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# Who Really Benefits From Quality-Improving Innovation?

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ABSTRACT

The results of an extension of an investigation by Ohyama (1998) and Shirai (2010), the effect of quality-improving innovation on international trade in the imperfect competition market, will be presented in this paper. Using the two-country two-good model, Shirai previously demonstrated the effect of cost-cutting innovation on international trade. In this study, the author found that cost-cutting innovation has a possibility of decreasing the welfare of the home country where the innovation has occurred. This possibility increases when the degree of monopoly at the export industry in the home country is high, the elasticity of the world demand to exporting goods is low and the ratio of exports in the home country is high. On the other hand, quality-improving innovation has a possibility of decreasing the welfare of the foreign country that imports innovated

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goods. This possibility will likely increase if the home country values quality-increasing innovation more than the foreign country and the degree of monopoly at the export industry in the home country is high.

Keywords : quality-improving innovation; cost-cutting innovation.
JEL Classification Numbers : D20; F10; F12; F19; O33.

# 1. Introduction

Recently, we have recognized that many industries are dealing with technological competition and are making efforts to achieve quality-improving as well as cost-cutting innovation. This recognition and publicity has led to a number of studies investigating the effect of innovation on international trade. In particular, Ohyama (1998) compares the welfare effect of cost-cutting innovation and quality-improving innovation under the perfect competition market. He shows that cost-cutting innovation can decrease the welfare of the country where the innovation occurred[2], and, on the other hand, quality-improving innovation can decrease the welfare of the country that imports innovative goods[3]. Shirai (2010) analyzes the effect of cost-cutting innovation on international trade under the imperfect competition market. He found that both cost-cutting innovation and the degree of the monopoly can affect international trade. Cost-cutting innovation can decrease the welfare of the country where the innovation occurred, depending on the degree of monopoly.

The purpose of this study was to examine the effect of quality-improving innovation on international trade under the imperfect competition market. This study extends the two-country two-good model, demonstrated in Ohyama (1998) and Shirai (2010). The model in Ohyama (1998) assumes a perfect competitive market in which firms maximize

2) Bhagwati (1958a, b) named this phenomenon as "immiserizing growth".
3) Ohyama (1998) named this phenomenon as "inverse immiserizing growth" counterpointed with "immiserizing growth".

profits, which are driven to the zero level in equilibrium. In this study, the exported industry in the home country is under the imperfect competition market. Considering a lot of export industries are under the imperfect competition in the real world (e. g. Semiconductor, Automobile and so on), this assumption makes it possible to compare the welfare effect of quality-improving innovation in a more realistic situation than Ohyama (1998). In addition, the quality function, not taken into account in Shirai (2010), is added into the model. These additions make it possible to compare the welfare effect of cost-cutting innovation and quality-improving innovation under the imperfect competition model by extending the model of Ohyama (1998) and Shirai (2010). As reported by Shirai (2010), cost-cutting innovation has a possibility of decreasing the welfare of the home country where innovation has occurred. This possibility will increase if the degree of monopoly at the export industry in the home country is high, the elasticity of the world demand to export goods is low and the ratio of exports in the home country is high. On the other hand, quality-improving innovation has a possibility of decreasing the welfare of the foreign country that imports innovated goods. This possibility will increase if the home country values quality-increasing innovation more than the foreign country and the degree of monopoly at the export industry in the home country is high.

The rest of this paper is organized as follows. Section 2 introduces the basic model and explains quality-improving innovation. In Section 3, the author analyzes the welfare effect of quality-improving innovation on international trade.

## 2. The Model

This section demonstrates the basic structure of the two-country two-good model extending the model demonstrated in Ohyama (1989) and Shirai (2010). To envision the extended model the reader must think of the two-country two-good model, which is freely tradable between countries, assume that the price of goods is equal internationally under free trade and the production factor is not transferred internationally. The home country produces good X and good Y, on the other hand, the foreign country is completely specialized in the production of good Y. The home country exports good X abroad and imports good Y from the foreign country. Good X is produced under the imperfect competition market in the home country. Good Y is under the perfect competition market in the home country and the foreign country. Labor is the only factor endowment, and the full employment condition is satisfied. Only the quality of good X is considered.

Denote the quasi-linear utility function in the home country as

$$u = y + v(x, q),\ v_1 > 0,\ v_2 > 0,\ v_{11} < 0,\ v_{22} < 0,\ v_{12} > 0 \tag{1}$$

where $x$ is the consumption of good X, $y$ is the consumption of good Y and $q$ is quality of good X. $v_1$, $v_2$ mean the partial differential of $v(\cdot)$ regarding $x$, $q$. $v_{11}$, $v_{12}$ mean the partial differential of $v_1(\cdot)$ regarding $x$, $q$. Similarly, the quasi-linear utility function in the foreign country is written as

$$u^* = y^* + v^*(x^*, q),\ v_1^* > 0,\ v_2^* > 0,\ v_{11}^* < 0,\ v_{22}^* < 0,\ v_{12}^* > 0 \tag{2}$$

All the variables of the foreign country were put *(asterisk) in order to

distinguish from the home country.

Assuming the extra profit is allocated to consumers, the budget constraint of the home country and the foreign country is written as

$$px + y = w\bar{L} + \pi^e \tag{3}$$

$$px^* + y^* = w^*\bar{L}^* \tag{4}$$

$p$ is the price ratio between good X and good Y. $w$ is the wage ratio of producing good X and good Y. In other words, good Y is assumed as numeraire. Let $\bar{L}$ be the labor endowment and $\pi^e$ be the extra profit. The extra profit is assumed to be allocated to consumers in the home country.

As a result of solving the utility maximization problem subject to the budget constraint, we obtain

$$v_1(x, q) = p \tag{5}$$

$$v_1^*(x^*, q) = p \tag{6}$$

Therefore, the demand function is written as

$$x = x(p, q) \tag{7}$$

$$x^* = x^*(p, q) \tag{8}$$

As the imperfect competition market, assume firms of good X in the home country behave in Cournot-Nash fashion. Hence, the profit function of good X in the home country can be written as

$$\pi_{x_i} = p(X_i + X_{-i})X_i - wa_{LX}X_i \tag{9}$$

$X_i$ is the output of the firm $i$, and $X_{-i}$ is the total output of other firms except the firm $i$. Let $a_{LX}$ be the amount of labor that is required to produce one unit of good X. From $\varepsilon = -\frac{p}{X}\frac{\partial X}{\partial P}$ and $\frac{X}{X_i} = n$, the profit maximization condition of good X in the home country is

$$wa_{LX} = (1 - \frac{1}{n\varepsilon})\, p \tag{10}$$

where $\varepsilon$ is the price elasticity of world demand of good X and $n$ is the number of firms. Hence, the extra profit of good X firms is written as

$$\pi^e = \frac{pX}{n\varepsilon} \tag{11}$$

On the other hand, the profit functions of good Y in both countries are

$$\pi_Y = Y - wa_{LY}Y$$

$$\pi^*_Y = Y - w^*a^*_{LY}Y^*$$

The profit maximization condition of good Y is

$$wa_{LY} = p_y \tag{12}$$

$$w^*a^*_{LY} = p^*_y \tag{13}$$

where $a_{LY}$ is the amount of labor that is required to produce one unit of good Y. As mentioned above, $p_y = 1$ and $a_{LY} = 1$ since good Y is assumed as numeraire. Thus, (12) and (13) is modified as

$$wa_{LY} = 1 \tag{14}$$

$$w^*a^*_{LY} = 1^* \tag{15}$$

Now, the equilibrium condition of supply and demand in the international goods market is defined as

$$x + x^* = X \tag{16}$$

Given $x = x(p, q)$ and $x^* = x^*(p, q)$, the equilibrium condition of supply and demand in the international goods market is written as

$$x(p, q) + x^*(p, q) = X \tag{17}$$

From Walras' Law, if good X market is in equilibrium, then good Y market must also be in equilibrium.

Labor in the home country is used for good X and good Y. Therefore, the full employment condition in the home country is written as

$$\bar{L} = a_{LX} X + Y \tag{18}$$

On the other hand, since labor in the foreign country is used only for good Y, the full employment condition in the foreign country is written as

$$\bar{L}^* = a_{LX}^* Y^* \tag{19}$$

Given (5) and (6), by calculating the total derivative of (1), (2), (4), (10), (11), (14), (15), (18) and (19), I obtain,

$$du = (X - x)\,dp + p dX + dY + v_2\,dq \tag{20}$$

$$du^* = -x^* dp + v_2^*\,dq \tag{21}$$

In calculation, $a_{LX}$ and $q$ are assumed as parameters.

Notice that (20) shows four components that correspond to increase and

decrease the welfare of the home country: terms of trade, the supply of product X, the supply of product Y and quality. Similarly, (21) shows two components that of the foreign country: terms of trade and quality.

**Proposition 1.** *The welfare effect of the home country depends on the following components:*

- *Terms of trade*
- *The supply of product X*
- *The supply of product Y*
- *Quality*

Proof: see (20). ■

**Proposition 2.** *The welfare effect of the foreign country depends on the following components:*

- *Terms of trade*
- *Quality*

Proof: see (21). ■

## 3. The Effect Of Quality-Improving Innovation

### 3.1. The Home Country

Given $\varepsilon = \varepsilon(p, q)$, calculating the total derivative of (10), I obtain

$$\frac{dp}{dq} = -\frac{p}{n\varepsilon^2}\frac{\partial \varepsilon}{\partial q}\left(1 - \frac{1}{n\varepsilon} + \frac{p}{n\varepsilon^2}\frac{\partial \varepsilon}{\partial q}\right)^{-1} \tag{22}$$

From $\varepsilon = -\frac{p}{X}\frac{dX}{dp}$ and (17), I have

$$\frac{\partial \varepsilon}{\partial p} = -\frac{1}{X}(x_1 + x_1^*) + \frac{p}{X^2}(x_1 + x_1^*)^2 - \frac{p}{X}\frac{\partial^2 X}{\partial p^2} \tag{23}$$

$$\frac{\partial \varepsilon}{\partial q} = \frac{p}{X^2}(x_1 + x_1^*)(x_2 + x_2^*)^2 - \frac{p}{X}\frac{\partial X}{\partial p\,\partial q} \tag{24}$$

Now, assuming $\frac{\partial^2 X}{\partial p^2} = 0$ and $\frac{\partial X}{\partial p\,\partial q} = 0$ for simplicity[4], plugging (23) and (24) in (22) results in

$$\frac{dp}{dq} = -\frac{1}{n+1}\frac{(x_2 + x_2^*)}{(x_1 + x_1^*)} \tag{25}$$

Considering (5) and (6), (25) can be re-written as

$$\frac{dp}{dq} = \frac{1}{n+1}\left(\frac{v_{11}v_{12}^* + v_{12}v_{11}^*}{v_{11} + v_{11}^*}\right) > 0 \tag{26}$$

Notice that quality-improving innovation of good X brings an increase of its price. Also, the higher the degree of monopoly in good X market is, the more the price of good X increases.

**Proposition 3.** *Quality-improving innovation of exporting goods leads to an increase of its price. The higher the degree of monopoly in good X market is, the more the price of good X increases.*

Proof: see (26). ■

Substituting (7) and (8) into (16) and differentiating $X$ by $q$, I obtain

$$\frac{dX}{dq} = (x_1 + x_1^*)\frac{dp}{dq} + (x_2 + x_2^*) \tag{27}$$

4) This assumption means that the demand function is linear.

Given (5) and (6), by plugging (26) in (27), I observe that

$$\frac{dX}{dq} = -\frac{n}{n+1}\left(\frac{v_{11}v_{12}^{*} + v_{12}v_{11}^{*}}{v_{11}v_{11}^{*}}\right) > 0 \tag{28}$$

This shows that quality-innovation of good X brings an increase of its supply[5]. Also, the more the number of firms there are, the more the supply of good X increases.

**Proposition 4.** *Quality-improving innovation of exporting goods leads to an increase of its supply. The lower the degree of monopoly in a good X market is, the more the supply of good X increases.*

Proof: see (28). ■

Given (28), by calculating the total derivative of (18), I obtain

$$\frac{dY}{dq} = -a_{LX}\frac{dX}{dq} < 0 \tag{29}$$

The supply of good Y in the home country decreases from quality innovation of good X. This is because, from Proposition 4, quality-innovation of good X brings an increase of its supply, and this increase makes labor in the home country used for producing good X more than good Y.

**Proposition 5.** *Quality-improving innovation of exporting goods leads to a decrease of good Y supply. The lower the degree of monopoly in a good X*

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5) In calculation, I observe $\frac{\partial \frac{n}{n+1}}{\partial n} = (n+1)^{-2} > 0$.

*market is, the more the supply of good X increases.*

Proof: see (29). ■

Plugging (10) and (29) in (20) results in

$$\frac{du}{dq} = (X - x)\frac{dp}{dq} + \frac{p}{n\varepsilon}\frac{dX}{dq} + v_2 > 0 \tag{30}$$

where $a_{LX}$ is given, and $q$ is a parameter.

From (26) and (28), the first term (price effects), the second term (supply effects) and the third term (quality effects) on the right side of (30) are positive. Notice that quality-improving innovation of good X increases the welfare of the home country.

**Proposition 6.** *Quality-improving innovation of exporting goods in the home country leads to an increase of the welfare of the home country.*

Proof: see (30). ■

### 3.2. The Foreign Country

In this section, the author analyzes how quality-improving innovations occurred in the home country affect the utility in the foreign country.

As is the case with the home country, from (21), the effect on the utility in the foreign country can be written as

$$\frac{du^*}{dq} = -x^*\frac{dp}{dq} + v_2^* > 0 \tag{31}$$

Notice that the effect on the utility in foreign county cannot be settled since, on the right side of (31), the first term has the negative effect and the second term has the positive effect. In other words, price effects and

quality effects work in the opposite way. Thus, by quality-improving innovation in the home country, there is a possibility that the welfare of the foreign country will decrease. In Ohyama (1998), this possibility is named "inverse immiserizing growth".

If $v_2^* = 0$, quality-improving innovation in the home country has the negative effect on the utility in the foreign country. $v_2^* = 0$ implies that quality-improving innovation in the home country is not valued by consumers in the foreign country at all.

Substituting (26) into (31), (31) can be re-written in a slightly different way:

$$\frac{du^*}{dq} = x^* v_{12}^* \left( \frac{1}{\tau^*} - \frac{1}{n+1} \frac{v_{11} + v_{11}^* \dfrac{v_{12}}{v_{12}^*}}{v_{11} + v_{11}^*} \right) \tag{32}$$

where $\tau^* = \dfrac{v_{21}^* x^*}{v_2^*} > 0$ shows the demand change of consumers in the foreign country in response to a change in the utility of the foreign country by quality-improving innovation ("The elasticity of demand for marginal utility by quality-improving innovation"). If $\dfrac{du^*}{dq} < 0$, the utility in the foreign country decreases from quality-improving innovation. Hence, the necessary and sufficient condition of inverse immiserizing growth is

$$\tau^* > (n+1) \frac{v_{11} + v_{11}^*}{v_{11} + v_{11}^* \dfrac{v_{12}}{v_{12}^*}} \tag{33}$$

Notice that the higher the elasticity of demand for marginal utility by quality-improving innovation and the degree of monopoly are, the higher the possibility of inverse immiserizing growth is. Moreover, if the increase of marginal utility in the foreign country by innovation is lower compared to the home country, the possibility of inverse immiserizing

growth is much higher. This implies that quality-improving innovation is not valued in the foreign country compared to the home country.

On the contrary, however, if $n$ is higher, this possibility becomes lower. Thus, we can make the possibility of inverse immiserizing growth lower by making the market more competitive through a competition policy.

**Proposition 7.** *There is a possibility that quality-improving innovation of exporting goods in the home country leads to a decrease of the welfare of the foreign country that imports these goods. The possibility is higher in the following conditions:*

- *The elasticity of demand for marginal utility by quality-improving innovation is high*
- *The increase of marginal utility in the foreign country by innovation is lower compared to the home country*
- *The degree of monopoly is high*

Proof: see (33). ■

## 4. Welfare effects

I adopt the following utility functions as a basic sample:

$$u = y - \frac{a}{2}x^2 + qbx \tag{34}$$

$$u^* = y^* - \frac{a}{2}x^{*2} + \alpha qbx^*, \ \alpha \geq 0 \tag{35}$$

where $v(x, q) = -\frac{a}{2}x^2 + qbx$ and $v^*(x^*, q) = -\frac{a}{2}x^{*2} + \alpha qbx^*$.

From (5) and (6), demand functions in both countries are as follows:

$$p = -ax + qb \tag{36}$$

$$p = -ax^* + \alpha qb \tag{37}$$

(36) and (37) can be manipulated to obtain the following two expressions:

$$v_{12} = b \tag{38}$$

$$v_{12}^* = \alpha b \tag{39}$$

In this sample, if $\alpha < 1$, $v_{12} > v_{12}^*$. $v_{12} > v_{12}^*$ implies that, compared to consumers in the home country, consumers in the foreign country do not value quality-improving innovation of good X.

The price elasticity of world demand for good X in this sample is as follows:

$$\varepsilon = \frac{2p}{2p - qp(1+\alpha)} \tag{40}$$

From (26), the price effect by quality-improving innovation is

$$\frac{dp}{dq} = \frac{b(1+\alpha)}{2(1+n)} > 0 \tag{41}$$

Quality-improving innovation increases the price, and the effect of this increase is higher if the degree of monopoly is high. These increases lead to a positive effect on the utility in the home country.

From (28), the supply effect is determined as follows:

$$\frac{dX}{dq} = \frac{bn(1+\alpha)}{a(1+n)} > 0 \tag{42}$$

Therefore, substituting (41) and (42) into (30), it is observed that quality-improving innovation occurring in the home country increases the welfare of the home country.

On the other hand, the effect on the welfare of the foreign country is not determined.

Plugging (41) in (31) results in

$$\frac{du^*}{dq} = \alpha b x^* \left\{ 1 - \frac{1+\alpha}{2\alpha(1+n)} \right\} \tag{43}$$

where $v_2^* = \alpha b x^*$.

In this sample, $\tau^* = 1$. Therefore, from (33), the necessary and sufficient condition of inverse immiserizing growth is

$$\alpha < \frac{1}{1+2n} \tag{44}$$

Notice that the lower the valuation of quality-improving innovation in foreign country is, the higher the possibility of inverse immiserizing growth becomes since the left side of (44) is lower. As mentioned at the previous chapter, if companies in the market are regulated through the competitive inhibition policy, the possibility of inverse immiserizing growth becomes high since the right side of (44) is higher.

When the home country is the advanced county and the foreign country is the developing one, the strategy of quality-improving innovation at the exporting industry in the advanced country is focused on the domestic market since the scale of the domestic market in the advanced country is larger than the market in the developing country. In this case, the advanced country can obtain the profit from the innovation. The interesting point is that, unlike common wisdom, it is not necessarily the case that the developing country also can obtain the profit from quality-improving innovation. The developing country can suffer the loss from

quality-improving innovation in the case that the loss from the negative effect of terms of trade surpasses the benefit from the innovation. This occurs because quality-innovation in the advanced country is not valued by the developing country.

On the contrary, the reader should think about the case when the home country is the developing country and the foreign country is the advanced country. The strategy of quality-improving innovation in the exporting industry in the developing country is focused on the foreign market since the scale of the market in the advanced country is larger than the domestic market in the developing country. In this case, both countries can obtain the benefit from quality-improving innovation. This is because quality-improving innovation in the developing country is also valued in the advanced country and the benefit from the innovation in the advanced country exceeds the loss from the negative effect of trade of terms.

## 5. Concluding remarks

This study investigates the effect of quality-improving innovation on international trade in two-country two-good model under imperfect competition. The result, that quality-improving innovation occurred in the home country, can cause an increase in the welfare of the home country. However, there is a possibility that the welfare of the foreign country can be decreased. This possibility is named as "inverse immiserizing growth" in Ohyama (1998). This result is opposite from the case of cost-cutting innovation, which is analyzed in Shirai (2010). In Shirai (2010), cost-cutting innovation can decrease the welfare of the

home country, not of the foreign country. This possibility is named as "immiserizing growth" in Bhagwati (1958a, b).

I derived the necessary and sufficient condition of "inverse immiserizing growth" as follows:

- The elasticity of demand for marginal utility by quality-improving innovation is high
- The increase of marginal utility in foreign country by innovation is low
- The degree of monopoly is high

In Ohyama (1998), the first condition and the second condition above are also identified. However, by extending the imperfect competition model, this study has found that the third condition, the degree of monopoly, is the important condition of inverse immiserizing growth. The higher the degree of monopoly in the exporting industry where the innovation has occurred is, the higher the possibility that the welfare of foreign country will decrease. This implies that, through the competition policy, we can make the possibility of inverse immiserizing growth lower.

My results are strongly supportive of innovation in the exporting industry and in the case that quality is given. I recommend extending the approach to investigate the effect of the innovation in the import substitution industry. Further, one might internalize quality by considering quality function. In order to analyze quality function, the cost of quality-improving innovation must be considered. In this study, the quality-choice problem needs consideration. That is, there is a distinct possibility that the company will not choose quality-improving innovation because of the research and development costs.

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