are price takers may be justified. See Ishikawa and Spencer (1999) for a discussion on the justification of price-taking behavior by the final-good firms in vertical Cournot oligopolies.

subgame perfect equilibrium, which is obtained by a process of backward induction.

The policy game assumes that the foreign government chooses its production subsidy first, and subsequently, the domestic government chooses its import tariffs. This timing of policy decisions is based on the procedure for imposing a countervailing duty. A countervailing duty can only be imposed after a detailed investigation has established that there are subsidized imports, injury to a domestic industry, and a causal link between the subsidized imports and the injury.

The domestic final-good firm and the foreign final-good firm produce outputs y and y^*, respectively, of the final good. Aggregate supplies of the final good to the domestic final-good market are represented by $Y \equiv my + y^*$. The inverse demand function of the final good in the domestic country is given by

$$p = p(Y) = \alpha - Y, \quad \alpha > 0 \tag{1}$$

where p represents the price of the final good in the domestic country.

The technology of the final-good production is simplified by assuming that one unit of the intermediate good is required to produce one unit of the final good. The profits of the domestic final-good firm and the foreign final-good firm are given by

$$\Pi = (p - r)y, \tag{2}$$

$$\Pi^* = (p - r^* - T)y^*, \tag{3}$$

respectively, where r, r^*, and T denote the price of intermediate good in the domestic country, the price of intermediate good in the foreign country, and the specific import tariff on the final good imposed by the domestic government, respectively.

The domestic intermediate-good firm produces output x of the intermediate good. The foreign intermediate-good firm produces output x^* of the intermediate good to be sold in the domestic country and output X^* for sale in the foreign country. Aggregate supplies of the intermediate good in the domestic country are given by $X \equiv nx + x^*$. For simplicity, it is assumed that the marginal costs to produce the intermediate good are constant at a level c for the domestic and foreign intermediate-good firms. The profits of the domestic intermediate-good firm and the foreign intermediate-good firm are given by

$$\pi = (r - c)x, \tag{4}$$

$$\pi^* = (r - c + s^* - t)x^* + (r^* - c + s^*)X^*, \tag{5}$$

respectively, where s^* and t denote the specific production subsidy to the intermediate good provided by the foreign government and the specific import tariff on the intermediate good imposed by the domestic government, respectively.[9]

The welfare of the domestic country is given by the sum of the total profits of the domestic intermediate-good and final-good firms, the consumer surplus, CS, and the tariff revenue:

[9] The production subsidy s^* can be regarded as a combination of equal amounts of an export subsidy and a foreign sale subsidy given by the foreign government to the foreign intermediate-good firm.

$$W = n\pi + m\Pi + CS + tx^* + Ty^* = n(r-c)x + m(p-r)y + \left[\int_0^Y p(v)dv - p(Y)Y\right] + tx^* + Ty^*. \quad (6)$$

The welfare of the foreign country is the total profits of the foreign intermediate-good and final-good firms less the production subsidy payments:

$$W^* = \pi^* + \Pi^* - s^*(x^* + X^*) = (r-c-t)x^* + (r^*-c)X^* + (p-r^*-T)y^*. \quad (7)$$

3. Market equilibrium and comparative statics

We first set up the conditions determining the Cournot-Nash equilibrium in the domestic final-good market in stage 4. Given r and r^*, the first-order profit-maximizing conditions for the domestic final-good firm and the foreign final-good firm under the Cournot assumption are

$$\frac{\partial \Pi}{\partial y} = p - r + yp' = 0, \quad (8)$$

$$\frac{\partial \Pi^*}{\partial y^*} = p - r^* - T + y^* p' = 0, \quad (9)$$

respectively. Solving these first-order conditions simultaneously, we can define the equilibrium outputs as functions of r, r^*, and T:

$$y(r, r^*, T) = \frac{\alpha - 2r + r^* + T}{m+2} \quad \text{and} \quad y^*(r, r^*, T) = \frac{\alpha + mr - (m+1)r^* - (m+1)T}{m+2}. \quad (10)$$

In stage 3, the domestic and foreign intermediate-good firms anticipate the derived demand for the intermediate good arising from the Cournot-Nash equilibrium in stage 4. In order to equate demand with supply in the domestic and foreign countries, we set

$$my(r, r^*, T) = X \quad \text{and} \quad y^*(r, r^*, T) = X^*. \quad (11)$$

Solving these equations simultaneously, we can define the inverse demand functions of the intermediate good in the domestic and foreign countries as

$$r(X, X^*) = \alpha - \frac{m+1}{m}X - X^* \quad \text{and} \quad r^*(X, X^*, T) = \alpha - X - 2X^* - T,$$

$$\text{where} \quad \frac{\partial r}{\partial X} = -\frac{m+1}{m}, \quad \frac{\partial r}{\partial X^*} = -1, \quad \frac{\partial r^*}{\partial X} = -1, \quad \frac{\partial r^*}{\partial X^*} = -2. \quad (12)$$

respectively.

The first-order profit-maximizing conditions for the domestic and foreign intermediate-good firms under Cournot behavior are

$$\frac{\partial \pi}{\partial x} = r - c + x\frac{\partial r}{\partial X} = 0, \quad (13)$$

$$\frac{\partial \pi^*}{\partial x^*} = r - c + s^* - t + x^*\frac{\partial r}{\partial X} + X^*\frac{\partial r^*}{\partial X} = 0, \quad (14)$$

$$\frac{\partial \pi^*}{\partial X^*} = x^*\frac{\partial r}{\partial X^*} + r^* - c + s^* + X^*\frac{\partial r^*}{\partial X^*} = 0. \quad (15)$$

We can obtain the equilibrium outputs of the intermediate good by solving these first-order conditions

simultaneously:

$$x = \frac{m(\alpha - c - s^* + t)}{(m+1)(n+2)}, \tag{16}$$

$$x^* = \frac{m[(2m-n+2)(\alpha-c)+(2mn+2m+3n+2)s^* - (3mn+4m+4n+4)t + (m+1)(n+2)T]}{2(m+1)(m+2)(n+2)}, \tag{17}$$

$$X^* = \frac{\alpha - c + s^* + mt - (m+1)T}{2(m+2)}. \tag{18}$$

From (12), we can obtain the equilibrium prices of the intermediate good:

$$r = \frac{\alpha + (n+1)c - s^* + t}{n+2}, \tag{19}$$

$$r^* = \frac{(2m+n+2)\alpha + (2mn+2m+n+2)c - (2m+n+2)s^* - mnt - (m+1)(n+2)T}{2(m+1)(n+2)}. \tag{20}$$

Noting that $my = X$ and $y^* = X^*$, we can obtain the equilibrium outputs of the final good:

$$y = \frac{(2mn+2m+3n+2)(\alpha-c)+(2m-n+2)s^* - (mn+4m+4)t + (m+1)(n+2)T}{2(m+1)(m+2)(n+2)}, \tag{21}$$

$$y^* = \frac{\alpha - c + s^* + mt - (m+1)T}{2(m+2)}, \tag{22}$$

$$Y = \frac{[2m(m+2)(n+1)+n+2](\alpha-c)+[2m(m+2)+n+2]s^* - m(2m-n+2)t - (m+1)(n+2)T}{2(m+1)(m+2)(n+2)}. \tag{23}$$

Using the first-order profit-maximizing conditions (8), (9), (13), (14), and (15), we can write the equilibrium profits as follows:

$$\Pi = y^2, \quad \Pi^* = y^{*2}, \quad \pi = \frac{m+1}{m}x^2, \quad \pi^* = \frac{m+1}{m}x^{*2} + 2x^*X^* + 2X^{*2} \tag{24}$$

In the following analysis, we assume that the following condition holds:

$$2m - n + 2 > 0 \tag{25}$$

Condition (25) is needed to ensure that the output x^* supplied by the foreign intermediate-good firm to the domestic country is positive.[10]

Using (16)–(23) and (25), we obtain the following comparative static results for the effects of a foreign production subsidy to the intermediate good:

$$\frac{\partial x}{\partial s^*} = -\frac{m}{(m+1)(n+2)} < 0, \quad \frac{\partial x^*}{\partial s^*} = \frac{m(2mn+2m+3n+2)}{2(m+1)(m+2)(n+2)} > 0, \quad \frac{\partial X^*}{\partial s^*} = \frac{1}{2(m+2)} > 0,$$

[10] When the foreign and domestic countries pursue a policy of laissez-faire (i.e., $s^* = t = T = 0$), from (17) the volume x^* of

$$\frac{\partial r}{\partial s^*} = -\frac{1}{n+2} < 0, \quad \frac{\partial r^*}{\partial s^*} = -\frac{2m+n+2}{2(m+1)(n+2)} < 0, \quad \frac{\partial y}{\partial s^*} = \frac{2m-n+2}{2(m+1)(m+2)(n+2)} > 0,$$

$$\frac{\partial y^*}{\partial s^*} = \frac{1}{2(m+2)} > 0, \quad \frac{\partial p}{\partial s^*} = p' \frac{\partial Y}{\partial s^*} = -\frac{2m(m+2)+n+2}{2(m+1)(m+2)(n+2)} < 0. \tag{26}$$

With regard to the effects of a foreign production subsidy on the profits of each firm, from (24) and (26), we have

$$\frac{\partial \Pi}{\partial s^*} > 0, \quad \frac{\partial \Pi^*}{\partial s^*} > 0, \quad \frac{\partial \pi}{\partial s^*} < 0, \quad \frac{\partial \pi^*}{\partial s^*} > 0. \tag{27}$$

From (16)–(23) and (25), the effects of a domestic import tariff on the intermediate good are given as:

$$\frac{\partial x}{\partial t} = \frac{m}{(m+1)(n+2)} > 0, \quad \frac{\partial x^*}{\partial t} = -\frac{m(3mn+4m+4n+4)}{2(m+1)(m+2)(n+2)} < 0, \quad \frac{\partial X^*}{\partial t} = \frac{m}{2(m+2)} > 0,$$

$$\frac{\partial r}{\partial t} = \frac{1}{n+2} > 0, \quad \frac{\partial r^*}{\partial t} = -\frac{mn}{2(m+1)(n+2)} < 0, \quad \frac{\partial y}{\partial t} = -\frac{mn+4m+4}{2(m+1)(m+2)(n+2)} < 0,$$

$$\frac{\partial y^*}{\partial t} = \frac{m}{2(m+2)} > 0, \quad \frac{\partial p}{\partial t} = p' \frac{\partial Y}{\partial t} = \frac{m(2m-n+2)}{2(m+1)(m+2)(n+2)} > 0. \tag{28}$$

From (24) and (28), the effects on the profits of a tariff on the intermediate good are

$$\frac{\partial \Pi}{\partial t} < 0, \quad \frac{\partial \Pi^*}{\partial t} > 0, \quad \frac{\partial \pi}{\partial t} > 0, \quad \frac{\partial \pi^*}{\partial t} = -\frac{2(m+1)(n+1)x^* + mnX^*}{(m+1)(n+2)} < 0. \tag{29}$$

From (16)–(23), the effects of a domestic import tariff on the final good are given as:

$$\frac{\partial x}{\partial T} = 0, \quad \frac{\partial x^*}{\partial T} = \frac{m}{2(m+2)} > 0, \quad \frac{\partial X^*}{\partial T} = -\frac{m+1}{2(m+2)} < 0, \quad \frac{\partial r}{\partial T} = 0, \quad \frac{\partial r^*}{\partial T} = -\frac{1}{2} < 0,$$

$$\frac{\partial y}{\partial T} = \frac{1}{2(m+2)} > 0, \quad \frac{\partial y^*}{\partial T} = -\frac{m+1}{2(m+2)} < 0, \quad \frac{\partial p}{\partial T} = p' \frac{\partial Y}{\partial T} = \frac{1}{2(m+2)} > 0. \tag{30}$$

From (24) and (30), the effects on profits of a tariff on the final good are

$$\frac{\partial \Pi}{\partial T} > 0, \quad \frac{\partial \Pi^*}{\partial T} < 0, \quad \frac{\partial \pi}{\partial T} = 0, \quad \frac{\partial \pi^*}{\partial T} = -X^* < 0. \tag{31}$$

4. Foreign production subsidy to the intermediate good

This section considers the effects of a foreign production subsidy to the intermediate good on foreign and domestic welfare in the absence of any domestic trade policy, $t = T = 0$. The effect of a foreign production subsidy to the intermediate good on foreign welfare (7) is

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foreign exports of the intermediate good is positive if and only if $2m - n + 2 > 0$.

$$\frac{\partial W^*}{\partial s^*} = (r-c)\frac{\partial x^*}{\partial s^*} + x^*\frac{\partial r}{\partial s^*} + (r^*-c)\frac{\partial X^*}{\partial s^*} + (p-r^*)\frac{\partial y^*}{\partial s^*} + y^*\frac{\partial p}{\partial s^*}. \tag{32}$$

The first term is the profit-shifting effect: a foreign production subsidy to the intermediate good increases the foreign intermediate-good firm's output for the domestic market and thereby shifts profits from the domestic to the foreign intermediate-good firm. The second term is the terms of trade effect on exports of the intermediate good: the production subsidy reduces the price the foreign intermediate-good firm receives for its exports, deteriorating terms of trade. The third and fourth terms are the efficiency gain effect: the production subsidy increases the foreign intermediate-good firm's production for the foreign market and the foreign final-good firm's output and thereby reduces the efficiency loss arising from "double-marginalization." The fifth term is the terms of trade effect on exports of the final good: the production subsidy lowers the price the foreign final-good firm receives for its exports, worsening the terms of trade. Using the comparative static results from (26), together with the first-order profit-maximizing conditions from (9), (14) and (15), to evaluate the overall welfare effect, yields

$$\left.\frac{\partial W^*}{\partial s^*}\right|_{s^*=0} = \frac{n}{n+2}x^* + \frac{nm(m+2)+(m+1)(n+2)}{(m+1)(m+2)(n+2)}X^* > 0. \tag{33}$$

This implies that a small subsidy to foreign intermediate-good production raises foreign welfare. Setting $\partial W^*/\partial s^* = 0$ yields the optimal foreign production subsidy:

$$s^* = \frac{2\{n(m+1)(m+2)x^* + [nm(m+2)+(m+1)(n+2)]X^*\}}{2m(m+2)(n+1)+n+2} > 0. \tag{34}$$

The foreign country has a unilateral incentive to offer a production subsidy to the foreign intermediate-good firm.

The effect of a foreign production subsidy on domestic welfare (6) in the absence of domestic intervention is

$$\frac{\partial W}{\partial s^*} = n(r-c)\frac{\partial x}{\partial s^*} - (my-nx)\frac{\partial r}{\partial s^*} + m(p-r)\frac{\partial y}{\partial s^*} - (Y-my)\frac{\partial p}{\partial s^*}. \tag{35}$$

The first term is the profit-shifting effect: a foreign production subsidy decreases the output of the domestic intermediate-good firm and thereby shifts profits from the domestic to the foreign intermediate-good firm. The second term is the terms of trade effect on imports of the intermediate good: the production subsidy reduces the price paid to the foreign intermediate-good firm, improving terms of trade. The third term is the efficiency gain effect: the production subsidy causes an efficiency gain from an increase in domestic production of the final good whose price exceeds marginal cost. The fourth term is the terms of trade effect on imports of the final good: the production subsidy lowers the price paid to the foreign final-good firm, improving terms of trade. Using the comparative static results from (26), together with the first-order profit-maximizing conditions from (8) and (13), the overall welfare effect is obtained as:

$$\frac{\partial W}{\partial s^*} = \frac{-[2(m+1)^2+n]nx + [2(m+1)(m+2)+2m-n+2]x^* + [2m(m+2)+n+2]y^*}{2(m+1)(m+2)(n+2)}. \tag{36}$$

From Section 1 of the Appendix, a foreign production subsidy to the intermediate good may reduce domestic welfare if there are two or more domestic intermediate-good firms (i.e., if $n \geq 2$).

5. Foreign production subsidy to the intermediate good and domestic import tariffs on the intermediate and final goods

This section considers the interaction of domestic and foreign policies when the domestic government uses import tariffs on the intermediate and final goods in response to the foreign production subsidy to the intermediate good.

In stage 2, the domestic government sets its import tariffs on the intermediate and final goods to maximize domestic welfare, taking the production subsidy set by the foreign government in stage 1 as given. Maximizing domestic welfare (6) with respect to t and T yields the first-order conditions:

$$\frac{\partial W}{\partial t} = n(r-c)\frac{\partial x}{\partial t} - x^*\left(\frac{\partial r}{\partial t} - 1\right) + m(p-r)\frac{\partial y}{\partial t} - y^*\frac{\partial p}{\partial t} + t\frac{\partial x^*}{\partial t} + T\frac{\partial y^*}{\partial t} = 0, \tag{37}$$

$$\frac{\partial W}{\partial T} = n(r-c)\frac{\partial x}{\partial T} - x^*\frac{\partial r}{\partial T} + m(p-r)\frac{\partial y}{\partial T} - y^*\left(\frac{\partial p}{\partial T} - 1\right) + t\frac{\partial x^*}{\partial T} + T\frac{\partial y^*}{\partial T} = 0. \tag{38}$$

In (37), the first term is the positive profit-shifting effect from the foreign to the domestic intermediate-good firm, the second term is the positive terms of trade effect on intermediate-good imports, the third term is the efficiency loss effect from a reduction in domestic final-good production, and the fourth term is the negative terms of trade on final-good imports.[11] In (38), the first and second terms are zero because a tariff on the final good does not affect the domestic intermediate-good firm's output and the domestic intermediate-good price, the third term is the positive profit-shifting effect from the foreign to the domestic final-good firm, and the fourth term is the positive terms of trade effect on final-good imports.[12] The final two terms of (37) and (38) are the tariff revenue effect. Using the comparative static results from (28) and (30), together with (8) and (13), yields

$$\begin{bmatrix} -m(3mn+4m+4n+4) & m(m+1)(n+2) \\ m & -(m+1) \end{bmatrix}\begin{bmatrix} t \\ T \end{bmatrix}$$

$$= \begin{bmatrix} (mn+4m+4)my - 2(m+1)(m+2)nx - 2(m+1)(m+2)(n+1)x^* + (2m-n+2)my^* \\ -my - (2m+3)y^* \end{bmatrix}.$$

Solving for the optimal policies yields

$$t = \frac{mnx + (mn+m+n)x^* + (n+1)my^*}{m(n+1)} > 0, \tag{39}$$

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[11] From (28), $\partial r/\partial t - 1 = -(n+1)/(n+2) < 0$. We can also call the second term of (37) the profit-extraction effect from the foreign intermediate-good firm.

[12] From (30), $\partial p/\partial T - 1 = -(2m+3)/2(m+2) < 0$. We can also call the fourth term of (38) the profit-extraction effect from the foreign final-good firm.

$$T=\frac{(m+1)nx+nmy+(m+1)(n+1)x^*+3(m+1)(n+1)y^*}{(m+1)(n+1)}>0. \tag{40}$$

The optimal tariffs on the intermediate and final goods are positive.

In Section 4, it was shown that a foreign production subsidy to the intermediate good may reduce domestic welfare in the absence of domestic intervention. Now, consider the effect of a foreign production subsidy to the intermediate good on domestic welfare when the domestic government sets its tariffs on the intermediate and final goods optimally. The effect of a foreign production subsidy on domestic welfare (6) is given as:

$$\frac{dW}{ds^*}=\frac{\partial W}{\partial s^*}+\frac{\partial W}{\partial t}\frac{dt}{ds^*}+\frac{\partial W}{\partial T}\frac{dT}{ds^*}. \tag{41}$$

Since the tariffs on the intermediate and final goods are set optimally, $\partial W/\partial t=\partial W/\partial T=0$. Therefore, only the direct effect of a foreign production subsidy on domestic welfare should be considered. The effect of the foreign production subsidy on domestic welfare is

$$\frac{dW}{ds^*}=\frac{\partial W}{\partial s^*}=n(r-c)\frac{\partial x}{\partial s^*}-x^*\frac{\partial r}{\partial s^*}+m(p-r)\frac{\partial y}{\partial s^*}-y^*\frac{\partial p}{\partial s^*}+t\frac{\partial x^*}{\partial s^*}+T\frac{\partial y^*}{\partial s^*}. \tag{42}$$

Using the comparative static results from (26), together with (8) and (13), as well as the optimal import tariffs from (39) and (40) to evaluate at the optimum, yields

$$\frac{dW}{ds^*}=y^*+x^*>0 \tag{43}$$

A subsidy to foreign intermediate-good production always raises domestic welfare, provided the domestic government sets its tariffs on the intermediate and final goods optimally.

The effect of a foreign production subsidy on the optimal domestic tariffs can be determined by totally differentiating (39) and (40), and using the comparative static results from (26), (28), and (30). This yields

$$\begin{bmatrix} 4(m+1)(m+2)(n+1)^2+m(2m-n+2) & (m+1)(n+2) \\ -m(2mn+m+n+1)(2m-n+2) & (m+1)(n+1)[4m(m+1)(n+1)+6mn+7m+7n+7] \end{bmatrix}\begin{bmatrix} dt/ds^* \\ dT/ds^* \end{bmatrix}$$

$$=\begin{bmatrix} 2(m+1)(m+2)[n(n+1)+1]-(2m-n+2) \\ 2mn^2(m+1)(m+2)+m(2m-n+2)[(m+2)n+m+1]+3(m+1)^2(n+1)(n+2) \end{bmatrix}. \tag{44}$$

Solving (44), the optimal domestic response to a foreign production subsidy is given by

$$\frac{dt}{ds^*}=\frac{(4m^2+10m+7)n^2+2(2m^2+5m+4)n+2(m+1)(2m+1)}{2[(4m^2+10m+7)n^2+2(4m^2+10m+7)n+(6m+7)(m+1)]}>0, \tag{45}$$

$$\frac{dT}{ds^*}=\frac{(m+2)(4m^2+6m+3)n^2+4(m+3)(m+1)^2n+2(2m+3)(m+1)^2}{2(m+1)[(4m^2+10m+7)n^2+2(4m^2+10m+7)n+(6m+7)(m+1)]}>0. \tag{46}$$

The optimal domestic response to a foreign production subsidy is to increase the tariffs on the intermediate and final goods. From Section 2 of the Appendix, the optimal countervailing tariff fraction on the intermediate good, dt/ds^*, is less than a half. The optimal countervailing tariff fraction on the

final good, dT/ds^*, is also less than a half.[13] This result is in line with the results of Dixit (1988) and Collie (1991, 1992, 1994), which consider subsidies and countervailing tariffs on the final good in a model without an intermediate good sector. For a Cournot duopoly, Dixit (1988) shows that the optimal countervailing tariff fraction is exactly one third when demand is linear. For a Cournot oligopoly, Collie (1994) shows that the optimal countervailing tariff fraction is less than a half in the case of linear demand.[14]

The foreign production subsidy to the intermediate good increases the profit of the foreign intermediate-good firm that the domestic country can extract with the tariff on the intermediate good. This will increase the optimal tariff on the intermediate good. However, the foreign production subsidy lowers the domestic price of the intermediate good. A reduction in the marginal cost faced by the domestic final-good firm increases its output and profit. The production subsidy also reduces the domestic price of the final good, causing an increase in the consumer surplus in the domestic country. These will reduce the optimal tariff on the intermediate good. Hence, the optimal domestic response to a foreign production subsidy is a partially countervailing tariff on the intermediate good.

The subsidy to foreign intermediate-good production increases the foreign final-good firm's profit extractable by the domestic country through the tariff on the final good. This will increase the optimal tariff on the final good. However, the foreign production subsidy lowers the domestic final-good price, which benefits domestic consumers. This will reduce the optimal tariff on the final good. Therefore, the optimal domestic response to a foreign production subsidy is a less than fully countervailing tariff on the final good.

From Section 2 of the Appendix, the optimal countervailing tariff fraction on the final good is greater than that on the intermediate good.[15] The countervailing tariff on the intermediate good increases the profit of the domestic intermediate-good firm at the expense of the domestic final-good firm. On the other hand, the countervailing tariff on the final good increases the profit of the domestic final-good firm without harming the domestic intermediate-good firm. Thus, the domestic government has the incentive to impose a higher countervailing tariff on final-good imports than on intermediate-good imports.

In stage 1, the foreign government sets its production subsidy to the intermediate good to maximize foreign welfare, realizing the effect that its decision will have on the optimal tariffs on the intermediate and final goods set by the domestic government in stage 2. The effect of a foreign production subsidy on foreign welfare (7) is

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[13] In the case of $m = n = 1$, from (16), (17), (21), (22), (39) and (40), the optimal tariffs on the intermediate and final goods are given by $t = 22(\alpha - c)/89 + 55s^*/178$ and $T = 75(\alpha - c)/178 + 143s^*/356$, respectively. $22(\alpha - c)/89$ and $75(\alpha - c)/178$ are the tariffs that the domestic government would impose on the intermediate and final goods, respectively, in the absence of any foreign production subsidy (i.e., $s^* = 0$). $55s^*/178$ and $143s^*/356$ are the countervailing tariffs imposed by the domestic government on the intermediate and final goods, respectively, in response to the foreign subsidy. Therefore, it is inappropriate to consider the entire optimal tariffs on the intermediate and final goods as the domestic government's countervailing tariffs. Regarding this point, see Wong (1995).

[14] In Dixit (1988) and Collie (1994), the foreign and domestic products are assumed to be differentiated. Collie (1992) shows that the optimal countervailing tariff is a half in a homogeneous product Cournot oligopoly with free entry of domestic firms.

[15] From Section 2 of the Appendix, the optimal countervailing tariffs on the intermediate and final goods are larger when the number of domestic intermediate-good firms is greater.

$$\frac{dW^*}{ds^*}=(r-c-t)\left(\frac{\partial x^*}{\partial s^*}+\frac{\partial x^*}{\partial t}\frac{dt}{ds^*}+\frac{\partial x^*}{\partial T}\frac{dT}{ds^*}\right)+x^*\left[\frac{\partial r}{\partial s^*}+\left(\frac{\partial r}{\partial t}-1\right)\frac{dt}{ds^*}+\frac{\partial r}{\partial T}\frac{dT}{ds^*}\right]+(r^*-c)\left(\frac{\partial X^*}{\partial s^*}+\frac{\partial X^*}{\partial t}\frac{dt}{ds^*}+\frac{\partial X^*}{\partial T}\frac{dT}{ds^*}\right)$$

$$+(p-r^*-T)\left(\frac{\partial y^*}{\partial s^*}+\frac{\partial y^*}{\partial t}\frac{dt}{ds^*}+\frac{\partial y^*}{\partial T}\frac{dT}{ds^*}\right)+y^*\left[\frac{\partial p}{\partial s^*}+\frac{\partial p}{\partial t}\frac{dt}{ds^*}+\left(\frac{\partial p}{\partial T}-1\right)\frac{dT}{ds^*}\right]. \tag{47}$$

The first term is the profit-shifting effect, the second term is the terms of trade effect on exports of the intermediate good, the third and fourth terms are the efficiency gain effect, and the fifth term is the terms of trade on exports of the final good. The domestic government's countervailing tariff on the intermediate good reduces the profit-shifting effect of the production subsidy and deteriorates the terms of trade with respect to the intermediate good. However, it strengthens the efficiency gain effect and improves the terms of trade for the final good. The countervailing tariff on the final good increases the profit-shifting effect; however, it reduces the efficiency gain effect and worsens the terms of trade for the final good.

Using the comparative static results from (26), (28) and (30) together with (9), (14) and (15), as well as the optimal domestic response from (45) and (46) to evaluate (47) at $s^*=0$, yields

$$\left.\frac{dW^*}{ds^*}\right|_{s^*=0}=-\frac{[m(2m+3)+n+1][(m+1)x^*+(m+n+1)X^*]}{(m+1)[(4m^2+10m+7)n^2+2(4m^2+10m+7)n+(6m+7)(m+1)]}<0. \tag{48}$$

The total effect of a foreign production subsidy on foreign welfare is negative. Setting $dW^*/ds^*=0$ and solving for the optimal foreign production subsidy to the intermediate good, yields

$$s^*=-\frac{2[m(2m+3)+n+1][(m+1)x^*+(m+n+1)X^*]}{(4m^3+10m^2+9m+2)n^2+4(2m+1)(m+1)^2n+2(2m+1)(m+1)^2}<0. \tag{49}$$

The optimal foreign policy is a production tax on the intermediate good. The foreign production subsidy to the intermediate good itself increases the profits of the foreign intermediate-good and final-good firms. However, the domestic country's countervailing tariff on the final good reduces the profits of the foreign intermediate-good and final-good firms. The countervailing tariff on the intermediate good harms the foreign intermediate-good firm. Thus, retaliation by the domestic country with countervailing tariffs on the intermediate and final goods deters the foreign country from subsidizing its intermediate-good production. This result can be extended to the case where the foreign country uses production subsidies to the intermediate and final goods.[16]

6. Foreign production subsidy to the intermediate good and domestic import tariff on the intermediate good

In the previous section, the domestic government could impose import tariffs on both the intermediate and final goods; however, in this section, the domestic government can only impose an

[16] See Section 3 of the Appendix.

import tariff on the intermediate good.[17] Therefore, in stage 1, the foreign government sets its production subsidy to the intermediate good. Then, in stage 2, the domestic government sets its import tariff on the intermediate good in response to the foreign production subsidy.

In stage 2, given the foreign production subsidy, the domestic government sets its tariff on the intermediate good to maximize domestic welfare (6). The first-order condition is

$$\frac{\partial W}{\partial t} = n(r-c)\frac{\partial x}{\partial t} - x^*\left(\frac{\partial r}{\partial t} - 1\right) + m(p-r)\frac{\partial y}{\partial t} - y^*\frac{\partial p}{\partial t} + t\frac{\partial x^*}{\partial t} = 0. \tag{50}$$

Using the comparative static results from (28), together with (8) and (13), yields the optimal tariff:

$$t = \frac{(2m-n+2)mnx + [(3m+4)n + 2m(m+1)(n+1)]x^* - (2m-n+2)my^*}{m(3mn+4m+4n+4)}. \tag{51}$$

From Section 4 of the Appendix, the optimal tariff on the intermediate good is positive.

In the previous section, it was shown that if the domestic country sets its tariffs on the intermediate and final goods optimally, it always gains from a foreign production subsidy to the intermediate good. When the domestic government uses only an optimal tariff on the intermediate good, the effect of a foreign production subsidy on domestic welfare (6) is

$$\frac{dW}{ds^*} = \frac{\partial W}{\partial s^*} + \frac{\partial W}{\partial t}\frac{dt}{ds^*}. \tag{52}$$

Since the tariff on the intermediate good is set optimally, $\partial W/\partial t = 0$. Thus,

$$\frac{dW}{ds^*} = \frac{\partial W}{\partial s^*} = n(r-c)\frac{\partial x}{\partial s^*} - x^*\frac{\partial r}{\partial s^*} + m(p-r)\frac{\partial y}{\partial s^*} - y^*\frac{\partial p}{\partial s^*} + t\frac{\partial x^*}{\partial s^*}. \tag{53}$$

Using the comparative static results from (26) together with (8) and (13), and the optimal tariff from (51) to evaluate at the optimum yields

$$\frac{dW}{ds^*} = \frac{-(m+n+1)nx + (m+1)(2n+3)x^* + (m+n+1)y^*}{3mn+4m+4n+4}. \tag{54}$$

From Section 4 of the Appendix, when the domestic country sets its tariff on the intermediate good optimally, a foreign production subsidy to the intermediate good may reduce domestic welfare if there are two domestic intermediate-good firms and more than one domestic final-good firm (i.e., if $n = 2$ and $m \geq 2$) or if there are more than two domestic intermediate-good firms (i.e., if $n \geq 3$). In contrast, Collie (1991, 1994) shows that when the domestic country pursues an optimal trade policy, a foreign export subsidy will always raise domestic welfare.

To obtain the effect of a foreign production subsidy on the optimal domestic tariff, totally differentiate (51), using the comparative static results from (26) and (28) to give

$$\frac{dt}{ds^*} = \frac{(4m^3+18m^2+28m+13)n^2 + 2(m+1)(2m^2+3m+4)n + 4(m-1)(m+1)^2}{(12m^3+50m^2+71m+32)n^2 + 4(m+1)(8m^2+21m+16)n + 4(7m+8)(m+1)^2} > 0. \tag{55}$$

The optimal domestic response to a foreign production subsidy is to increase the tariff on the intermediate good. From Section 4 of the Appendix, the optimal countervailing tariff fraction is less than

[17] In this section, we assume that $T = 0$ for simplicity.

one third.[18]

The foreign production subsidy to the intermediate good increases the profit of the foreign intermediate-good firm that the domestic country can extract with the tariff on the intermediate good. This will raise the optimal tariff on the intermediate good. However, the foreign production subsidy increases the profit of the domestic final-good firm and the consumer surplus in the domestic country. This will reduce the optimal tariff. Therefore, the optimal domestic response to a foreign production subsidy to the intermediate good is a partially countervailing tariff.

From Section 4 of the Appendix, the optimal countervailing tariff fraction on the intermediate good is smaller when the domestic country uses only a tariff on the intermediate good than when the domestic country uses tariffs on the intermediate and final goods. The countervailing tariff on the intermediate good decreases the profit of the domestic final-good firm. This harmful effect can be reduced by the use of a tariff on the final good. If the domestic country cannot use a tariff on the final good, this harmful effect weakens the incentive for a countervailing tariff on the intermediate good.

In stage 1, the foreign government sets its production subsidy to the intermediate good in order to maximize foreign welfare, realizing the effect this will have on the optimal domestic tariff on the intermediate good. The effect of a foreign production subsidy on foreign welfare (7) is given by

$$\frac{dW^*}{ds^*} = (r-c-t)\left(\frac{\partial x^*}{\partial s^*} + \frac{\partial x^*}{\partial t}\frac{dt}{ds^*}\right) + x^*\left[\frac{\partial r}{\partial s^*} + \left(\frac{\partial r}{\partial t} - 1\right)\frac{dt}{ds^*}\right] + (r^* - c)\left(\frac{\partial X^*}{\partial s^*} + \frac{\partial X^*}{\partial t}\frac{dt}{ds^*}\right)$$

$$+ (p - r^*)\left(\frac{\partial y^*}{\partial s^*} + \frac{\partial y^*}{\partial t}\frac{dt}{ds^*}\right) + y^*\left(\frac{\partial p}{\partial s^*} + \frac{\partial p}{\partial t}\frac{dt}{ds^*}\right). \tag{56}$$

Using the comparative static results from (26) and (28) together with (9), (14) and (15), and the optimal countervailing tariff from (55) to evaluate (56) at $s^* = 0$, yields

$$\left.\frac{dW^*}{ds^*}\right|_{s^*=0} = \frac{\Lambda x^* + \Omega X^*}{(12m^3 + 50m^2 + 71m + 32)n^2 + 4(m+1)(8m^2 + 21m + 16)n + 4(7m+8)(m+1)^2} > 0, \tag{57}$$

where $\Lambda = 4(n^2 + 2n - 1)m^3 + 2(7n^2 + 16n - 2)m^2 + (15n^2 + 34n + 4)n + 2(n+1)(3n+2) > 0$,

$$\Omega = 4(n+1)(3n+1)m^3 + 2(23n^2 + 32n + 12)m^2 + (53n^2 + 80n + 36)m + 16(n+1)^2 > 0.$$

The overall effect of a foreign production subsidy on foreign welfare is positive. Setting $dW^*/ds^* = 0$ and solving for the optimal foreign production subsidy to the intermediate good yields

$$s^* = \frac{\Lambda x^* + \Omega X^*}{2\left[(4m^3 + 13m^2 + 14m + 4)n^2 + 2(5m+4)(m+1)^2 n + 2(3m+2)(m+1)^2\right]} > 0. \tag{58}$$

The optimal foreign policy is a production subsidy to the intermediate good. The foreign production subsidy to the intermediate good itself benefits the foreign intermediate-good and final-good firms. The

[18] From Section 4 of the Appendix, the optimal countervailing tariff on the intermediate good increases as a result of an increase in the number of domestic intermediate-good firms.

domestic country's countervailing tariff on the intermediate good harms the foreign intermediate-good firm, but benefits the foreign final-good firm.[19] Retaliation with a countervailing tariff on the intermediate good is less harmful to the foreign country than retaliation with countervailing tariffs on the intermediate and final goods. Therefore, if the domestic country retaliates using only a tariff on the intermediate good, the foreign country will gain from a production subsidy to the intermediate good. The coexistence of a foreign production subsidy and a domestic countervailing duty on the intermediate good can be explained by our model.[20] This result is in contrast with the result in Collie (1991, 1994) that retaliation with a countervailing tariff will deter foreign subsidization.[21]

7. Concluding remarks

This paper analyzes a foreign production subsidy to the intermediate good and domestic import tariffs on the intermediate and final goods in vertically related markets that are characterized by Cournot competition. Domestic and foreign policies are modeled as a multistage game. At the first stage, the foreign government sets its production subsidy to the intermediate good. Then, at the second stage, the domestic government sets its import tariffs in response to the foreign subsidy. Two cases are considered. The first is a case where the domestic government uses import tariffs on the intermediate and final goods. The second is a case where the domestic government uses only an import tariffs on the intermediate good.

In the first case if the domestic country sets its tariffs on the intermediate and final goods optimally, it will always benefit from a foreign production subsidy. The optimal domestic response to a foreign subsidy is to increase the tariffs on the intermediate and final goods by less than a half of the foreign production subsidy. When the foreign country faces such a domestic response, its optimal policy is to tax its intermediate-good production. Retaliation with countervailing tariffs on the intermediate and final goods deters the foreign country from subsidizing its intermediate-good production.

In the second case if the domestic country sets its tariff on the intermediate good optimally, it may be harmed by a foreign production subsidy. The optimal domestic response to a foreign subsidy is a partially countervailing tariff on the intermediate good. The optimal countervailing tariff fraction is less than one third and is smaller when the domestic country uses only a tariff on the intermediate good than when it uses tariffs on the intermediate and final goods. When the domestic country retaliates with only a countervailing tariff on the intermediate good, the optimal foreign policy is a subsidy to intermediate-good production. This paper provides a possible explanation for the coexistence of subsidies and countervailing duties.

The analysis in this paper can be extended to the case of Bertrand competition with product differentiation in the final-good industry. From Section 5 of the Appendix, assuming Bertrand

[19] Since the countervailing tariff on the intermediate good is smaller when the domestic country uses only a tariff on the intermediate good, the harmful effect of the countervailing tariff is smaller.

[20] Qiu (1995) emphasizes the coexistence of export subsidies and countervailing duties and shows that factors such as delay in retaliation, the GATT constraint on the amount of countervailing duties, and the voluntary export restraints reduce the efficacy of countervailing duty retaliation, and therefore, countervailing duties fail to deter export subsidization.

[21] For a Cournot oligopoly with non linear demand and homogeneous products, Collie (1991) shows that when the foreign country faces retaliation with a countervailing tariff, the optimal foreign policy is usually an export tax. Collie (1991) also shows that when the domestic country retaliates with a tariff and a production subsidy, the optimal foreign policy is a zero export subsidy if demand is linear and an export subsidy if demand is non linear. Collie (1992) argues that if the domestic country uses a countervailing tariff, the optimal foreign export subsidy is zero when there is free entry in the domestic country.

competition rather than Cournot competition in the final-good industry does not alter the results in any qualitative manne

Appendix

1. Effect of a foreign production subsidy on domestic welfare when there is no retaliation

Suppose $t = T = 0$. Substituting (16), (17), and (22) into (36) yields

$$\frac{\partial W}{\partial s^*} = \frac{F_1 s^* + F_2(\alpha - c)}{4(m+1)^2(m+2)^2(n+2)^2},$$

where $F_1 = (2m+1)n^2 + 4(m+1)^2(2m^2+6m+1)n + 4(m+1)^2(m^2+4m+1) > 0$,

$$F_2 = -(2m^2+2m-1)n^2 - 4(m+1)(m^3+3m^2+3m-1)n + 4(m+1)^2(m^2+4m+1).$$

$F_2 = 8m^3 + 14m^2 + 14m + 9 > 0$ for $n = 1$. Since $F_2 = -4(m^4+2m^3+4m^2-4) < 0$ for $n = 2$ and $\partial F_2/\partial n = -2(2m^2+2m-1)n - 4(m+1)(m^3+3m^2+3m-1) < 0$, $F_2 < 0$ for $n \geq 2$. Therefore, when $s^* > 0$, $\partial W/\partial s^*$ is positive if $n = 1$ and $\partial W/\partial s^*$ may be negative if $n \geq 2$.

2. Domestic countervailing tariffs on the intermediate and final goods

From (45) and (46),

$$\frac{dt}{ds^*} = \frac{G_2}{2G_1}, \quad \frac{dT}{ds^*} = \frac{G_3}{2(m+1)G_1}, \tag{A.1}$$

where $G_1 = (4m^2+10m+7)n^2 + 2(4m^2+10m+7)n + (6m+7)(m+1) > 0$,

$$G_2 = (4m^2+10m+7)n^2 + 2(2m^2+5m+4)n + 2(m+1)(2m+1) > 0,$$

$$G_3 = (m+2)(4m^2+6m+3)n^2 + 4(m+3)(m+1)^2 n + 2(2m+3)(m+1)^2 > 0.$$

Since $2G_1 - 2G_2 = 2(m+1)(4mn+2m+6n+5) > 0$, $dt/ds^* = G_2/2G_1 < 1/2$. Since $2(m+1)G_1 - 2G_3 = 2(2mn+m+n+1)[m(2m+3)+n+1] > 0$, $dT/ds^* = G_3/2(m+1)G_1 < 1/2$.

Subtracting the optimal countervailing tariff on the intermediate good from that on the final good yields

$$\frac{dT}{ds^*} - \frac{dt}{ds^*} = \frac{G_4}{2(m+1)G_1},$$

where $G_4 = -(2m+1)n^2 + 2(m+1)(3m+2)n + 4(m+1)^2 = -(2m+1)\left[n - \frac{(m+1)(3m+2)}{2m+1}\right]^2 + \frac{(m+1)^2(9m^2+20m+8)}{2m+1}$.

G_4 is the quadratic function of n and attains its largest value, which is $(m+1)^2(9m^2+20m+8)/(2m+1) > 0$, at $n = (m+1)(3m+2)/(2m+1) > 0$. From (25), $0 < n < 2(m+1)$. Since $G_4 = 4(m+1)^2 > 0$ at $n = 0$ and $G_4 = 4(m+2)(m+1)^2 > 0$ at $n = 2(m+1)$, $G_4 > 0$ for $0 < n < 2(m+1)$. Therefore, $dT/ds^* > dt/ds^*$.

Differentiating (A.1) with respect to n yields

$$\frac{\partial}{\partial n}\left(\frac{dt}{ds^*}\right) = \frac{(m+1)G_5}{G_1^2} > 0, \quad \frac{\partial}{\partial n}\left(\frac{dT}{ds^*}\right) = \frac{mG_6}{(m+1)G_1^2} > 0,$$

where $G_5 = 4(2n^2+2n-1)m^3 + 4(8n^2+10n-1)m^2 + (44n^2+64n+11)m + 7(n+1)(3n+2) > 0$,

$G_6 = 4(2n^2+2n-1)m^4 + 2(18n^2+20n-5)m^3 + 2(29n^2+34n-2)m + (33n^2+47n+6)m + (n+1)(7n+4) > 0$.

3. Foreign production subsidies to the intermediate and final goods

We let S^* denote the production subsidy to the final good. For example, consider the case of $m = n = 1$. When the domestic country pursues a policy of laissez-faire, the optimal foreign production subsidies to the intermediate and final goods are given by

$$s^* = \frac{1}{4}(\alpha - c) > 0, \quad S^* = \frac{7}{8}(\alpha - c) > 0,$$

respectively.

When the domestic country uses import tariffs on the intermediate and final goods to countervail foreign subsidies, the optimal tariffs on the intermediate and final goods are given by

$$t = \frac{55}{178}s^* + \frac{3}{89}S^* + \frac{22}{89}(\alpha - c), \quad T = \frac{143}{356}s^* + \frac{79}{178}S^* + \frac{75}{178}(\alpha - c),$$

respectively.

When the foreign country faces such a domestic response, its optimal production subsidies to the intermediate and final goods are given by

$$s^* = -\frac{2x^* + 3X^*}{8} < 0, \quad S^* = -\frac{2x^* + 3X^*}{16} < 0,$$

respectively. Retaliation with countervailing tariffs on the intermediate and final goods deters the foreign country from subsidizing its intermediate-good and final-good production.

4. Domestic countervailing tariff on the intermediate good

Suppose $T = 0$. Substituting (16), (17), and (22) into (51) and solving for the optimal tariff yields

$$t = \frac{H_2}{H_1} s^* + \frac{H_3}{H_1}(\alpha - c), \tag{A. 2}$$

where

$$H_1 = (12m^3 + 50m^2 + 71m + 32)n^2 + 4(m+1)(8m^2 + 21m + 16)n + 4(7m+8)(m+1)^2 > 0,$$

$$H_2 = (4m^3 + 18m^2 + 28m + 13)n^2 + 2(m+1)(2m^2 + 3m + 4)n + 4(m-1)(m+1)^2 > 0,$$

$$H_3 = (2m - n + 2)[(2m+3)(2m+1)n + 2(m-1)(m+1)] > 0.$$

That is, the optimal tariff on the intermediate good is positive for $s^* > 0$.

Substituting (16), (17), (22), and (A. 2) into (54) yields

$$\frac{dW}{ds^*} = \frac{H_4}{H_1} s^* - \frac{2(m+n+1)H_5}{H_1}(\alpha - c),$$

where $H_4 = (4m^3 + 12m^2 + 13m + 2)n^2 + 4(4m+1)(m+1)^2 n + 2(4m+1)(m+1)^2 > 0$,

$$H_5 = (2m^2 + 4m - 1)n - (m+1)(4m+1).$$

$H_5 = -(2m^2 + m + 2) < 0$ for $n = 1$. When $n = 2$, $H_5 = 0$ if $m = 1$ and $H_5 = 3(m-1) > 0$ if $m \geq 2$. Since $\partial H_5 / \partial n = 2m^2 + 4m - 1 > 0$, $H_5 > 0$ for $n \geq 3$. Therefore, when $s^* > 0$, dW/ds^* is positive if $n = 1$ or if $n = 2$ and $m = 1$, and dW/ds^* may be negative if $n = 2$ and $m \geq 2$ or if $n \geq 3$. For example, consider the case of $n = 3$ and $m = 5$. From Section 1 of the Appendix, $\partial W / \partial s^* < 0$ for $s^* < 23(\alpha - c)/103$ if the domestic country pursues a laissez-faire policy. $dW/ds^* < 0$ for $s^* < 18(\alpha - c)/227$ if the domestic country sets its import tariff on the intermediate good optimally. Even if the domestic country imposes an optimal tariff on the intermediate good, it may be harmed by a foreign production subsidy.

From (A.2), the optimal countervailing tariff on the intermediate good is given by

$$\frac{dt}{ds^*} = \frac{H_2}{H_1}. \tag{A.3}$$

$$H_1 - 3H_2 = -(4m^2 + 13m + 7)n^2 + 2(2m+5)(5m+4)(m+1)n + 4(4m+11)(m+1)^2$$

$$= -(4m^2 + 13m + 7)\left[n - \frac{(2m+5)(5m+4)(m+1)}{4m^2 + 13m + 7}\right]^2 + \frac{(m+1)^2(m+2)^2(100m^2 + 324m + 177)}{4m^2 + 13m + 7}.$$

This is the quadratic function of n that attains its maximum $(m+1)^2(m+2)^2(100m^2+324m+177)/(4m^2+13m+7)>0$ at $n=(2m+5)(5m+4)(m+1)/(4m^2+13m+7)>0$.

From (25), $0<n<2(m+1)$. Since $H_1-3H_2=4(4m+11)(m+1)^2>0$ at $n=0$ and $H_1-3H_2=24(m+2)^2(m+1)^2>0$ at $n=2(m+1)$, $H_1-3H_2>0$ for $0<n<2(m+1)$.

Therefore, $dt/ds^*=H_2/H_1<1/3$.

Using (A.1) and (A.3) to compare the two optimal countervailing tariffs yields

$$\frac{G_2}{2G_1}-\frac{H_2}{H_1}=\frac{(n+2)\left[(4m^2+10m+7)n+2(4m+5)(m+1)\right]H_6}{2G_1H_1}>0,$$

where $H_6=(m+2)(4m^2+6m+3)n^2+4(m+3)(m+1)^2n+2(2m+3)(m+1)^2>0$. This implies the optimal countervailing tariff on the intermediate good is smaller when the domestic country only uses a tariff on the intermediate good than when the domestic country uses tariffs on the intermediate and final goods.

Differentiating (A.3) with respect to n yields

$$\frac{\partial}{\partial n}\left(\frac{dt}{ds^*}\right)=\frac{(m+1)(m+2)H_7}{H_1^{\,2}}>0,$$

where $H_7=8(5n^2+8n-1)m^4+4(60n^2+104n+11)m^3+4(128n^2+231n+60)m^2$

$$+(459n^2+844n+316)m+16(n+1)(9n+8)>0.$$

5. Bertrand competition with product differentiation in the final-good industry

We now consider the Bertrand competition case in the final-good industry. A domestic and a foreign final-good firm are Bertrand competitors producing differentiated final goods. A domestic and a foreign intermediate-good are still of the Cournot type.

The domestic final-good firm sets price p, and sells output y, while the foreign final-good firm sets price p^*, and sells output y^*. In the domestic country there is a representative consumer with quasi-linear preferences that are given by the quadratic utility function:

$$U(y,y^*)=\alpha y+\alpha y^*-\frac{1}{2}\left(y^2+2\gamma yy^*+y^{*2}\right),\quad \alpha,\gamma>0, \tag{A.4}$$

where $0<\gamma<1$ is a measure of the degree of product substitutability ranging from zero when the domestic and foreign final goods are independent to one when they are perfect substitutes. The utility function (A.4) yields the following inverse and direct demand functions:

$$p=\alpha-y-\gamma y^*,\quad p^*=\alpha-y^*-\gamma y,$$

$$y=\frac{1}{1-\gamma^2}\left[\alpha(1-\gamma)-p+\gamma p^*\right],\quad y^*=\frac{1}{1-\gamma^2}\left[\alpha(1-\gamma)-p^*+\gamma p\right].$$

Given (A.4), consumer surplus is

$$CS=U-py-p^*y^*=\frac{1}{2}y^2+\frac{1}{2}y^{*2}+\gamma yy^*.$$

The profits of the domestic final-good firm and the foreign final-good firm are given by

$$\Pi=(p-r)y,\quad \Pi^*=(p^*-r^*-T)y^*,$$

respectively. The profits of the domestic intermediate-good firm and the foreign intermediate-good firm are given by (4) and (5), respectively.

The welfare of the domestic country is given by

$$W=\pi+\Pi+CS+tx^*+Ty^*=(r-c)x+(p-r)y+\frac{1}{2}y^2+\frac{1}{2}y^{*2}+\gamma yy^*+tx^*+Ty^*.$$

The welfare of the foreign country is given by

$$W^*=\pi^*+\Pi^*-s^*(x^*+X^*)=(r-c-t)x^*+(r^*-c)X^*+(p^*-r^*-T)y^*.$$

Using procedures analogous to those used in Section 3, the equilibrium values in the case of Bertrand competition in the final-good industry are given by:

$$x=\frac{\alpha-c-s^*+t}{3(2-\gamma^2)},$$

$$x^*=\frac{(4-\gamma-2\gamma^2)(2+\gamma)(1-\gamma)(\alpha-c)+(8+\gamma-4\gamma^2)(2+\gamma)(1-\gamma)s^*-(4+\gamma-2\gamma^2)(4-\gamma-2\gamma^2)t+3\gamma(2-\gamma^2)T}{6(4-\gamma^2)(2-\gamma^2)(1-\gamma^2)},$$

$$X^*=y^*=\frac{(2+\gamma)(1-\gamma)(\alpha-c)+(2+\gamma)(1-\gamma)s^*+\gamma t-(2-\gamma^2)T}{2(4-\gamma^2)(1-\gamma^2)},$$

$$y=\frac{(8+\gamma-4\gamma^2)(2+\gamma)(1-\gamma)(\alpha-c)+(4-\gamma-2\gamma^2)(2+\gamma)(1-\gamma)s^*-(8-7\gamma^2+2\gamma^4)t+3\gamma(2-\gamma^2)T}{6(4-\gamma^2)(2-\gamma^2)(1-\gamma^2)},$$

$$r=\frac{\alpha+2c-s^*+t}{3},\qquad \text{(A.5)}$$

$$r^*=\frac{(6-\gamma-3\gamma^2)\alpha+(6+\gamma-3\gamma^2)c-(6-\gamma-3\gamma^2)s^*-\gamma t-3(2-\gamma^2)T}{6(2-\gamma^2)},$$

$$p=\frac{(16-11\gamma-9\gamma^2+6\gamma^3)(2+\gamma)\alpha+(8-\gamma-3\gamma^2)(2+\gamma)c-(4-3\gamma)(2+\gamma)(1+\gamma)s^*+(8-5\gamma^2)t+3\gamma(2-\gamma^2)T}{6(4-\gamma^2)(2-\gamma^2)},$$

$$p^* = \frac{(9-7\gamma-4\gamma^2+3\gamma^3)(2+\gamma)\alpha+(3-2\gamma)(2+\gamma)(1+\gamma)c-(3-\gamma-\gamma^2)(2+\gamma)s^*+\gamma(1-\gamma^2)t+3(2-\gamma^2)T}{3(4-\gamma^2)(2-\gamma^2)}.$$

When the domestic country pursues a policy of laissez-faire, the optimal foreign production subsidy to the intermediate good is given by

$$s^* = \frac{2(1+\gamma)[(2-\gamma^2)(2-\gamma)x^* + (6-4\gamma-4\gamma^2+3\gamma^3)X^*]}{14+\gamma-7\gamma^2} > 0.$$

When the domestic country uses import tariffs on the intermediate and final goods in response to a foreign production subsidy to the intermediate good, the optimal tariffs on the intermediate and final goods are given by

$$t = \frac{x+(3-\gamma^2)x^*+2\gamma y^*}{2} > 0,$$

$$T = \frac{\gamma(2-\gamma^2)x+2\gamma(2-\gamma^2)x^*+\gamma(1-\gamma^2)y+2(2-\gamma^2)(3-2\gamma^2)y^*}{2(2-\gamma^2)} > 0,$$

respectively. The optimal domestic response to a foreign production subsidy is given by

$$\frac{dt}{ds^*} = \frac{70+6\gamma-54\gamma^2-3\gamma^3+8\gamma^4}{238-189\gamma^2+32\gamma^4} > 0,$$

$$\frac{dT}{ds^*} = \frac{204-16\gamma-278\gamma^2+17\gamma^3+120\gamma^4-4\gamma^5-16\gamma^6}{(238-189\gamma^2+32\gamma^4)(2-\gamma^2)} > 0.$$

The optimal countervailing tariff fraction on the intermediate good, dt/ds^*, is less than one third.

The optimal countervailing tariff fraction on the final good, dT/ds^*, is less than a half, and is greater than that on the intermediate good.

When the foreign country faces retaliation with countervailing tariffs on the intermediate and final goods, the effect of a foreign production subsidy on foreign welfare is

$$\left.\frac{dW^*}{ds^*}\right|_{s^*=0} = -\frac{(14+8\gamma-9\gamma^2-4\gamma^3)(2-\gamma^2)x^*+(68+4\gamma-76\gamma^2-16\gamma^3+21\gamma^4+8\gamma^5)X^*}{(238-189\gamma^2+32\gamma^4)(2-\gamma^2)} < 0.$$

The optimal foreign policy is to tax intermediate-good production.

When the domestic country uses an import tariff on the intermediate good to countervail a foreign production subsidy to the intermediate good, the optimal tariff is given by

$$t = \frac{(1-\gamma^2)[(8-5\gamma^2)x+(24-17\gamma^2+2\gamma^4)x^*-2\gamma(1-\gamma^2)y^*]}{(4-\gamma-2\gamma^2)(4+\gamma-2\gamma^2)}$$

$$=\frac{(1-\gamma)\left[(64+22\gamma-65\gamma^2-20\gamma^3+16\gamma^4+4\gamma^5)(\alpha-c)+(80+38\gamma-79\gamma^2-34\gamma^3+20\gamma^4+8\gamma^5)s^*\right]}{(4-\gamma-2\gamma^2)(4+\gamma-2\gamma^2)(17-8\gamma^2)}>0. \quad \text{(A.6)}$$

The optimal domestic response to a foreign production subsidy is given by

$$\frac{dt}{ds^*}=\frac{(1-\gamma)(80+38\gamma-79\gamma^2-34\gamma^3+20\gamma^4+8\gamma^5)}{(4-\gamma-2\gamma^2)(4+\gamma-2\gamma^2)(17-8\gamma^2)}>0.$$

The optimal countervailing tariff fraction on the intermediate good is less than one third, and is smaller when the domestic country uses only a tariff on the intermediate good than when it uses tariffs on the intermediate and final goods.

When the foreign country faces retaliation with a countervailing tariff on the intermediate good, the effect of a foreign production subsidy on foreign welfare is

$$\left.\frac{dW^*}{ds^*}\right|_{s^*=0}=\frac{-16+56\gamma+17\gamma^2-60\gamma^3-4\gamma^4+16\gamma^5}{(4-\gamma-2\gamma^2)(4+\gamma-2\gamma^2)(17-8\gamma^2)}x^*$$

$$+\frac{544-64\gamma-1120\gamma^2+132\gamma^3+847\gamma^4-84\gamma^5-276\gamma^6+16\gamma^7+32\gamma^8}{(4-\gamma-2\gamma^2)(4+\gamma-2\gamma^2)(17-8\gamma^2)(4-\gamma^2)}X^*.$$

Using (A.5) and (A.6), it can be shown that $dW^*/ds^*|_{s^*=0}>0$. The optimal foreign policy is to subsidize intermediate-good production.

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