Cross-border interdependence of vertically related industries and welfare implications

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Abstract

We examine the effects of the cross-border interdependence of vertically related industries on trade policies and welfare of related countries. With the rapid trends of globalization of value-adding chains of multinational firms, fragmentation of the production process is a widespread phenomenon of corporate strategies. This paper demonstrates that as the cross-border interdependency of vertically related industries is deepened, protective trade policies are replaced by pro-trade policies based on an oligopoly model where each representative firm competes over vertically interdependent products. In addition, when the market power of the upstream firm is higher, the tariffs imposed on the intermediate goods are lowered. Although welfare implications of cross-border interdependence of vertically related industries are affected by the relative technology structures of the upstream firms and the downstream firm of competing economies, a firm with technological advantage benefits more from the deepened cross-border interdependence with increased competition due to the higher homogeneity of the final products.

Introduction

Recent feature of global production networks is characterized with the enhanced fragmentation of value-adding chains of corporate production process. Moreover, the high value-added sectors of industries have larger stages of vertical production process, which deepen the trends of fragmentation. The rapid progress of information and communication technologies has reduced the cross-border transaction costs sharply, and the global offshoring strategies became a dominant strategy to procure intermediate goods.
Based on these increasing trends of fragmentation and cross-border outsourcing of the intermediate goods, this paper examines the effects of the cross-border interdependence of vertically related industries on trade policies and welfare of related countries. We focus on a case where representative firms of two countries with asymmetric technologies are competing over differentiated final products while downstream firms are dependent on upstream firms in different levels of cross-border interdependency in vertically related production processes. This paper demonstrates that as the cross-border interdependency of vertically related industries is deepened, protective trade policies are replaced by the pro-trade policies. In addition, when the market power of the upstream firm is higher, the tariffs imposed on the intermediate goods are lowered. Although welfare implications of cross-border interdependence of the vertically related industries are affected by the relative technology structures of the upstream firms and the downstream firm of competing economies, a firm with technological advantage benefits more from the deepened cross-border interdependence with increased competition due to the higher homogeneity of the final products.

A numerous literatures studied the vertically integrated industrial structures, and seminal papers about the vertical production processes include the follows: Markusen (1990) examines the query of tariff protection in a model of differentiated final goods. While the conclusion of the normative analysis is that a small tariff must be welfare improving, he shows that a small tariff can reduce welfare when specialized inputs are sufficiently complementary. Spencer and Jones (1991) examine a model with a low-cost vertically integrated firm exported the intermediate goods to rival firm of the final goods. The main findings are that first, the vertical supply decision is affected by the importing country’s supply condition for the intermediate goods and the tariff on the final goods exported by exporting country. Secondly when there is Cournot competition for the homogeneous final goods, policy by the exporting country tends to support the private incentives. If the difference in profit margins is positive, optimal policy tends to increase the extent of vertical supply. While if the difference in profit margins is negative, optimal policy tends to shift supply decision from vertical supply to vertical foreclosure. Ishikawa and Lee (1997) analyze the effects on the domestic economy of domestic tariffs imposed on the intermediate goods or the final goods in vertically related markets. They show that tariffs on the intermediate goods induced the entry damage domestic intermediate goods firm and/or benefit domestic final goods firm, first. Secondly, tariff on the final goods induced the exit damage both domestic intermediate goods and final goods firms. Horiuchi and Ishikawa (2009) examine the relationship between tariffs on a final goods and technology transfer in vertically related markets. They show that not only tariff increases but also tariff reductions may lead to technology transfer. Increase of tariff on the final goods induces ‘tariff-jumping’ technology transfer, whereas ‘entry-deterring’ technology transfer is generated by tariff reductions.

The major contribution of this paper lies in that we demonstrated the impacts of different level of cross-border interdependency in vertically related industries taking consideration of technology asymmetries of the upstream industries and downstream industries while the earlier literatures did not consider the technology structure of the vertical production processes in explicit ways. Based on our detailed analysis of the vertical production processes with technology asymmetries, we could determine the condition for welfare improvement with the cross-border interdependency of vertical production processes.

The rest of the paper is organized as follows. Section 2 describes the basic structure of the model. Section 3 examines the effects of tariffs in the interdependence of nations of the intermediate goods. Section 4 we analyze economic welfare under the interdependence of nations of the intermediate goods. Section 5 provides the conclusion and some final remarks.

The model

We assume that there are two countries, a domestic and a foreign country, and that each country has a single imperfectly competitive firm that produces a differentiated good, with the home firm in a home country and the foreign firm in a foreign country. Typical domestic and foreign final-good producers are referred to as firm $D_d$ and $F_d$, respectively, and typical domestic and foreign intermediate-good producers as firm $D_u$ and $F_u$, respectively. In the upstream stage, homogeneous intermediate goods are produced under unilateral trade in the intermediate goods, while differentiated intermediate goods are produced under bilateral trade. In the downstream stage, differentiated final goods are produced by each country. We focus on the intermediate goods and final goods markets which are both
characterized by Cournot oligopolies. There exist one final-good firm and intermediate-good firm in each country. The domestic and foreign governments impose a specific tariff both on the intermediate goods and the final goods.

A representative consumer in the home country and in the foreign country, respectively, is assumed to have quasi-linear preferences that can be represented by a quadratic utility function

\[ U_D(q_{DD}, q_{FD}, z) = aq_{DD} + aq_{FD} - \frac{(q_{DD}^2 + q_{FD}^2)}{2} - bq_{DD}q_{FD} + z \]  

(1)

\[ U_F(q_{DF}, q_{FF}, z) = aq_{DF} + aq_{FF} - \frac{(q_{DF}^2 + q_{FF}^2)}{2} - bq_{DF}q_{FF} + z \]  

(2)

where \( a > 0, 0 < b < 1 \). The market structure ranges from the case where the goods are independent \( (b = 0) \) to the homogeneous good case \( (b = 1) \).

The utility functions (1) and (2) give rise to a linear demand structure. Inverse demand functions are given by

\[ p_{DD} = a - bq_{FD} - q_{DD} \]  

(3)

\[ p_{FD} = a - bq_{DD} - q_{FD} \]  

(4)

\[ p_{DF} = a - bq_{FF} - q_{DF} \]  

(5)

\[ p_{FF} = a - bq_{DF} - q_{FF} \]  

(6)

There are three stages of decision. In stage 1, the domestic government and foreign government decide their optimal tariffs of the intermediate goods and the final goods. In stage 2, taking the optimal tariffs of the intermediate goods and final goods as given, the domestic and foreign intermediate-good producers decide the levels of price of the intermediate goods. In stage 3, taking the price of the intermediate goods as given, the domestic and foreign final-good producers decide the levels of output of the final goods.

The effects of tariffs in the interdependence of nations

In this section, we examine the effects of tariffs in the interdependence of nations on the intermediate goods which produced by each country. We first analyze the case of no trade in the intermediate goods and then examine the case with it.

3.1. No trade in the intermediate goods

We consider the case where a single vertically-integrated firm exists in each country. In order to obtain a sub-game perfect Nash equilibrium, we solve the game by backwards induction. The profit functions for firms \( D_l \) and \( F_l \) are

\[ \text{Max} \Pi_{D_l}(q_{DD}, q_{DF}) = (p_{DD} - c_u - c_d)q_{DD} + (p_{DF} - c_u - c_d - t_1)q_{DF} \]  

(7)

\[ \text{Max} \Pi_{F_l}(q_{DF}, q_{FF}) = (p_{FD} - \beta c_u - \alpha c_d - t_2)q_{FD} + (p_{FF} - \beta c_u - \alpha c_d)q_{FF} \]  

(8)

In the second stage, solving these first-order conditions simultaneously, we can obtain the profit maximizing outputs as functions of \( t_1 \) and \( t_2 \) by each firm:

\[ q_{DD}(t_2) = \frac{a(b - 2) - (\alpha b - 2)c_d - (\beta b - 2)c_u - bt_2}{b^2 - 4} \]  

(9)

\[ q_{DF}(t_1) = \frac{a(b - 2) - (\alpha b - 2)c_d - (\beta b - 2)c_u + 2t_1}{b^2 - 4} \]  

(10)
\[ q_{FD}(t_2) = \frac{a(b-2)-(b-2\alpha)c_d-(b-2\beta)c_u + 2t_2}{b^2 - 4} \]  
(11)

\[ q_{FF}(t_1) = \frac{a(b-2)-(b-2\alpha)c_d-(b-2\beta)c_u - bt_1}{b^2 - 4} \]  
(12).

In the first stage, given the equilibrium outputs and prices, we can obtain the optimal tariffs on the final goods in each country:

\[ t_1 = \frac{1}{3}(a - c_d - c_u) \]  
(13)

\[ t_2 = \frac{1}{3}(a - \alpha c_d - \beta c_u) \]  
(14).

In case of no trade in the intermediate goods, the optimal tariffs on the final goods are affected by the change of constant marginal cost both in the intermediate goods and in the final goods regardless of product differentiation. The market share of final goods depends on the constant marginal cost both in the intermediate goods and in the final goods from rival country. Thus if the marginal costs of the intermediate goods and the final goods in domestic country decrease, the foreign government imposes the higher tariff on the final goods which exported by domestic country; and that if the marginal costs of the intermediate goods and final goods in domestic country increase, the foreign government imposes the lower tariff on the final goods which exported by domestic country.

The above analysis is summarized in the following proposition.

**Proposition 1.** If the marginal costs of the intermediate goods and the final goods in domestic (foreign) country decrease, the foreign (domestic) government imposes the higher tariffs on the final goods imported from the foreign (domestic) country. The full vertical integration of the upstream and downstream firms in each country, with no cross-border interdependency in intermediate goods, induces each country to take more protective trade policies when she faces more competitive rivals with lower production costs.

### 3.2. Unilateral trade vs Bilateral trade in the intermediate goods

In this section, we consider the case where unilateral trade in the intermediate goods and bilateral trade in the intermediate goods. In order to obtain a sub-game perfect Nash equilibrium, we solve the game by backwards induction. The profit functions for firms \( D_d \) and \( F_d \) are

\[
\text{Max}\Pi_{D_d}(q_{DD}, q_{DF}) = (p_{DD} - w_{D_d} - c_d)q_{DD} + (p_{DF} - w_{D_d} - c_d - t_1)q_{DF}
\]  
(15)

\[
\text{Max}\Pi_{F_d}(q_{FD}, q_{FF}) = (p_{FD} - w_{D_d} - \alpha c_d - t_2)q_{FD} + (p_{FF} - w_{D_d} - \alpha c_d)q_{FF}
\]  
(16)

In the third stage, the firms \( D_d \) and \( F_d \) take the price of the intermediate goods as given and choose outputs to maximize their profits. The profit maximizing outputs of the firms \( D_d \) and \( F_d \) are given by

\[ q_{DD}(w_{D_d}, w_{D_d}, t_2) = \frac{(b-2)a - (b\alpha - 2)c_d - bt_2 + 2w_{D_d} - bw_{D_d}}{b^2 - 4} \]  
(17)

\[ q_{DF}(w_{D_d}, w_{D_d}, t_1) = \frac{(b-2)a - (b\alpha - 2)c_d + 2t_1 + 2w_{D_d} - bw_{D_d}}{b^2 - 4} \]  
(18)

\[ q_{FD}(w_{D_d}, w_{D_d}, t_2) = \frac{(b-2)a - (b - 2\alpha)c_d + 2t_2 - bw_{D_d} + 2w_{D_d}}{b^2 - 4} \]  
(19)
In the second stage, the firms $D_u$ and $F_u$ take the demand as given by Eq. (17)-(20) and choose the price of the intermediate goods $w_{D_1}$ and $w_{D_2}$ to maximize their profits. 

$$\text{Max} \Pi_{D_u}(w_{D_1}, w_{D_2}) = (w_{D_1} - c_d)(q_{DD} + q_{DF}) + (w_{D_2} - c_u - t_3)(q_{FD} + q_{FF})$$

The profit maximizing the price of the intermediate goods of the firms $D_u$ and $F_u$ are given by

$$w_{D_1}(t_1) = \frac{1}{4}(2a - 2c_d + 2c_u - t_1)$$

$$w_{D_2}(t_2, t_3) = \frac{1}{4}(2a - 2\alpha c_d + 2c_u - t_2 + 2t_3)$$

In the first stage, given the equilibrium outputs and prices, we can obtain the optimal tariffs on the final goods and the intermediate goods in each country:

$$t_1 = \frac{2(c_d(7120 - (448b\alpha + 5008b^2 + 416b^3 + 171b^4 - 164b^5 - 1443b^6 - 1443b^7 + 117b^8)) + (a - c_d)(1208b + 1432b^2 - 293b^3 + 56b^4 - 1872a) - (a - c_d)(1208b + 1432b^2 - 293b^3 + 56b^4 - 1872a)}{37520b^2 - 70976b^2 + 2856b^2 - 55536}$$

$$t_2 = \frac{4(c_d(1208b + 1432b^2 - 293b^3 + 56b^4 - 1872a) - (a - c_d)(1208b + 1432b^2 - 293b^3 + 56b^4 - 1872a))}{37520b^2 - 70976b^2 + 2856b^2 - 55536}$$

$$t_3 = \frac{c_d(16848\alpha - 7312b + 14048b^2\alpha - 6244b + 2855b^2\alpha + 1176b^3 + 55b^4) + (a - c_d)(7312b + 14048b^2 - 6244b^3 - 2855b^4 + 1176b^5 + 55b^6 - 1648)}{37520b^2 - 70976b^2 + 2856b^2 - 55536}$$

Next we examine the case where bilateral trade in the intermediate goods and compare to the case where unilateral trade in the intermediate goods. In order to obtain a sub-game perfect Nash equilibrium, we solve the game by backwards induction. The profit functions for firms $D_d$ and $F_d$ are

$$\text{Max} \Pi_{D_d}(q_{DD}, q_{DF}) = (p_{DD} - w_F - c_d)q_{DD} + (p_{DF} - w_F - c_u - t_1)q_{DF}$$

$$\text{Max} \Pi_{F_d}(q_{FD}, q_{FF}) = (p_{FD} - w_D - \alpha c_d - t_2)q_{FD} + (p_{FF} - w_D - \alpha c_d)q_{FF}$$

In the third stage, the firms $D_d$ and $F_d$ take the price of the intermediate goods as given and choose outputs to maximize their profits. The profit maximizing outputs of the firms $D_d$ and $F_d$ are given by

$$q_{DD}(w_D, w_F, t_2) = \frac{(b - 2)a - (b - 2\alpha)c_d - bt_2 - bw_D + 2w_F}{b^2 - 4}$$

$$q_{DF}(w_D, w_F, t_1) = \frac{(b - 2)a - (b - 2\alpha)c_d + 2t_1 - bw_D + 2w_F}{b^2 - 4}$$

$$q_{FD}(w_D, w_F, t_2) = \frac{(b - 2)a - (b - 2\alpha)c_d + 2t_2 + 2w_D - bw_F}{b^2 - 4}$$

$$q_{FF}(w_D, w_F, t_1) = \frac{(b - 2)a - (b - 2\alpha)c_d - bt_1 + 2w_D - bw_F}{b^2 - 4}$$
In the second stage, the firms $D_u$ and $F_u$ take the demand as given by Eq. (18)-(21) and choose the price of the intermediate goods $w_{D_1}$ and $w_{D_2}$ to maximize their profits.

$$\text{Max} \Pi_{D_u}(w_D) = (w_D - c_u - t_3)(q_{FD} + q_{FF})$$

$$\text{Max} \Pi_{F_u}(w_F) = (w_F - \beta c_u - t_4)(q_{DD} + q_{DF})$$

The profit maximizing the price of the intermediate goods of the firms $D_u$ and $F_u$ are given by

$$w_D = \frac{2(a(b - 2)(b + 4) + 4t_2 - 8t_3) - 2(2b + \alpha(b^2 - 8))c_d - 4(4 + b\beta)c_u - b(2t_1 + bt_2 + 4t_4)}{2(b^2 - 16)}$$

$$w_F = \frac{2a(b - 2)(b + 4) - 2(b^2 + 2b\alpha - 8)c_d - 4(b^2 + 4\beta)c_u - (b^2 - 8)t_1 - 2bt_2 - 4bt_3 - 16t_4}{2(b^2 - 16)}$$

In the first stage, given the equilibrium outputs and prices, we can obtain the optimal tariffs on the final goods and the intermediate goods in each country:

$$2(-a(-2+b)^2)(-12+b(3+b)(-2+3b))(-712-128b+378b^2+56b^3+b^4(-10+b)(5+b))$$

$$+c_u(34176-10944b\alpha - 49696b^2 + 16928b^3 + 25240b^4 - 8532b^5 + 5674b^6 + 1778b^7 + 568b^8 + b^9\alpha(-20b + 3(-49+b^3)))$$

$$t_1 = c_u(34176\beta - 10944b - 49696b^2 + 16928b^3 + 25240b^4 - 8532b^5 - 5674b^6 + 1778b^7 + 568b^8 + b^9\beta(-147 + 3b^2 - 20b\beta))$$

$$506944 - 554656b^2 + 228420b^3 - 43640b^4 + 3816b^5 - 125b^{10} + b^{12}$$

$$2(-a(-2+b)^2)(-12+b(3+b)(-2+3b))(-712-128b+378b^2+56b^3+b^4(-10+b)(5+b))$$

$$+c_u(34176\alpha - 10944b - 49696b^2 + 16928b^3 + 25240b^4 - 8532b^5 - 5674b^6 + 1778b^7 + 568b^8 + b^9\alpha(-147 + 3b^2 - 20b\alpha))$$

$$t_2 = c_u(34176\beta - 10944b - 49696b^2 + 16928b^3 + 25240b^4 - 8532b^5 - 5674b^6 + 1778b^7 + 568b^8 + b^9\beta(-20b + 3\beta(-49+b^3)))$$

$$506944 - 554656b^2 + 228420b^3 - 43640b^4 + 3816b^5 - 125b^{10} + b^{12}$$

$$a(-712-128b+378b^2+56b^3+b^4(-10+b)(5+b))(-432+64b + 34b^2 - 76b^3 - 56b^4 + b^5(9+b))$$

$$-c_u(307584 + 9728b - 419264b\alpha + b^9(9568 - 9520b^2 + 2262b^4 - 190b^6 + 4b^8 + b(206328 - 45440b^4 + 4410b^6 - 151b^8 + b^9)))$$

$$t_3 = c_u(307584 + 9728b - 419264b^2 + 9568b^3 + 206328b^4 - 9520b^5 - 45440b^6 + 2262b^7 + 4410b^8 - 190b^9 + b^9\beta(-151 + b^7 + 4b\beta))$$

$$2(506944 - 554656b^2 + 228420b^3 - 43640b^4 + 3816b^5 - 125b^{10} + b^{12})$$

$$a(-712-128b+378b^2+56b^3+b^4(-10+b)(5+b))(-432+64b + 34b^2 - 76b^3 - 56b^4 + b^5(9+b))$$

$$-c_u(307584 + 9728b - 419264b^2 + 9568b^3 + 206328b^4 - 9520b^5 - 45440b^6 + 2262b^7 + 4410b^8 - 190b^9 + b^9\alpha(-151 + b^7 + 4b\alpha))$$

$$t_4 = c_u(307584 + 9728b - 419264b^2 + b^9(9568 - 9520b^2 + 2262b^4 - 190b^6 + 4b^8 + b(206328 - 45440b^4 + 4410b^6 - 151b^8 + b^9)))$$

$$2(506944 - 554656b^2 + 228420b^3 - 43640b^4 + 3816b^5 - 125b^{10} + b^{12})$$
The difference in the impact of a tariff in the interdependence of nations depends on: (i) the degree of product differentiation between final goods; (ii) the difference of constant marginal costs of production at both the final and the intermediate goods.

The above analysis is summarized in the following proposition.
Proposition 2. The optimal tariff level on the final goods produced by domestic firm under unilateral trade in the intermediate goods is higher than bilateral trade in the intermediate goods. Also the optimal tariff level on the final goods produced by foreign firm under unilateral trade in the intermediate goods is higher than bilateral trade. As the cross-border interdependence of vertical production process deepens, trade barriers between interdependent countries are reduced to more pro-trade regimes with all different patterns of technology asymmetries.

The equilibrium trade policies on the intermediate goods are characterized as follows:

Proposition 3. The optimal tariff level on the intermediate goods produced by domestic firm under bilateral trade in the intermediate goods is higher than unilateral trade in the intermediate goods. That is, when the foreign country is more dependent on the intermediate goods produced by the domestic country with unilateral trade in intermediate goods, the optimal tariffs of the foreign country are lower than the case of the bilateral trade in intermediate goods mainly due to increased importance of consumer surplus in welfare consideration.

Figure 1 summarizes the features of the optimal tariffs on the intermediate goods and final goods under unilateral trade and bilateral trade in the intermediate goods with varying ranges of production differentiation and technology asymmetries in the upstream and downstream industries discussed in Proposition 2 and 3.

Welfare Analysis

In this section, we examine the welfare implications of different level of cross-border interdependence of vertical production processes in the domestic and foreign countries, considering the consumer surplus, producer surplus, and tariff revenues in each case.

The consumer surpluses in the domestic and the foreign country, respectively, are

\[ CS_D = U_D - p_{DD}q_{DD} - p_{FD}q_{FD} - z = \frac{1}{2}q_{DD}^2 + \frac{1}{2}q_{FD}^2 + bq_{DD}q_{FD} \]

\[ CS_F = U_F - p_{DF}q_{DF} - p_{FF}q_{FF} - z = \frac{1}{2}q_{DF}^2 + \frac{1}{2}q_{FF}^2 + bq_{DF}q_{FF} \].

The welfare of the domestic and the foreign country, respectively, under multilateral free trade is given by the sum of consumer surplus from its domestic market and the profit of its own firm and tariff revenue:

\[ W_D = CS_D + PS_D + GS_D \]

\[ W_F = CS_F + PS_F + GS_F \].
Fig. 2. The effects of welfare in the interdependence of nations.
The major findings of welfare implication of different level of cross-border interdependency in vertical production processes are summarized in the proposition 4 focusing on the case where the domestic upstream firm has the technology advantage over the foreign upstream firm.

**Proposition 4.** In case of $c_u < \beta c_u$, if $c_d > \alpha c_d$, the welfare of the domestic country, which has a higher technology in the upstream firm, is highest when $b$ gets closer to 1, implying that a firm with technological advantage benefits more from the deepened cross-border interdependence with increased competition due to the higher homogeneity of the final products.

The welfare implication cross-border interdependence of the vertical production process for a country with technology disadvantage is summarized in Proposition 5.

**Proposition 5.** In case $c_u > \beta c_u$, if $c_d > \alpha c_d$, the domestic country’s social welfare is highest with the case of full vertical integration in each country resulting in no trade in intermediate goods, implicating that the enhanced cross-border interdependency does not guarantee the welfare improvement when a country suffers technology disadvantage.

**Concluding remarks**

This paper examined the effects of the cross-border interdependence of vertically related industries on trade policies and welfare of related countries. Based on a model assuming representative firms of two countries where downstream firms are dependent on upstream firms, we demonstrate that as the cross-border interdependency of vertically related industries is deepened, protective trade policies are replaced by the pro-trade policies. In addition, when the market power of the upstream firm is higher, the tariffs imposed on the intermediate goods are lowered. Although welfare implications of cross-border interdependence of the vertically related industries are affected by the relative technology structures of the upstream firms and the downstream firm of competing economies, a firm with technological advantage benefits more from the deepened cross-border interdependence with increased competition due to the higher homogeneity of the final products. In addition, the enhanced cross-border interdependency of vertical production process does not guarantee the welfare gains when a country shows technology disadvantages.

Although this paper contributed to existing literatures by demonstrating the impacts of different level of cross-border interdependency in vertically related industries taking consideration of technology asymmetries of the upstream industries and downstream industries, the following works should be complemented for more general insights: the general functional approach in terms of preference system and production technologies should introduced for a more general policy implications in the future studies.

**Reference**


