Multipuroduct Firms and Dumping*

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In this paper, we first develop a model of an international oligopolistic Cournot industry in which firms trade core goods and their incompatible accessories. We then examine some issues concerned with dumping. We find that such firms set the core goods price below cost (below-cost dumping, henceforth) even under perfect competition. We also find that firms might simultaneously engage in both price-discriminating dumping in the market for accessories and below-cost dumping in the market for core goods. Furthermore, we demonstrate that antidumping tariffs on both core goods and accessories may expand the dumping margin in the accessories market.

Keywords: Multiproduct firms, Closely related products, Dumping, Anti-dumping tariffs.

JEL classification: F12, F13

1. Introduction

Currently, there are several international industries in which firms produce multiple products that are closely related to each other.[1] Such multiproduct firms seem to adapt pricing and output decisions that are quite different from those of single-product firms. In maximizing total profits, a multiproduct firm might benefit greatly by dumping some of its products to ensure high demand for its other products. However, there seems to be no established theory to explain this behavior in international industries. Therefore, it is necessary and useful to examine the optimal pricing and output decisions of multiproduct firms in order to discuss issues about dumping in the real world. In this paper, we develop an international trade model of multiproduct firms that produce the same category of core goods and complementary products (henceforth, accessories) and analyze issues related to dumping and antidumping tariffs.

As is well known, there are two types of dumping in international trade. The first relates to price discrimination, and involves firms exporting products to foreign countries at prices below those charged in the domestic market. We will term this price-discriminating dumping. This is often observed in an industry in which firms supply their products to both domestic and foreign markets. The second type of dumping relates to below-cost pricing, which involves firms exporting goods to foreign coun-

* We thank Kenzo Abe, Jota Ishikawa, Naoto Jinji, Kazuharu Kiyono, Laixun Zhao, and seminar participants for their helpful comments and suggestions at the conference of the Center of Excellence at Waseda University and the Ishii section of the Institute for Research in Contemporary Political and Economic Affairs on January 14, 2006 and at the Asian Pacific Trade Seminars Kobe conference at Kobe University on July 15 and 16, 2006.

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tries at prices that are below production costs. We term this below-cost dumping. This type of dumping also occurs in industries in which firms specialize in exporting products but do not sell those products in the domestic market.

Of the two types of dumping mentioned above, the analysis of price-discriminating dumping has a longer history, there are many studies of this type of dumping. This strand of literature has been concerned with the renowned theory of the price differential policy of a monopolist that supplies goods to both domestic and foreign markets.[2] The analysis of below-cost dumping has a relatively shorter history, there have been very few studies of this type of dumping until quite recently. However, in recent years, there has been a considerable surge of interest in the latter type of dumping; hence the number of papers concerned with this type of dumping has increased recently.

Studies of below-cost dumping can be classified into two groups. In the first group, price uncertainty is considered.[3] These studies show that firms dump at below-cost *ex post* if they must decide their optimal policy under price uncertainty *ex ante*. In the other group of studies, inter-temporal markets are incorporated.[4] These studies show that below-cost dumping may occur in initially if a firm can obtain higher total profits by increasing its production in the second stage. Although these studies of below-cost dumping are interesting and useful, they have focused on the case of firms conducting with below-cost dumping; they have not analyzed the case of firms engaging simultaneously in price-discriminating dumping and below-cost dumping. In this paper, by considering an international oligopolistic industry in which firms produce core goods and their accessories, we develop a model that can be used to examine the a possibility of double dumping by firms.

Although, Blackstone (1975), did not develop a formal analysis of multiproduct firms' dumping, in a descriptive research of the American copying industry in the 1960s, he demonstrated that some copying machine firms set machine prices relatively close to their costs and priced the associated supplies (excluding free service and maintenance) well above their costs. Furthermore, in international trade, trade friction occurred between the European Community and Japan in the 1980's because Japanese copier makers set their copier machine prices below cost, or to achieve minimal profit, when considering the sale of accessories such as toner cartridges. Because a copying machine's life is generally much longer than that of toner cartridges, a copying machine generates a demand for several toner cartridges. Hence, a copying machine firm can earn high profits through selling the associated toner cartridges even if it dumps its copying machine.

In this paper, we develop an international oligopoly model in which firms produce and export core goods and their accessories. We then investigate the conditions under which both price-discriminating dumping and below-cost dumping occur simultaneously.[5] We also use our model to analyze the effects of anti-dumping tariffs which involves imposing anti-dumping tariffs on core goods and/or accessories to increase dumping margin on accessories. Related anti-dumping studies include those by Anderson (1992) and Tivig and Walz (2000), who study the threat of antidumping tariffs on firms. Our paper is different because we assume that the country importing goods is the first mover in the anti-dumping analysis.[6]

The rest of the paper is organized as follows. In section 2, we develop the model and discuss the conditions for below-cost dumping in the core goods market. In particular, we examine the conditions for below-cost dumping under perfect competition. In Sections 3 and 4, we analyze the conditions under which dumping occurs in both the core goods market and the accessories market. In Sections 5 and 6, we

investigate the effects of antidumping tariffs on core goods and accessories, respectively. We find that imposing tariffs on core goods or accessories may increase dumping margins on accessories, increase the profits of importing industries, and decrease the profits of dumping firms. In Section 7, we present concluding remarks.

2. The Model and its Assumptions

We consider an international Cournot industry in which multiproduct firms in two countries, the domestic country and the foreign country, produce core goods and accessories. Each firm's accessories are requirements of its core goods and are only compatible with its own core goods. For example, copying machine is a core good and its toner cartridge is its accessory. We assume, for simplification, that while domestic firms supply their core goods and accessories only to the domestic market, foreign firms supply similar products to both domestic and foreign markets. It is also assumed that while the outputs of domestic and foreign firms differ, the products produced by firms in the same country are identical to each other. Furthermore, given that users generally treat core goods as primary purchases, and accessories as secondary acquisitions, we assume that firms first supply core goods and then subsequent supply accessories to their respective markets.

Before developing the model, we describe the main notations used in this paper. Variables with a subscript $i(=d$ or $f)$ are demonstrated by a (domestic or foreign) firm. Variables with (without) a superscript * relate to the foreign (domestic) country or market.

Figure 1 illustrates the model. First, we focus on the domestic country. In the first stage, n_d domestic firms and n_f foreign firms produce core goods. A core goods is produced at a constant marginal cost of c_i by firm i with $i=$ d or f. Each domestic (foreign) firm's output is $x_d(x_f)$. Then total output of core goods in the domestic market $z=n_dx_d+n_fx_f=X_d+X_f$. Note that $n_d+n_f=N$. In the second stage, n_d domestic firms and n_f foreign firms produce accessories. An accessory is produced at a constant marginal cost of C_i by firm i with $i=$ d or f. Each domestic (foreign) firm's output of accessories in the domestic market is denoted by $y_d(y_f)$.

Secondly, we consider the foreign country in

Figure 1. Market Structure

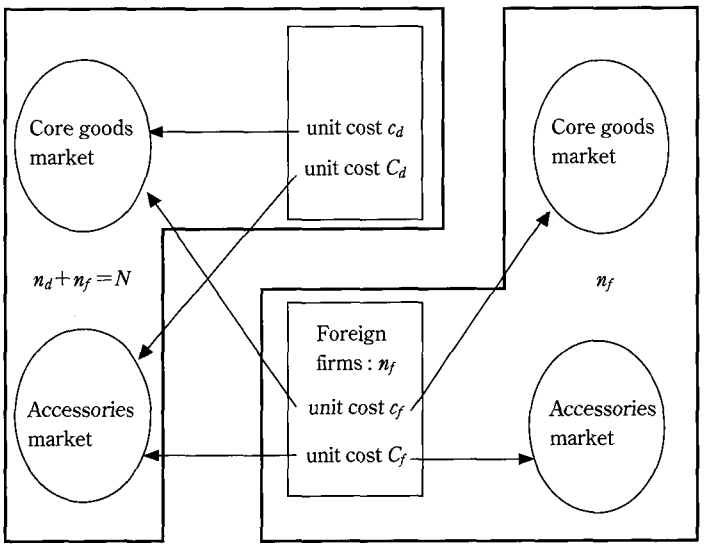

Figure 1. In the first stage, n_f foreign firms produce core goods using technologies that generate constant marginal cost of c_f in the foreign core goods market. Each foreign firm's output is x_f^*, and total output of core goods in the foreign market is $z^*=X_f^*=n_f x_f^*$. In the second stage, n_f foreign firms produce accessories at a constant marginal cost of C_f. Each foreign firm's output of accessories in the foreign market is denoted by y_f^*.

Because accessories are not compatible between firms, each firm can act as a monopoly in selling its accessory. The demand for its accessories depends strongly on the supply of its core goods. Thus, the price of an accessory sold by firm i in the domestic country is given by the inverse demand function, $q_i=q_i(y_i, x_i)$.[7] For simplicity, we assume that this inverse demand function has the following properties: $q_{ixx}=\frac{\partial^2 q_i}{(\partial x_i)^2}=0$, $q_{ix}=\frac{\partial q_i}{\partial x_i}>0$ and $q_{iy}=\frac{\partial q_i}{\partial y_i}<0$. Similarly, it is also assumed that the price of an accessory sold by firm i in the foreign country is given by the inverse demand function, $q_i^*=q_i^*(y_i^*, x_i^*)$, with $q_{ix}^*>0$, $q_{iy}^*<0$ and $q_{ixx}^*=0$.

In the domestic and foreign markets for core goods, firms cannot act monopolistically because many firms supply core goods belonging to the same category and because users can freely choose between the core goods of many firms. Firms cannot enclose users, as they can in accessories markets. Hence, we assume that both the domestic and foreign markets for core goods are oligopolistic and that firms engage in Cournot competition in these markets. Then, the price p of a core good in the domestic (and foreign) market is respectively given by the inverse demand function of $p=p(z)$ (and $p^*=p^*(z)$), and we make the standard assumption that $p'(z)<0 (p^{*\prime}(z^*)<0)$.

Given the inverse demand functions, the profits of domestic and foreign firms, π_d and π_f, are respectively defined as

$$\pi_d=p(z)x_d-c_d x_d+q_d(y_d, x_d)y_d-C_d y_d \quad (1)$$

and

$$\pi_f=p(z)x_f-c_f x_f+q_f(y_f, x_f)y_f-C_f y_f$$
$$+p^*(z^*)x_f^*-c_f x_f^*+q_f^*(y_f^*, x_f^*)y_f^*-C_f y_f^*. \quad (2)$$

Firms choose outputs levels of core goods and accessories to maximize their profits. Because firms first supply core goods and then provide accessories to their markets, they face a two-stage game; that is, in the first stage, firms choose their optimal outputs of core goods, and then determine their optimal output of accessories in the second stage. Therefore, we solve this two-stage game by using backward induction.

The first-and second-order conditions for profit maximization by firm i in the domestic accessories market in the second stage are,

$$q_i(x_i, y_i)+y_i q_{iy}-C_i=0, \quad (3)$$

and

$$2q_{iy}+y_i q_{iyy}<0 \qquad i=d, f, \quad (4)$$

where $q_{iyy}=\frac{\partial^2 q_i}{(\partial y_i)^2}$.

The first-and second-order conditions for profit maximization by the foreign firm in its own accessories market in the second stage are

$$q_f^*(x_f^*, y_f^*)+y_f^* q_{fy^*}^*-C_f=0, \quad (5)$$

and

$$2q_{fy^*}^*+y_f^* q_{fy^*y^*}^*<0 \quad (6)$$

The Cournot-Nash equilibrium for the domestic core goods market in the first stage is obtained by solving the following system of equations:

$$p(z)+p'(z)x_i-c_i+y_i q_{ix}=0 \qquad i=d, f. \quad (7)$$

Equation (7) consists of the firms' first-order conditions for profit maximization in the first stage. The second-order condition of firm i in the first stage is assumed to be satisfied ($2p'+x_i p''<0$). As is well known, these second-order conditions do not hold in general. Furthermore, there is not guarantee that the stability conditions for industry equilibrium hold. However, we assume that these conditions are satisfied.

A foreign firm's first-order condition for profit maximization in the foreign core goods

market is given by

$$p^*(z^*)+p^{*\prime}(z^*)x_f^*-c_f+y_f^*q_{fx^*}^*=0, \quad (8)$$

The second-order condition, $2p^{*\prime}+x_f{}^*p^{*\prime\prime}<0$, and the stability condition are assumed to be satisfied.

3. Below-cost Dumping

In this section, we investigate the possibility that below-cost dumping occurs in core goods markets. First, we analyze the domestic core goods market. By rearranging equation (7), we obtain

$$p-c_i=-x_ip'-y_iq_{ix}. \quad (9)$$

The left-hand side of equation (9) represents the price-cost margin. If the sign of the right-hand side of equation (9) is negative, below-cost dumping occurs. The first term on the right-hand side, $-x_ip'$, is the mark-up on the core goods; this is expected to be positive. The second term, $-y_iq_{ix}$, is the additional accessories revenue obtained when the firm increases its core goods output; this is expected to be negative. If the absolute value of the second term is larger than that of the first term, then firm i sells its output below cost in the domestic market.

By rearranging equation (9), we obtain

$$\frac{p-c_i}{p}=\frac{\lambda_i}{\rho}-\frac{\theta_i}{\delta_i}, \quad (10)$$

In equation (10), λ_i is the share of the firm's domestic supply $\left(\frac{x_i}{z}\right)$, ρ is the elasticity of core goods demand $\left(-\frac{p}{zp'}\right)$, δ_i is the elasticity of core goods demand given an increase in the accessories price $\left(\frac{q_i}{x_iq_{ix}}\right)$, and θ_i is the ratio of firm i's total accessories revenue to its total core goods revenue $\left(\frac{q_iy_i}{px_i}\right)$. The left-hand side of equation (10) represents firm i's dumping margin for its core goods in the domestic market. Equation (10) implies that dumping occurs in the core goods market if and only if (iff) $\frac{\lambda_i}{\rho}<\frac{\theta_i}{\delta_i}$. That is, if λ_i and δ_i are sufficiently small and ρ and θ_i are sufficiently large, firm i dumps output in the core goods market. When the core goods share of the firm $i(\lambda_i)$ is small and the demand elasticity for core goods (ρ) is large, the firm's price-cost margin is low, which gives rise to the possibility of dumping. Furthermore, when the elasticity of core goods demand given an increase in the accessories price (δ_i) is small, the firm must sell a large number of core goods in order to raise the price of accessories. This is because an increase in the accessories price lowers the core goods price, which may promote dumping. When the ratio of the firm's total accessories revenue to its total core goods revenue (θ_i) is large, the firm prioritizes accessories revenue and sells a large amount of core goods in order to raise the accessories price, which also leads to dumping.

Proposition 1: *Foreign firms dump at below cost in the domestic market iff* $\frac{\lambda_f}{\rho}<\frac{\theta_f}{\delta_f}$.

If we assume that the cost and demand functions for accessories for domestic and foreign firms are symmetrical, we obtain

$$\frac{(p-c)}{p}=\frac{\left(\frac{\delta}{N\rho}-\theta\right)}{\delta}. \quad (10')$$

Dumping occurs if $\frac{\delta}{N\rho}<\theta$. In particular, dumping occurs under perfect competition $(N=\infty)$ in the core goods market. This is because the price-cost margin is zero under perfect competition; hence only the negative term for additional accessories revenue is relevant.

Proposition 2: *When domestic and foreign firms and their demand functions for accessories are symmetrical, below-cost dumping occurs under perfect competition.*

Next, we focus on the foreign core goods market. We obtain the condition for dumping by the foreign firm in its own core goods market in the same way as in the domestic core goods market.

By rearranging equation (8), we obtain

$$p^*-c_f=-x_f^*p^{*\prime}-y_f^*q_{fx^*}^*. \tag{11}$$

This equation rearranged into

$$\frac{(p^*-c_f)}{p^*}=\frac{\lambda_f^*}{\rho^*}-\frac{\theta_f^*}{\delta_f^*}. \tag{12}$$

It is only if equation (12) is negative, that is, if, $\frac{\lambda_f^*}{\rho^*}<\frac{\theta_f^*}{\delta_f^*}$, that a foreign firm dumps at below cost in the foreign core goods market. For this to occur, two conditions must be satisfied: the elasticity of foreign core goods demand, ρ^*, and the ratio of foreign firm's total accessories revenue to its total core goods revenue, θ_f^*, must sufficiently large; and the foreign core goods share of each foreign firm, λ_f^*, and the elasticity of foreign core goods demand given an increase in the accessories price, δ_f^*, must be sufficiently small.

Price-discriminating dumping is possible in the core goods market if the foreign firm's domestic price-cost margin is less than its foreign price-cost margin; that is; if $\frac{p-c_f}{p}<\frac{p^*-c_f}{p^*}$. From equations (10) and (12), we obtain

$$\frac{\lambda_f^*}{\rho^*}-\frac{\lambda_f}{\rho}>\frac{\theta_f^*}{\delta_f^*}-\frac{\theta_f}{\delta_f} \tag{13}$$

Thus, below-cost dumping in both the domestic and foreign core goods markets and price-discriminating dumping in the core goods market can occur simultaneously.

4. Dumping in both the Core Goods and Accessories Markets

We also consider the accessories market for these producers. For accessories price-discriminating dumping to occur in the domestic market, we require $q_f<q_f^*$. From equations (3) and (5), we have

$$\varepsilon_f>\varepsilon_f^*, \tag{14}$$

where $\varepsilon_i(\varepsilon_i^*)$ is the domestic (foreign) demand elasticity for the accessories of firm i. Inequality (14) implies that dumping occurs in the domestic accessories market iff the accessories demand in the home market is more elastic than is the demand in the foreign market. Thus we obtain Proposition 3.

Proposition 3: *Dumping in the accessories market is compatible with the occurrence of dumping in the core goods market iff,* $\frac{\lambda_f}{\rho}<\frac{\theta_f}{\delta_f}$, $\frac{\lambda_f^*}{\rho^*}<\frac{\theta_f^*}{\delta_f^*}$ *and* $\varepsilon_f>\varepsilon_f^*$. *Furthermore, price-discrimination dumping occurs in both the core goods and accessories markets iff inequalities (13) and (14) are satisfied.*

5. The Effects of Import Tariffs on Core Goods

We suppose that the domestic government imposes a specific tariff t on each unit of core goods imports from foreign firms. As the tariff t is assumed to be sufficiently low, foreign firms are able to supply the domestic core goods market. Thus, the foreign firm's profit function is

$$\pi_f=p(z)x_f+p^*(z^*)x_f^*-c_f(x_f+x_f^*)-tx_f \\ +q_f(x_f,y_f)y_f+q_f^*(x_f^*,y_f^*)y_f^*-C_f(y_f+y_f^*) \tag{15}$$

The first-order condition for profit maximization by the foreign firm that supplies core goods to the domestic market is given by

$$p(z)+x_fp'+y_fq_{fx}-c_f-t=0 \tag{16}$$

The Nash solution for the core goods domestic output level satisfies equations (7), which implies profit maximization under free trade by the domestic firm, and equation (16), which implies profit maximization by the foreign firm on which a tariff is imposed. The following stability condition is satisfied:

$$(n_i+1)p'+X_ip''=p'(n_i+1-\sigma_i\eta)<0 \quad i=d,f \\ p'^2(N-\eta+1)\equiv p'^2A>0 \tag{17}$$

where σ_i represents the total core goods share of firm i (that is, $\frac{X_i}{z}$) and η denotes the elasticity of the slope of the demand curve for core goods $\left(-\frac{zp''}{p'}\right)$. For simplicity, we assume that $\eta \leq 0$, which implies that demand curve for the core goods is not convex. Given that $p'<0$, $p'^2>0$, and $\eta \leq 0$, it follows that $n_i+1-\sigma_i\eta$ and $n-\eta+1=A$ are both positive.[8]

Totally differentiating (7), which relates to the domestic firm, and (16), which relates to the foreign firm, and using Cramer's law yields

$$x_{dt}=-\frac{n_f}{n_d}\left[\frac{n_d-\sigma_d\eta}{p'A}\right]>0 \tag{18}$$

and

$$x_{ft}=\frac{n_d+1-\sigma_d\eta}{p'A}<0, \tag{19}$$

where $x_{it}=\frac{dx_i}{dt}$, $p'<0$, $A>0$, and $n_i+1-\sigma_i\eta>0$. Given that $\eta \leq 0$, the term in the second bracket on the right hand side of equation (18) is negative. Thus, an increase in the tariff on foreign core goods in the domestic market raises the output of domestic core goods ($x_{dt}>0$). The sign of equation (19) is negative. This is because $n_i+1-\sigma_i\eta$ which is the numerator on the right hand side of (19), is positive and because the denominator, $p'A$, is negative.

Total domestic core goods output increases and total foreign core goods output falls as follows:

$$X_{dt}=n_dx_{dt}=\frac{n_f(n_d-\sigma_d\eta)}{p'A}>0$$

$$X_{ft}=n_fx_{ft}=\frac{n_f(n_d+1-\sigma_d\eta)}{p'A}<0. \tag{20}$$

The change in total core goods output in the domestic market is

$$z_t=X_{dt}+X_{ft}=\frac{n_f}{p'A}<0. \tag{21}$$

Thus, the price of core goods in the domestic market increases by following an increase in the tariff on foreign core goods ($p'z_t>0$).

Ironically, based on the results of this model, the domestic government's imposition of a tariff on foreign core goods induces those foreign manufacturers to reduce the prices of their accessories in the domestic market, and thereby exacerbate the accessories' price differential.

We find that $q_{dt}=q_{dx}x_{dt}>0$, $q_{ft}=q_{fx}x_{ft}<0$, and $q^*_{f*t}=0$. Thus, there is an increase in the domestic manufacturer's prices of accessories in the domestic market, and a decrease in the foreign manufacturer's accessories prices in the domestic market. The foreign manufacturer's prices of accessories in the foreign market are unaffected.

If dumping already occurs in the domestic accessories market, the foreign firm's dumping margin of the accessories expands. If the foreign firm has not been dumping in the domestic accessories market, the new lower accessories prices may constitute dumping.

Tariffs on foreign core goods in the domestic market decrease foreign core goods output. The decrease in foreign output for the domestic core goods market affects the accessories price; that is, the foreign accessories price declines in the domestic market. Thus, we have Proposition 4.

Proposition 4: *Tariffs on imports of foreign core goods*

(i) raise the core goods price in the domestic market;

(ii) may expand the dumping margin of foreign accessories.

Next, we focus on firms' profit changes. The domestic firm's profit change is

$$\frac{d\pi_d}{dt}=\left(\frac{\partial\pi_d}{\partial x_d}\right)x_{dt}+\left[\frac{\partial\pi_d}{\partial(z-x_d)}\right](z_t-x_{dt})+\left(\frac{\partial\pi_d}{\partial y_d}\right)y_{dt}+\frac{\partial\pi_d}{dt}. \tag{22}$$

From the envelope theorem, the first, third, and fourth terms on the right-hand side equal zero. Then, we obtain

$$\frac{d\pi_d}{dt}=x_dp'(z_t-x_{dt})=-\frac{x_d\left(2n_f-\frac{\sigma_d\eta}{n_d}\right)}{A}>0, \tag{22'}$$

where $\eta \leq 0$ and $A>0$. Given that the bracket term in the numerator, $2n_f - \frac{\sigma_d \eta}{n_d}$, is positive (because $\eta \leq 0$), the sign of equation (22') is positive.

The profit change of the foreign firm is

$$\frac{d\pi_f}{dt} = \frac{x_f[\eta(1+\sigma_d)-2(n_d+1)]}{A} < 0, \quad (23)$$

where $\eta \leq 0$ and $A>0$. Because the bracket term in the numerator, $\eta(1+\sigma_d)-2(n_d+1)$, is negative (because $\eta \leq 0$), the sign of equation (23) is negative. Consequently, we can state Proposition 5.

Proposition 5: *When the domestic government imposes tariffs on foreign core goods imports, the domestic firm's profit increases and the foreign firm's profit decreases.*

6. Tariff Imposition on Foreign Accessories

Suppose the domestic government imposes specific tariffs (τ) on foreign accessories. We assume that τ is small enough for foreign firms to supply to the domestic accessories market. Then, the foreign firm's profit function is given by

$$\pi_f = p(z)x_f + p^*(z^*)x_f^* - c_f(x_f + x_f^*) + q_f(x_f, y_f)y_f + q_f^*(x_f^*, y_f^*)y_f^* - C_f(y_f + y_f^*) - \tau y_f \quad (24)$$

The first-order condition for the foreign firm's profit maximization from accessories in the domestic market is given by

$$\frac{\partial \pi_f}{\partial y_f} = q_f(x_f, y_f) + y_f q_{fy} - C_f - \tau = 0. \quad (25)$$

Let $\hat{y}_f(\tau)$ be the foreign firm's optimal output of accessories given the tariff τ. By rearranging equation (25), we obtain

$$\hat{y}_f(\tau) = \frac{(q_f - C_f - \tau)}{q_{fy}}. \quad (26)$$

Given that $q_f - C_f - \tau > 0$ and $q_{fy} < 0$, $\hat{y}_f(\tau) > 0$, it follows that an increase in τ decreases the foreign firm's output of accessories in the domestic market $\left(\frac{\partial \hat{y}_f(\tau)}{\partial \tau} = \frac{1}{q_{fy}} < 0\right)$. Thus, $y_{ft} = \frac{\partial y_f}{\partial \tau} < 0$. However, the foreign firm's accessories output in the foreign market and the domestic firm's accessories output in the domestic market do not change when a tariff of τ is imposed.

Given the firm's optimum accessories output $\hat{y}_f(\tau)$, backward induction can be used to drive equation (27), which is the foreign firm's first-order condition for profit maximization of the core goods output.

$$\frac{\partial \pi_f}{\partial x_f} = p + x_f p' + \hat{y}_f(\tau) q_{fx} - c_f = 0. \quad (27)$$

By rearranging equation (27), we obtain

$$p + x_f p' = c_f - \hat{y}_f(\tau) q_{fx} > c_f - \hat{y}_f(0) q_{fx}, \quad (28)$$

where $\hat{y}_f(0)$ denotes the foreign firm's optimal accessories output in the domestic market under free trade. Equation (28) implies that the foreign firm's reaction curve for core goods lies below the free trade reaction curve.

Tariffs on imports of foreign accessories may increase domestic firm's core goods output and reduce foreign firm's core goods output in the domestic market, as indicated by the following equation:

$$x_{d\tau} = \alpha\left(\frac{n_d}{n_f}\right)\left(\frac{n_d - \sigma_d \eta}{p'A}\right) > 0, \quad (29)$$

where, given that $\alpha = \left(\frac{\partial \hat{y}(\tau)}{\partial \tau}\right) q_{fx} < 0$ as $\frac{\partial \hat{y}_f(\tau)}{\partial \tau} = \frac{1}{q_{fy}} < 0$, $q_{fx} > 0$, $\eta \leq 0$ and $p'A < 0$.

Equation (29) represents the output change of a domestic firm, and shows that an increase in the tariff on foreign accessories in the domestic market raises the output of domestic core goods.

The foreign firm's output change is

$$x_{f\tau} = -\frac{\alpha(n_d + 1 - \sigma_d \eta)}{p'A} < 0 \quad (30)$$

Given that, $\alpha < 0$, $n_d + 1 - \sigma_d \eta > 0$ and $p'A < 0$, it follows that $x_{f\tau}$ is negative. Equation (30) implies that the foreign firm's core goods output in the domestic market decreases when tariffs on

foreign accessories increase.

The total core goods output of domestic firms increases whereas foreign firms' output declines, as follows:

$$X_{d\tau}=n_d x_{d\tau}=\frac{\alpha n_d(n_d-\sigma_d\eta)}{p'A}>0$$

$$X_{f\tau}=n_f x_{f\tau}=-\frac{\alpha n_f(n_d+1-\sigma_d\eta)}{p'A}<0 \quad (31)$$

Total core goods output in the domestic market falls as the following equation shows:

$$z_\tau=X_{d\tau}+X_{f\tau}=-\frac{\alpha n_f}{p'A}<0 \quad (32)$$

where $\alpha<0$ and $p'A<0$. Thus, the price of core goods in the domestic market increases following an increase in the tariff on foreign accessories ($p'z_\tau>0$).

We consider changes in the price of accessories' price. The domestic firm's accessories' price change is shown in

$$q_{d\tau}=q_{dx}x_{d\tau}>0, \quad (33)$$

where $q_{dx}>0$, and $x_{d\tau}>0$ from equation (29).

However, we cannot say anything yet about the foreign accessories price, which is given by

$$q_{f\tau}=q_{fx}x_{f\tau}+q_{fy}y_{f\tau}, \quad (34)$$

where $q_{fx}>0$, $x_{f\tau}<0$, $q_{fy}<0$, and $y_{f\tau}<0$. The first term on the right hand side of equation (34) shows that the price of the foreign firm's accessories decreases as the foreign firm's output of core goods decreases, thus, this term is negative. Conversely, the second term on the right hand side indicates that as the price of the foreign firm's accessories increases, the quantity of accessories decreases; thus, this term is positive. If the absolute value of the first term exceeds that of the second term, then $q_{f\tau}<0$.

Equation (34) can be written as

$$q_{f\tau}=q^f\left(\frac{x_{f\tau}}{\delta_f x_f}-\frac{y_{f\tau}}{\varepsilon_f y_f}\right). \quad (34')$$

From equation (34'), the condition under which the foreign firm lowers the price of domestic accessories in the domestic market, $\frac{(x_{f\tau}/x_f)}{(y_{f\tau}/y_f)}<\frac{\delta_f}{\varepsilon_f}$ is. The left-hand side of this inequality is the ratio of the rate of change in the foreign firm's core goods output following an increase in the tariff on foreign accessories $\left(\frac{x_{f\tau}}{x_f}\right)$ to the rate of change in the foreign firm's accessory output following an increase in the tariff on foreign accessories $\left(\frac{y_{f\tau}}{y_f}\right)$. The right-hand side of the inequality is the elasticity of core goods demand given an increase in the accessories price (δ_f) relative to the accessories demand elasticity (ε_f) of the foreign firm. Thus, the foreign firm lowers its domestic accessories price if its rate of reduction in accessories production is high, the demand elasticity of foreign accessories is small, core goods production diminishes slightly, and the accessories price falls dramatically because of the decline in core goods production.

Hence, we can state Proposition 6.

Proposition 6: *Tariffs on foreign accessories*
(i) raise the domestic core goods price;
(ii) lower the foreign accessories price iff $\frac{(x_{f\tau}/x_f)}{(y_{f\tau}/y_f)}<\frac{\delta_f}{\varepsilon_f}$.

Because the equilibrium price of accessories in the foreign market does not change following an increase in τ, it follows that if $\frac{(x_{f\tau}/x_f)}{(y_{f\tau}/y_f)}<\frac{\delta_f}{\varepsilon_f}$, foreign firms raise their dumping margins.

Next, we focus on firms' profit changes. A domestic firm's profit change is

$$\frac{d\pi_d}{d\tau}=x_d p'(X_\tau-x_{d\tau})=-\alpha\left(2n_f-\frac{\sigma_d\eta}{n_d}\right)/A>0, \quad (35)$$

where, $\alpha<0$, $\eta\leq 0$, and $A>0$. An increase in the tariff on foreign accessories increases the domestic firm's profit because $2n_f-\frac{\sigma_d\eta}{n_d}>0$.

The profit change for the foreign firm is

$$\frac{d\pi_f}{d\tau}=x_f p'(X_\tau-x_{f\tau})-y_f=-\frac{\alpha x_f(n_f-n_d-1+\sigma_d\eta)}{A}-y_f, \quad (36)$$

where, $\alpha<0$, $\eta\leq 0$, and $A>0$. Notice that $n_d+1-\sigma_d\eta>0$ from the condition (17). If $n_f\leq n_d+1-\sigma_d\eta$, the foreign firm's profit declines. This

occurs if there are no more foreign firms than domestic firms.

Thus we obtain Proposition 7.

Proposition 7: *Tariffs on foreign accessories:*
(i) increase the domestic firm's profit;
(ii) reduce the foreign firm's profit if $n_f \leq n_d + 1 - \sigma_d \eta$.

If the domestic core goods market is a competitive duopoly, when the domestic government imposes a tariff on foreign accessories, domestic firms' profit increase whereas foreign firms' profits fall.

7. Concluding Remarks

We summarize the results of this research. When firms supply products, for which non-proprietary accessories are not available, domestic and foreign markets are segmented, and there is Cournot competition in the core goods market, we expect the following, according to our model. First, below cost dumping may occur in the core goods markets and price discrimination dumping may occur in the accessories market. Second the firm may also dump in both the core goods market and the accessories market. Third, tariff imposition on both core goods and accessories, which causes a core goods price increase, may increase the dumping margin in the related accessories market. Fourth, tariffs on both core goods and accessories raise the profits of domestic producers and lower the profits of foreign producers.

We did not analyze the effects of tariffs on domestic welfare. Moreover, we do not examine the strategic behavior of firms considering antidumping. These problems await further research.

Notes

1 Copying machine and ink or toner cartridges and hardware and software for computer games, are examples. If one uses a particular brand of copying machine or a computer game of a certain brand, one must use the same brand of ink cartridge or game software, respectively. Cartridges and software are incompatible in the sense that a cartridge or a piece of software produced by a different manufacturer cannot be used on the already purchased core good or hardware. Copying machines and ink cartridges, and computer hardware and software are perfect complements because one cannot use a copying machine or hardware without the correct ink cartridge or the right software.

2 Pigou (1920) was the first to model price discrimination by a monopolist.
Yntema (1928) first analyzed price-discriminating dumping in a model of international trade. The standard textbook treatment of price-discriminating dumping was perfected by von Haberler (1968).

3 Examples in the first group of papers, includes those by Ethier (1982) and Davies and McGuinness (1982).

4 For illustration, see Gruenspecht (1988), Anderson (1992), and Tivig and Walz (2000).

5 What have been studied in the context of related products are theories of two-part tariffs and tie-in sales. For example, Oi (1971) investigates Disneyland pricing, which involves the construction of two-part tariffs by a monopolist. If consumers have different utility functions, firm sets the price of rides below its cost. On the other hand, Shy (2001) analyzes a duopoly analysis that sells core goods and incompatible software, and finds that each firm's bundled price is lower than the bundled price when firms sell compatible software. However, the model of Oi (1971) cannot be applied to the dumping of core goods and accessories in international trade. Shy (2001) did not explain the price of core goods and accessories separately. Thus, these models are inappropriate for analyzing the dumping of core goods and proprietary accessories.

6 Dixit (1988) also analyzed the effects of the

government of an importing country imposing anti-dumping tariffs. However his model differs from ours and he does not investigate whether tariffs raise dumping margin.

7 We use an inverse demand function for core goods in our model. However, a demand function under consideration can also be considered as a function of the prices of core goods and accessories. For example, consider the two-firm linear demand case. Let the demand function for the core goods of the domestic firm be $x=x(p, p^*, q, q^*)=a+bp+cp^*+dq+eq^*$; let the demand function for the core goods of the foreign firm be $x^*=x^*(p, p^*, q, q^*)=a^*+b^*p^*+c^*p+d^*q^*+e^*q$,;let the demand function for the accessories of the domestic firm be $y=\alpha+\beta q$, and the demand function of the accessories facing foreign firm $y^*=\alpha^*+\beta^*q^*$. Deriving the inverse demand functions, and letting a >0, a$^*>0$, b<0, b$^*<0$, c>0, c$^*>0$, $\alpha>0$, $\alpha^*>0$, $\beta<0$, $\beta^*<0$ and bb$^*>$cc*, we obtain $p=p(x, x^*)$, $p^*=p^*(x, x^*)$, $q=q(x, x^*y)$ and $q^*=q(x, x^*y^*)$. Then, the inverse demand functions for the core goods are functions of the quantity of core goods only. Because we assume that the core goods are homogeneous and that accessories are incompatible between firms, the demand functions in our model assume these forms.

8 See Ishikawa and Spencer (1999).

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