Price and Quantitative Restrictions of Trade and Environment in an Open Economy

Shinya KAWAHARA*

【Abstract】

We examine the welfare effects of price and quantitative restrictions of trade and environment in an open economy. By extending the model developed by Copeland (1994) to include endogenous determination of terms of trade, we characterize the welfare-improving reforms of tariffs, import quotas, pollution taxes, and pollution quotas. First, we show that a reduction of all tariff distortions proportional to the degree of tariff distortion improves a large country's welfare if all the industries protected by tariffs are damage-intensive with respect to pollutants regulated by pollution taxes. Second, we characterize the conditions under which relaxing an import quota improves welfare. Third, we show that a reduction of all pollution tax distortions proportional to the degree of pollution tax distortion improves welfare under the same conditions as in tariff reforms. Finally, we characterize the conditions under which tightening a pollution quota improves welfare.

* Faculty of Economics, Rissho University, 4–2–16 Osaki, Shinagawa-ku, Tokyo 141–8602, Japan. Tel/Fax: +81–3–5487–3232. E-mail: kawahara@ris.ac.jp.

【**Keywords**】 Piecemeal Reform, Trade Policy, Environmental Policy, Trade and Environment
【**JEL Classification**】 F18, H23, Q56

1. Introduction

The welfare implications of trade and environmental policies in the context of piecemeal reforms have been extensively examined for decades. Copeland (1994), the first to study this issue, analyzes the welfare effects of piecemeal reforms of trade and environmental policies in a small open economy. Beghin et al. (1997) include consumption-generated pollution and firms' abatement activities to examine the reforms of consumption and production taxes in a small open economy. Turunen-Red and Woodland (2002) apply various formulae to examine the reforms of tariffs and pollution taxes in a small open economy. Turunen-Red and Woodland (2004) study the multilateral reforms of tariffs and pollution taxes in a multi-country framework. Kawahara (2009) examines the reforms of pollution taxes and quotas in a large open economy. Kawahara (2010) examines the unilateral reforms of tariffs and pollution taxes, also in a large open economy.

The purpose of this paper is to extend these previous studies and examine comprehensively the welfare impacts of trade and environmental policies in an open economy. In particular, we extend the models developed by Copeland (1994), Beghin et al. (1997), and Turunen-Red and Woodland (2002) to a large country case in which the country's terms of trade are endogenously determined. We extend Turunen-Red and Woodland (2004) and Kawahara (2010) to include the quantitative restrictions of trade and environment and examine how those policies can change the welfare implications of reforms of tariffs and pollution taxes. We extend Kawahara

(2009) to include trade policies and examine how those policies can affect the welfare effects of reforms of pollution taxes and quotas.

By extending the basic model developed by Copeland (1994) to include endogenous determination of terms of trade, this paper characterizes the welfare-improving reforms of tariffs, import quotas, pollution taxes, and pollution quotas. First, we show that a reduction of all tariff distortions proportional to the degree of tariff distortion can improve a large country's welfare if all the industries protected by tariffs are damage-intensive with respect to the pollutants regulated by pollution taxes. Second, we characterize the conditions under which relaxing an import quota on a good improves welfare. Third, we show that a reduction of all pollution tax distortions proportional to the degree of pollution tax distortions can improve welfare if all the industries protected by tariffs are damage-intensive with respect to the pollutants regulated by pollution taxes. Finally, we characterize the conditions under which tightening a pollution quota can improve welfare.

This paper is organized as follows. The next section introduces the basic model used throughout this study and derives the main equation used to assess the welfare impacts of policy reforms. Section 3 characterizes the welfare-improving reforms of tariffs, import quotas, pollution taxes, and pollution quotas. The final section concludes the paper.

2. The Basic Model

2.1 Description of the Economy

Our model is based on a framework developed by Copeland (1994). A large open economy produces/consumes n traded goods and generates k types of pollutants. Within the n traded goods, n^1 ($< n$) goods are subject to tariffs and n^2 ($= n - n^1$) goods are subject to import quotas. Within the

k types of pollutants, k^1 $(< k)$ pollutants z^1 are subject to pollution taxes s^1 and k^2 $(= k - k^1)$ pollutants are subject to marketable pollution quotas z^2 with prices s^2. Pollution in our model is a by-product of production and affects the representative consumer's utility. We assume that both trade and pollution quotas are binding. The technology set is assumed to be convex and is represented by T. All vectors are treated as column vectors, and a prime $(\prime)$ is used to denote a transpose.

The representative consumer has the following expenditure function:

$$e(p, z^1, z^2, u) = \min_c \{p'c \mid u(c, z^1, z^2) \geq u\},$$

where p is a vector of domestic price of goods and c is a vector of consumption of goods. Let p be partitioned as $p = (p^1, p^2)$, where p^1 represents a vector of the domestic price of goods that are subject to tariffs and p^2 represents a vector of the domestic price of goods that are subject to import quotas. Applying the envelope theorem yields the compensated demand for goods as $c = e_p(p, z^1, z^2, u)$.

The production side of the economy is represented by the GDP function:[1]

$$g(p, s^1, z^2) = \max_{y,z} \{p'y - s^{1\prime} z^1 \mid (y, z^1, z^2) \in T\},$$

where y is a vector of the net output.[2] Again, by applying the envelope theorem, we obtain the output of goods as $y = g_p(p, s^1, z^2)$.

The equilibrium of a large open economy can be given by the following set of equations:

$$e(p, z^1, z^2, u) = g(p, s^1, z^2) + \sum_{i=1}^{2} t^{i\prime} m^i + s^{1\prime} z^1, \tag{1}$$

[1] For the properties of the GDP functions, see Dixit and Norman (1980), Woodland (1982), and Feenstra (2004).

[2] The input vector is assumed to be fixed throughout this study and is therefore omitted in the GDP function.

$$m^i = e_{p^i}(p, z^1, z^2, u) - g_{p^i}(p, s^1, z^2),\ i = 1, 2, \tag{2}$$

$$p^i = p^{i*}(m) + t^i,\ i = 1, 2, \tag{3}$$

$$z^1 = -g_{s^1}(p, s^1, z^2), \tag{4}$$

$$s^2 = g_{z^2}(p, s^1, z^2), \tag{5}$$

where m^1 (m^2) is an import demand vector of tariff-protected (quota-protected) goods, and p^{1*} (p^{2*}) is the world price of tariff-protected (quota-protected) goods as a function of m, $e_{p^i} = \partial e/\partial p^i$, $g_{p^i} = \partial g/\partial p^i$, $g_{s^1} = \partial g/\partial s^1$, and $g_{z^2} = \partial g/\partial z^2$. Equation (1) represents the country's budget constraint that its expenditure equals the sum of its net output and the revenue from tariffs and pollution taxes. All government revenue is assumed to be uniformly distributed to the consumers. Equation (2) defines the import demand for goods as the difference between the demand for and supply of those goods. Equation (3) defines the domestic price of goods as the sum of its world price and tariff rate. Equations (4) and (5) show the level of pollution and the price of permits from the GDP function, respectively.

2.2 Deriving the Equation Linking Welfare Change to Policy Change

To examine the welfare effects of policy reforms, we derive an equation linking a change in the country's welfare to changes in its policy instruments. To do so, we totally differentiate (3) to obtain

$$dp^i = \sum_{j=1}^{2} p_j^{i*} dm^j + dt^i, \tag{6}$$

where $p_j^{i*} = \partial p^{i*}/\partial m^j$. This equation states that a change in the domestic prices of goods arises from changes in either its world price or the tariff rate. Changes in the world price of goods arise from changes in the import

demand for goods. Note that t^1 and m^2 are exogenous policy variables while m^1 and t^2 are endogenous variables. Next, we totally differentiate (1) and use (2),(4), (5), and (6) to obtain

$$e_u du = \sum_{i=1}^{2} \hat{t^i}' dm^i - \sum_{l=1}^{2} (e_{z^l} - s^l)' dz^l, \tag{7}$$

where $e_u = \partial e/\partial u$, $e_{z^l} = \partial e/\partial z^l$, and $\hat{t^i} = t^i - \sum_j m^{j\prime} p_i^{j*}$. The term $\hat{t^i}$ represents the deviation of actual tariff (including implicit tariff) rate from the optimum. Equation (7) states that a country's welfare can be affected by various sources of distortion. The first group of distortions comes from trade. This is captured by the first term on the right-hand side of (7). This can be decomposed into two terms: tariff distortions and distortions from import quotas. The second group of distortions comes from pollution. This is captured by the second term on the right-hand side of (7). Again, this can be decomposed into two terms: pollution tax distortions and distortions from pollution quotas. Although informative, this equation cannot be used to analyze policy reforms. This is because the equation represents welfare change as a function of both target variables (dm^1, dz^1) and policy variables (dm^2, dz^2). Thus, we need to express the change of target variables as a function of policy variables (dt^1, ds^1). To do so, we take the following three steps.

1. Derive equations expressing dm^1 and dz^1 as functions of both endogenous and exogenous variables.
2. Eliminate the endogenous variables and express dm^1 and dz^1 as functions of exogenous variables.
3. Substitute dm^1 and dz^1 into (7) to obtain the final equation.

As a first step, we totally differentiate (4) to obtain

$$dz^1 = -g_{s^1 p^1} dp^1 - g_{s^1 p^2} dp^2 - g_{s^1 s^1} ds^1 - g_{s^1 z^2} dz^2. \tag{8}$$

Note that dp^1 can be eliminated by (6). To eliminate dp^2 in (8), we totally differentiate (2) for $i = 2$ and solve for dp^2 to obtain

$$dp^2 = (E_{p^2p^2})^{-1}\{ - E_{p^2p^1}dp^1 + dm^2 + g_{p^2s^1}ds^1 \\ - (e_{p^2z^2} - g_{p^2z^2})dz^2 - x_{2I}e_u du - e_{p^2z^1}dz^1\}, \quad (9)$$

where $E_{p^ip^j} = e_{p^ip^j} - g_{p^ip^j}$ and $x_{2I} = e_{p^2u}/e_u$. $E_{p^2p^2}$ is a negative semi-definite matrix from the properties of expenditure and the GDP functions. The term x_{2I} represents the income effect for quota-protected goods. Using equations (6) and (9) to eliminate dp^1 and dp^2 in (8) gives

$$dz^1 = -B^1\tilde{g}_{s^1p^1}dt^1 - B^1\left[g_{s^1p^2}(E_{p^2p^2})^{-1} + \tilde{g}_{s^1p^1}p_2^{1^*}\right]dm^2 - B^1\tilde{g}_{s^1s^1}ds^1 \\ -B^1\tilde{g}_{s^1z^2}dz^2 + B^1g_{s^1p^2}(E_{p^2p^2})^{-1}x_{2I}e_u du - B^1\tilde{g}_{s^1p^1}p_1^{1^*}dm^1, \quad (10)$$

where

$$B^1 = \left[I - g_{s^1p^2}(E_{p^2p^2})^{-1}e_{p^2z^1}\right]^{-1},$$
$$\tilde{g}_{s^1p^1} = g_{s^1p^1} - g_{s^1p^2}(E_{p^2p^2})^{-1}E_{p^2p^1},$$
$$\tilde{g}_{s^1s^1} = g_{s^1s^1} + g_{s^1p^2}(E_{p^2p^2})^{-1}g_{p^2s^1},$$
$$\tilde{g}_{s^1z^2} = g_{s^1z^2} - g_{s^1p^2}(E_{p^2p^2})^{-1}(e_{p^2z^2} - g_{p^2z^2}).$$

We call the term B^1 a pollution multiplier. A change in z^1 for whatever reason would be expanded or dampened by induced changes in the domestic price of quota-protected goods. That is, a change in z^1 affects the import demand for quota-protected goods. With the binding quota constraints, the actual imports of those goods cannot be changed. In this case, the domestic price of those goods should be adjusted. Price changes affect the production of those goods and the amount of pollution z^1. The rest of the terms $\tilde{g}_{s^1p^1}$, $\tilde{g}_{s^1s^1}$, and $\tilde{g}_{s^1z^2}$ have the same interpretation as B^1. That is, the term $\tilde{g}_{s^1p^1}$ represents the effect of p^1 on z^1 taking into account the

induced changes in p^2. The term $\tilde{g}_{s^1 s^1}$ represents the effect of s^1 on z^1 taking into account the induced changes in p^2. The term $\tilde{g}_{s^1 z^2}$ represents the effect of z^2 on z^1 taking into account the induced changes in p^2.

Next, we totally differentiate (2) for $i = 1$ to obtain

$$dm^1 = E_{p^1 p^1} dp^1 + E_{p^1 p^2} dp^2 + e_{p^1 z^1} dz^1 + (e_{p^1 z^2} - g_{p^1 z^2}) dz^2 - g_{p^1 s^1} ds^1 + x_{1I} e_u du, \tag{11}$$

where $x_{1I} = e_{p^1 u}/e_u$. Eliminating dp^1 and dp^2 in (11) by using (6) and (9) gives

$$\begin{aligned} \left[I - \tilde{E}_{p^1 p^1} p_1^{1*} \right] dm^1 = {} & \tilde{E}_{p^1 p^1} dt^1 + \left[E_{p^1 p^2} (E_{p^2 p^2})^{-1} + \tilde{E}_{p^1 p^1} p_2^{1*} \right] dm^2 \\ & - \tilde{g}_{p^1 s^1} ds^1 + (\tilde{e}_{p^1 z^2} - \tilde{g}_{p^1 z^2}) dz^2 \\ & + \left[x_{1I} - E_{p^1 p^2} (E_{p^2 p^2})^{-1} x_{2I} \right] e_u du + \tilde{e}_{p^1 z^1} dz^1, \end{aligned} \tag{12}$$

where

$$\begin{aligned} \tilde{E}_{p^1 p^1} &= E_{p^1 p^1} - E_{p^1 p^2} (E_{p^2 p^2})^{-1} E_{p^2 p^1}, \\ \tilde{g}_{p^1 s^1} &= g_{p^1 s^1} - E_{p^1 p^2} (E_{p^2 p^2})^{-1} g_{p^2 s^1}, \\ \tilde{g}_{p^1 z^2} &= g_{p^1 z^2} - E_{p^1 p^2} (E_{p^2 p^2})^{-1} g_{p^2 z^2}, \\ \tilde{e}_{p^1 z^1} &= e_{p^1 z^1} - E_{p^1 p^2} (E_{p^2 p^2})^{-1} e_{p^2 z^1}. \\ \tilde{e}_{p^1 z^2} &= e_{p^1 z^2} - E_{p^1 p^2} (E_{p^2 p^2})^{-1} e_{p^2 z^2}, \end{aligned}$$

Note that the terms with tilde represent the effects taking into account the induced changes in p^2. That is, the term $\tilde{E}_{p^1 p^1}$ represents the effect of p^1 on the import demand for tariff-protected goods taking into account the induced changes in p^2. The term $\tilde{g}_{p^1 s^1}$ represents the effect of s^1 on the output of tariff-protected goods taking into account the induced changes in p^2. The term $\tilde{g}_{p^1 z^2}$ represents the effect of z^2 on the output of tariff-protected goods taking into account the induced changes in p^2. The term

$\tilde{e}_{p^1z^1}$ represents the effects of z^1 on the compensated demand for tariff-protected goods taking into account the induced changes in p^2. The term $\tilde{e}_{p^1z^2}$ represents the effects of z^1 on the compensated demand for tariff-protected goods taking into account the induced changes in p^2. Equations (10) and (12) are what we seek to derive in the first step.

The second step is to eliminate dm^1 in (10) and dz^1 in (12). To do so, we substitute (10) into (12) by eliminating dz^1 to obtain

$$\begin{aligned} dm^1 = {} & A^1\left[\tilde{E}_{p^1p^1} - \tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1p^1}\right]dt^1 + \tilde{m}^1_{m^2}dm^2 \\ & -A^1\left[\tilde{g}_{p^1s^1} + \tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1s^1}\right]ds^1 \\ & +A^1\left[(\tilde{e}_{p^1z^2} - \tilde{g}_{p^1z^2}) - \tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1z^2}\right]dz^2 + A^1\tilde{x}_{1I}e_u du, \quad (13) \end{aligned}$$

where

$$\begin{aligned} A^1 &= \left[I - \tilde{E}_{p^1p^1}p_1^{1^*} + \tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1p^1}p_1^{1^*}\right]^{-1}, \\ \tilde{m}^1_{m^2} &= A^1\Big\{E_{p^1p^2}(E_{p^2p^2})^{-1} + \tilde{E}_{p^1p^1}p_2^{1^*} \\ &\qquad -\tilde{e}_{p^1z^1}B^1\left[g_{s^1p^2}(E_{p^2p^2})^{-1} + \tilde{g}_{s^1p^1}p_2^{1^*}\right]\Big\}, \\ \tilde{x}_{1I} &= x_{1I} - E_{p^1p^2}(E_{p^2p^2})^{-1}x_{2I} + \tilde{e}_{p^1z^1}B^1g_{s^1p^2}(E_{p^2p^2})^{-1}x_{2I}. \end{aligned}$$

We call the term A^1 an import demand multiplier on tariff-protected goods.[3] A change in m^1 for whatever reason would be expanded or dampened by induced changes in the world price of tariff-protected goods. There are two induced effects. The first effect is captured by the term $-\tilde{E}_{p^1p^1}p_1^{1^*}$. Suppose that some unspecified shocks change m^1. This change in m^1 has an impact on p^{1^*}, and hence, further affects the import demand for those goods. The second effect is captured by the term $\tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1p^1}p_1^{1^*}$. The change in p^{1^*} affects z^1, which has an impact on the (import) demand for

[3] Neary (1995) discusses the import demand multiplier in his model of international trade without pollution.

those goods. The term $\tilde{m}^1_{m^2}$ represents the effect of relaxing import quota on import demand for tariff-protected goods. This effect can be divided into three components. The first comes from the change in p^2. Relaxing import quota m^2 affects p^2, which has an impact on m^1. The second effect comes from the change in p^{1^*}. Relaxing import quota affects p^{1^*}, which has an impact on m^1. The third effect comes from the change in z^1 due to the change in p^2 and p^{1^*}. A change in z^1 affects the demand for tariff-protected goods, which has an impact on m^1. Finally, the term $\tilde{x}_{1I}$ represents the income effect term on tariff-protected goods.

Next, to obtain the equation linking dz^1 to changes in exogenous policy variables, we substitute (13) into (10) and eliminate dm^1 to obtain

$$\begin{aligned} dz^1 = &-B^1\left\{\tilde{g}_{s^1p^1}p_1^{1^*}A^1\left[\tilde{E}_{p^1p^1}-\tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1p^1}\right]+\tilde{g}_{s^1p^1}\right\}dt^1+\tilde{z}^1_{m_2}dm^2\\ &+B^1\left\{\tilde{g}_{s^1p^1}p_1^{1^*}A^1\left[\tilde{g}_{p^1s^1}+\tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1s^1}\right]-\tilde{g}_{s^1s^1}\right\}ds^1\\ &-B^1\left\{\tilde{g}_{s^1p^1}p_1^{1^*}A^1\left[(\tilde{e}_{p^1z^2}-\tilde{g}_{p^1z^2})-\tilde{e}_{p^1z^1}B^1\tilde{g}_{s^1z^2}\right]+\tilde{g}_{s^1z^2}\right\}dz^2\\ &-B^1\left\{\tilde{g}_{s^1p^1}p_1^{1^*}A^1\tilde{x}_{1I}-g_{s^1p^2}(E_{p^2p^2})^{-1}x_{2I}\right\}e_u du, \end{aligned} \tag{14}$$

where

$$\tilde{z}^1_{m^2}=-B^1\left\{g_{s^1p^2}(E_{p^2p^2})^{-1}+\tilde{g}_{s^1p^1}p_2^{1^*}+\tilde{g}_{s^1p^1}p_1^{1^*}\tilde{m}^1_2\right\}.$$

The term $\tilde{z}^1_{m^2}$ represents the effect of relaxing import quota on the pollutants regulated by pollution taxes. This can be divided into three effects. The first comes from the change in p^2. Relaxing import quota affects p^2, which has an impact on z^1 through a change in production of quota-protected goods. The second effect comes from the change in p^{1^*}. Relaxing import quota affects p^{1^*}, which has an impact on z^1. The third effect comes from the change in m^1. Relaxing import quota affects m^1, which has an impact on p^{1^*} and hence z^1. Equations (13) and (14) are what we seek to obtain in the second step.

The final step is to substitute (13) and (14) into (7), which gives us our main equation.

$$\begin{aligned}
&\left[1 - \tilde{t^1}' \tilde{x}_{1I} + (e_{z^1} - s^1)' B^1 g_{s^1 p^2} (E_{p^2 p^2})^{-1} x_{2I}\right] e_u du \\
&= \left[\tilde{\delta}_{z^1} \tilde{g}_{s^1 p^1} + \tilde{t^1}' \tilde{E}_{p^1 p^1}\right] dt^1 + \left[\hat{t^2}' + \hat{t^1}' \tilde{m}^1_{m^2} - (e_{z^1} - s^1)' \tilde{z}^1_{m^2}\right] dm^2 \\
&+ \left[\tilde{\delta}_{z^1} \tilde{g}_{s^1 s^1} - \tilde{t^1}' \tilde{g}_{p^1 s^1}\right] ds^1 - \left[\delta_{z^2} - \tilde{\delta}_{z^1} \tilde{g}_{s^1 z^2} + \tilde{t^1}' \tilde{g}_{p^1 z^2}\right] dz^2, \qquad (15)
\end{aligned}$$

where

$$\begin{aligned}
\tilde{t^1}' &= \left[\hat{t^1}' + (e_{z^1} - s^1)' B^1 \tilde{g}_{s^1 p^1} p_1^{1*}\right] A^1, \\
\delta_{z^1} &= e'_{z^1} - \tilde{t^1}' e_{p^1 z^1} - s^{1\prime}, \\
\tilde{\delta}_{z^1} &= \delta_{z^1} B^1, \\
\delta_{z^2} &= e'_{z^2} - \tilde{t^1}' e_{p^1 z^2} - s^{2\prime}.
\end{aligned}$$

The term $\tilde{t^1}$ measures the effect of a change in m^1 on tariff distortions. Tariff distortions have two components. The first is excess tariff, that is, a deviation of the actual tariff rate from the optimum. The second is a deviation of marginal damage from tax-regulated pollutants e_{z^1} from actual tax rates s^1. We call $\tilde{t^1}$ a tariff distortion vector. The term δ_{z^1} represents the deviation of *appropriate* marginal damage from tax-regulated pollutants from actual pollution taxes. The appropriate marginal damage is the first two terms of δ_{z^1}. We call δ_{z^1} a pollution tax distortion vector. The term $\tilde{\delta}_{z^1}$ is the pollution tax distortion vector multiplied by the pollution multiplier. Finally, the term δ_{z^2} represents the deviation of appropriate marginal damage from quota-regulated pollutants from actual permit prices. We call δ_{z^2} a pollution quota distortion vector.

Equation (15) links the change in the country's welfare to changes in all exogenous policy variables, t^1, m^2, s^1, and z^2. By using this equation, in the next section, we examine the welfare-improving reforms of trade and

environmental policies. Note that the coefficient of $e_u du$ on the left-hand side of (15) plays an important role in determining the sign of the welfare effects of policy reforms. In particular, the inverse of this term is called tariff multiplier, or shadow price of foreign exchange. We assume that the sign of this term is positive.

3. Welfare Effects of Policy Reforms

This section examines the welfare effects of policy reforms. In particular, we focus on the second-best policy reforms; that is, the policymaker can adjust only one set of instruments at a time while maintaining the other policy instruments fixed. In this case, we have the well-known second-best problem: in correcting a particular type of distortion, there might be harmful spillover effects on the remaining sets of distortions. For a policy reform to be successful, we need to impose additional restrictions on the model.

3.1 Characterization

First, from (15), we obtain the following proposition that generally characterizes the welfare effect of policy reforms.

Proposition 1 :

1. For fixed import quotas, pollution taxes, and pollution quotas, a perturbation dt^1 on tariffs is welfare-improving if and only if
$$\left[\tilde{\delta}_{z^1}\tilde{g}_{s^1 p^1} + \tilde{t^1}'\tilde{E}_{p^1 p^1}\right] dt^1 > 0.$$
2. For fixed tariffs, pollution taxes, and pollution quotas, a perturbation dm^2 on import quotas is welfare-improving if and only if
$$\left[\hat{t^2}' + \hat{t^1}'\tilde{m}^1_{m^2} - (e_{z^1} - s^1)'\tilde{z}^1_{m^2}\right] dm^2 > 0.$$

3. For fixed tariffs, import quotas, and pollution quotas, a perturbation ds^1 on pollution taxes is welfare-improving if and only if

$$\left[\tilde{\delta}_{z^1}\tilde{g}_{s^1s^1} - \tilde{t^1}'\tilde{g}_{p^1s^1}\right] ds^1 > 0.$$

4. For fixed tariffs, import quotas, and pollution taxes, a perturbation dz^2 on pollution quotas is welfare-improving if and only if

$$\left[\delta_{z^2} - \tilde{\delta}_{z^1}\tilde{g}_{s^1z^2} + \tilde{t^1}'\tilde{g}_{p^1z^2}\right] dz^2 < 0.$$

While Proposition 1 characterizes the conditions under which the reforms of particular policy instruments can be welfare-improving, it does not tell us how the policymaker should pursue those successful reforms. In other words, it does not give specific directions for policy reforms. The next subsection addresses this issue.

3.2 Specific Directions for Reforms

3.2.1 Tariff Reform

To examine the tariff reforms, we set $dm^2 = ds^1 = dz^2 = 0$ in (15) to obtain

$$\left[1 - \tilde{t^1}'\tilde{x}_{1I} + (e_{z^1} - s^1)'B^1 g_{s^1p^2}(E_{p^2p^2})^{-1}x_{2I}\right] e_u du$$
$$= \left[\tilde{\delta}_{z^1}\tilde{g}_{s^1p^1} + \tilde{t^1}'\tilde{E}_{p^1p^1}\right] dt^1.$$

We consider a reduction of all tariff distortions proportional to the tariff distortion vector; $dt^1 = -\tilde{t^1}d\alpha$, where $d\alpha$ is a scalar and $d\alpha > 0$. This reform improves welfare if and only if

$$-\tilde{\delta}_{z^1}\tilde{g}_{s^1p^1}\tilde{t^1}d\alpha - \tilde{t^1}'\tilde{E}_{p^1p^1}\tilde{t^1}d\alpha > 0. \tag{16}$$

The first term on the left-hand side of (16) represents the effect of tariff reforms on pollution tax distortions. Tariff reforms change the domestic

price of tariff-protected goods. This could affect the production of those goods and hence, the amount of pollutants subject to pollution taxes. The sign of this term depends on how the tariff reform affects the output of polluting industries. The second term on the left-hand side represents the effect of tariff reforms on tariff distortions, and its sign is unambiguously non-negative because of the negative semi-definiteness of the term $\tilde{E}_{p^1p^1}$. That is, tariff reforms always correct the tariff distortions themselves. To characterize welfare-improving tariff reforms, we follow Copeland (1994) and define the following.

Definition : A tariff-protected industry h is damage-intensive with respect to the pollutants that are subject to pollution taxes if

$$-\tilde{\delta}_{z^1}\tilde{g}_{s^1p_h^1} > 0.$$

Thus, under a non-negative tariff distortion vector, we obtain the following proposition.

Proposition 2 : A reduction of all tariff distortions proportional to the tariff distortion vector $\tilde{t^1}$ can improve welfare if all industries protected by tariffs are damage-intensive with respect to the pollutants regulated by pollution taxes, that is, $-\tilde{\delta}_{z^1}\tilde{g}_{s^1p^1} > 0$.

A tariff reform proportional to the tariff distortion vector always corrects the existing tariff distortions, which typically reduces the production of tariff-protected industries. If those industries are damage-intensive with respect to the pollutants regulated by pollution taxes, the reform would correct the existing pollution tax distortions as well. Note that in pursuing tariff reforms, a policymaker needs to check only the correlation between tariff-protected industries and the pollutants regulated by pollution taxes, and does not have to care about the quota-protected industries or pollutants regulated by pollution quotas. Thus, import and pollution quotas do

not significantly affect the welfare-improving tariff reforms in a large open economy, as demonstrated by Kawahara (2010).

3.2.2 Reform of Import Quota

To examine the reforms of import quota, we set $dt^1 = ds^1 = dz^2 = 0$ in (15) to obtain

$$\left[1 - \tilde{t^1}'\tilde{x}_{1I} + (e_{z^1} - s^1)'B^1 g_{s^1 p^2}(E_{p^2 p^2})^{-1} x_{2I}\right] e_u du$$
$$= \left[\hat{t^2}' + \hat{t^1}'\tilde{m}^1_{m^2} - (e_{z^1} - s^1)'\tilde{z}^1_{m^2}\right] dm^2.$$

As is well known from previous literature, reforms of quantitative restrictions do not involve any intra-group spillover effect; that is, relaxing an import quota on a good has no spillover effect on the remaining distortions from the import quotas on other goods. In addition, no spillover effect exists on the remaining distortions from pollution quotas. However, there do exist spillover effects on the remaining distortions from tariffs and pollution taxes. Thus, we obtain the following proposition.

Proposition 3 : If for a certain good i that is subject to import quotas

$$\hat{t_i^2}' + \hat{t^1}'\tilde{m}^1_{m_i^2} - (e_{z^1} - s^1)'\tilde{z}^1_{m_i^2} > 0, \tag{17}$$

then relaxing an import quota on good i improves welfare.

The first term on the left-hand side of (17) represents the deviation of actual implicit tariff on quota-protected good i from its optimum, that is, the excess implicit tariff. The second term represents the effect of relaxing the import quota on good i on the excess tariffs on tariff-protected goods. If the sign of this term is positive, relaxing the import quota on good i would also correct tariff distortions. The third term represents the effect of relaxing the import quota on good i on the deviation of marginal damage

from tax-regulated pollutants from actual tax rates. If the sign of this term is positive, relaxing the import quota on good i would also correct the pollution tax distortions. Proposition 3 claims that for a reform of import quota to be welfare-improving, the sum of the three effects must be positive.

3.2.3 Pollution Tax Reform

To examine the pollution tax reforms, we set $dt^1 = dm^2 = dz^2 = 0$ in (15) to obtain

$$\left[1 - \tilde{t^1}' \tilde{x}_{1I} + (e_{z^1} - s^1)' B^1 g_{s^1 p^2} (E_{p^2 p^2})^{-1} x_{2I}\right] e_u du = \left[\tilde{\delta}_{z^1} \tilde{g}_{s^1 s^1} - \tilde{t^1}' \tilde{g}_{p^1 s^1}\right] ds^1.$$

We consider a reduction of all pollution tax distortions proportional to the pollution tax distortion vector; $ds^1 = \tilde{\delta}'_{z^1} d\alpha$, where $d\alpha$ is a scalar and $d\alpha > 0$. This reform improves welfare if and only if

$$\tilde{\delta}_{z^1} \tilde{g}_{s^1 s^1} \tilde{\delta}'_{z^1} d\alpha - \tilde{t^1}' \tilde{g}_{p^1 s^1} \tilde{\delta}'_{z^1} d\alpha > 0. \tag{18}$$

The first term on the left-hand side of (18) represents the effect of pollution tax reforms on pollution tax distortions. From the property of the GDP function, the term $\tilde{g}_{s^1 s^1}$ is positive semi-definite, and hence the sign of the first term is non-negative. That is, a pollution tax reform always corrects the pollution tax distortions themselves. The second term on the left-hand side represents the effect of pollution tax reforms on tariff distortions. A pollution tax reform typically reduces the production of industries regulated by pollution taxes. This could affect tariff distortions depending on whether the polluting industries are also tariff-protected ones. Note that this term is essentiality the same as the first term on the left-hand side of (16). Thus, under a non-negative tariff distortion vector, we obtain the following proposition.

Proposition 4 : A reduction of all pollution tax distortions proportional to the pollution tax distortion vector $\tilde{\delta}_{z^1}$ can improve welfare if all industries protected by tariffs are damage-intensive with respect to the pollutants regulated by pollution taxes; that is, $-\tilde{g}_{p^1 s^1}\tilde{\delta}'_{z^1} > 0$.

A pollution tax reform proportional to the pollution tax distortion vector always corrects the existing pollution tax distortions and typically reduces the production of industries regulated by pollution taxes. If those industries are also protected by tariffs, this reform can correct the existing tariff distortions as well. Thus, as with tariff reforms, in pursuing pollution tax reforms, a policymaker needs to check only the correlation between the pollutants regulated by pollution taxes and the tariff-protected industries and need not be concerned about quota-protected industries or the pollutants regulated by pollution quotas. Again, import quotas and pollution quotas do not significantly affect the welfare-improving pollution tax reforms in a large open economy, as demonstrated by Kawahara (2010).

3.2.4 Reform of Pollution Quota

To examine the reform of pollution quota, we set $dt^1 = dm^2 = ds^1 = 0$ in (15) to obtain

$$\left[1 - \tilde{t^1}'\tilde{x}_{1I} + (e_{z^1} - s^1)'B^1 g_{s^1 p^2}(E_{p^2 p^2})^{-1} x_{2I}\right] e_u du$$
$$= -\left[\delta_{z^2} - \tilde{\delta}_{z^1}\tilde{g}_{s^1 z^2} + \tilde{t^1}'\tilde{g}_{p^1 z^2}\right] dz^2.$$

As in the reform of import quota, a reform of pollution quota does not involve any intra-group spillover effect; that is, tightening a pollution quota on a pollutant has no spillover effect on the remaining distortions from quotas on other pollutants. In addition, there is no spillover effect on the remaining distortions from import quotas. However, there are spillover effects on the remaining distortions from tariffs and pollution taxes. We

obtain the following proposition.

Proposition 5 : If for a pollutant j that is subject to pollution quota

$$\delta_{z_j^2} - \tilde{\delta}_{z^1}\tilde{g}_{s^1 z_j^2} + \tilde{t^1}'\tilde{g}_{p^1 z_j^2} > 0, \tag{19}$$

then tightening a quota on pollutant j can improve welfare.

The first term on the left-hand side of (19) represents the deviation of appropriate marginal damage from quota-regulated pollutants from actual permit prices. The second term represents the effect of tightening a quota on pollutant j on pollution tax distortions. If the sign of this term is positive, tightening a quota on pollutant j also corrects the pollution tax distortions. The third term represents the effect of tightening a quota on pollutant j on tariff distortions. If the sign of this term is positive, tightening a quota on pollutant j also corrects tariff distortions. Proposition 5 claims that for a reform of pollution quota to be welfare-improving, the sum of the three effects must be positive.

4. Concluding Remarks

This paper examined comprehensively the welfare implications of trade and environmental policies in an open economy. By extending the basic model developed by Copeland (1994) to include endogenous determination of terms of trade, we characterized the welfare-improving reforms of tariffs, import quotas, pollution taxes, and pollution quotas. First, we showed that a reduction of all tariff distortions proportional to the degree of tariff distortion could improve a large country's welfare if all the industries protected by tariffs were damage-intensive with respect to the pollutants regulated by pollution taxes. Second, we characterized the conditions under which relaxing an import quota on a good could improve welfare. Third,

we showed that a reduction of all pollution tax distortions proportional to the degree of pollution tax distortion could improve welfare if all the industries protected by tariffs were damage-intensive with respect to the pollutants regulated by pollution taxes. Finally, we characterized the conditions under which tightening a pollution quota could improve welfare.

【Reference】

[1] Beghin, J., D. Roland-Holst, and D. Van Der Mensbrugghe. 1997. Trade and Pollution Linkages: Piecemeal Reform and Optimal Intervention. *Canadian Journal of Economics* 30, no. 2: 442–455.

[2] Copeland, B.R. 1994. International Trade and the Environment: Policy Reform in a Polluted Small Open Economy. *Journal of Environmental Economics and Management* 26, no.1: 44–65.

[3] Dixit, A.K., and V.D. Norman. 1980. *Theory of International Trade*. Cambridge: Cambridge University Press.

[4] Feenstra, R.C. 2004. *Advanced International Trade*. Princeton: Princeton University Press.

[5] Kawahara, S. 2009. Welfare-improving Reforms of Environmental Policy in a Large Open Economy. *Journal of Commerce, Economics and Economic History* 78, no.2: 1–13.

[6] Kawahara, S. 2010. Unilateral Reforms of Tariffs and Pollution Taxes in a Large Open Economy. *Journal of Commerce, Economics and Economic History* 78, no.4: 53–64.

[7] Neary, J.P. 1995. Trade Liberalisation and Shadow Prices in the Presence of Tariffs and Quotas. *International Economic Review* 36, no.3: 531–554.

[8] Turunen-Red, A.H., and A.D. Woodland. 2002. Unilateral Reforms of Trade and Environmental Policy. In *Economic Theory and International Trade: Essays in Honour of Murray C. Kemp*, ed. A.D. Woodland, 124–140. Northampton: Edward Elgar.

[9] Turunen-Red, A.H., and A.D. Woodland. 2004. Multilateral Reforms of Trade and Environmental Policy. *Review of International Economics* 12, no.3: 321–336.

［10］ Woodland, A.D. 1982. *International Trade and Resource Allocation*. Amsterdam: North-Holland.