International Trade in Emission Permits

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July 2007

Abstract

This paper examines the effect of international trade in emission permits on the national welfare of trading countries. We consider a situation in which countries introduce emission quotas and start trading permits after commodity-trade liberalization. We show that commodity-trade liberalization provides double gains from trade: standard gains from trade and improvement of the global environment. However, permit-trade after the commodity-trade liberalization may cause double losses from trade: worsening of the terms of trade and deterioration of the global environment. We also examine a distributional question of emission quotas among countries.

Keywords: global warming, emission quota, emission permit trade

JEL Classification Number: F18

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1 Introduction

At the end of 1997, the global agreement on cutting carbon emissions was agreed on in Kyoto. It is, however, difficult to implement the targets for cuts in greenhouse gas emissions. In particular, how to control carbon emissions is one of the most important questions. Among some measures to cut emissions, governments have recently paid more attention to the market-based carbon trading system. For instance, European governments launched a pan-European carbon trading system in 2005 (*Economist*, 2005). International emission control though market-based trading has been discussed, but there is a distributional question of which country should be given the generous quota of emission permits when trade starts.

In this paper, we examine the effects of permit trade on the national welfare of trading countries. We consider a situation in which countries introduce emission quotas and start trading emission permits as well as commodities. The effect of permit trade on the economic welfare generated controversy in recent years. Frankel (1999) states both developing and industrialized countries gain from trading emission rights. However, Copeland and Taylor (2000) shows that permit trade can be welfare-reducing due to the worsening of the terms of trade if countries are already trading goods. In our setting, welfare effects of permit trade can be decomposed into three effects: (i) the terms-of-trade effect in commodities, (ii) the volume-of-trade effect in emission permits, (iii) the emission-volume effect on the global environment. The first two effects are standard in trade theory. The last effect arises because international trade affects the world level of emissions through a change in the production patterns of trading countries. We show that commodity-trade liberalization provides double gains from trade: gains from commodity trade and the improvement of the global environment. However, permit-trade liberalization after commodity trade causes double losses due to the worsening of the terms of trade and the deterioration of the global environment.

We also examine a distributional question on emission-permit quotas in terms of the welfare effects of global permit trade. The question is which country should be given the more generous quota of emission permits when
permit trade starts. To examine this issue, we focus on a technology difference between countries: a country uses more emission-intensive technology than the other. And we ask whether the country using more emission-intensive technology should be given the generous emission quota or not. In terms of the global environment quality, the distribution of emission quotas might not matter at all. The level of global emissions expands and the world environment quality deteriorates regardless if the emission quota is generous or not for the country using the “dirty” technology. Further, the permit trade may hurt the country due to the deterioration of the terms of trade. Our result suggests that a country using environmentally less advanced technology could strongly oppose to global emission-permit trade due to the expected losses of its national welfare.

Our model is built on Ishikawa and Kiyono (2004) that develop a model in which (i) two goods are produced with labor, (ii) greenhouse gases (GHGs) are emitted during production, and (iii) there exists a technology to abate GHG emissions by using labor as an input. They examine how greenhouse-gas emission controls affect country’s industrial and trade structures with a model having both Ricardian and Heckscher-Ohlin features. This paper complements their work in that we examine the bilateral emission regulations, and allow international trade in emission permits in a two-country model. This paper is also related to the literature on trade theory with capital mobility including Mundell (1957), Markusen (1983), Jones (1980), Jones (2000), and Yomogida (2006) among others. We regard the GHG emission as the input of environmental resources, which enables us to treat trade in emission permits like trade in inputs such as capital. Nonetheless, unlike the welfare effect of capital movements, we evaluate the welfare effect of the permit trade in terms of the global environment quality in addition to the standard effects in trade theory.

The rest of this paper is organized as follows: In Section 2, we develop a basic model and examine equilibrium in a small open economy. In Section 3, we extend the basic model to a setting with two countries and examine the welfare effects of commodity trade. In Section 4, we analyze the welfare effect of permit trade after commodity-trade liberalization. In Section 5, we
close this paper with conclusion.

2 The Basic Model: A Small Open Economy

Two goods (goods X and Y) are initially produced using a single factor (labor) with a constant returns to scale technology and consumed by the household. Although good-Y production is clean (i.e., it does not damage the environment), good-X production is not. It emits greenhouse gases (GHG) and deteriorates the global environment quality leading to damages on the household. Let us first describe the production technology of each good.

2.1 Production Technology

Production of good X emits greenhouse gases (GHG), while production of good Y does not. Following the idea of Meade (1952), we may regard GHG emission as the input of the environmental resource for producing good X. This environmental resource is an unpaid factor of production and socially overused without any regulations. The environmental regulation is thus a policy to internalize the social opportunity cost of the environmental resource into the private evaluation of costs and benefits. Hereafter we may refer to the environmental resource as the emission for simplicity of exposition. And we specifically assume that the government enforces the total emission quota in the form of the domestic tradeable emission permit markets. Thus the emission price below is also the emission permit price.

Normalize the unit of good Y so that one unit of good Y is produced by one unit of labor. Good X requires both labor and environmental resources subject to the constant returns-to-scale technology. Let us denote by $w$ the wage and by $r$ the price of the environmental resource. Then the unit cost function of good X is expressed by $c(r, w)$. Shepherd’s lemma indicates that $\frac{\partial c(r, w)}{\partial r}$ is the emission coefficient, denoted by $e(r/w)$, and $\frac{\partial c(r, w)}{\partial w}$ is the labor coefficient, denoted by $a(r/w)$, so that there holds

$$c(r, w) = re(r/w) + wa(r/w).$$
We often let $\gamma := \frac{r}{w}$, the relative emission price.

We allow some substitution between labor and emission as stated by the following assumption.

**Assumption 1** *The input coefficients of good-X production satisfies the following properties.*

A 1-1: $e'(\gamma) < 0$ and $a'(\gamma) > 0$ for $\gamma > \gamma_R$.

A 1-2: $e(\gamma) = e_R$ and $a(\gamma) = a_R$ for $\gamma \leq \gamma_R$.

$\gamma_R$ is the critical relative emission price above which the emission price regulation is effective and promotes abatement in production of good X. We also let $z(\gamma) := e(\gamma)/a(\gamma)$ and call it the *emission intensity* of good-X production. The critical emission intensity for $\gamma_R$ is denoted by $z_R := e_R/a_R$.

This technology can be visualized by the downward-sloping curve shown in Figure 1.

In the figure, $\zeta := \frac{Z}{L}$ denotes the per-capita emission quota where $L$ represents the labor endowment and $Z$ the total emission quota imposed by the government. When the emission intensity of good X is equal to this per-capita emission quota given the full employment of the resources, then
there is no labor left for good-Y production, so that the country completely specializes in good X. The associated relative emission price, represented by $\gamma_D$, depends on the per-capita emission quota. We express this relation with the function $\gamma_D(\zeta)$ as shown in the figure.

When the relative emission price is less than $\gamma_D(\zeta)$ but higher than $\gamma_R$, there works substitution between labor and emission along the segment $DK$. But once the relative emission price is less than $\gamma_R$, the substitution ceases and the emission intensity becomes constant at the critical value $z_R$.

### 2.2 Supply-side Equilibrium

Given the good-X price $p$, the competitive supply-side equilibrium is governed by the following set of equations.

\[
L = a(r/w)X^* + Y^*,
\]

\[
Z = e(r/w)X^*,
\]

\[
c(r, w) \geq p, \quad X^* \geq 0, \quad (c(r, w) - p)X^* = 0
\]

\[
w \geq 1, \quad Y^* \geq 0, \quad (w - 1)Y^* = 0.
\]

For the time being, assume that the country is in incomplete specialization, so that there holds $w = 1$ and $p = c(r, 1) = re(r) + a(r)$. In the second quadrant of Figure 2, the relation between the commodity price $p$ and the emission price $r$ is shown by curve $p_R K DC$, while in the third quadrant we draw the technology described in Figure 1.

#### 2.2.1 Unit Cost Curve

For $r \leq \gamma_R$, the substitution between labor and emission ceases, so that the unit cost of good X is equal to $re_R + a_R$. The resulting relation between the unit cost and the emission price is shown by the line segment $Kp_R$, where $p_R = a_R$.

For $r \in (\gamma_R, \gamma_D(\zeta))$, the substitution between labor and emission works as shown by the curve $DK$ in the third quadrant, so that Shepherd’s lemma tells us that the slope of the tangent to the unit cost curve is equal to the
emission coefficient $e(r)$. The higher emission price promotes substitution of emission with labor, and thus the slope of the tangent becomes flatter as shown by the curve $DK$ in the second quadrant of the figure.

For $r \geq \gamma_D(\zeta)$, the substitution between labor and emission ceases again, for the economy’s emission intensity cannot be less than the per-capita emission quota $\zeta$ as shown in the third quadrant. We also find that the country completely specializes in good $X$, which implies that the wage exceeds unity and $\gamma_D(\zeta) = r/w$. Since there holds $\zeta = z(\gamma_D(\zeta))$, the the unit cost is equal to

$$re(\gamma_D(\zeta)) + \frac{r}{\gamma_D(\zeta)}a(\gamma_D(\zeta)) = r \left\{ e(\gamma_D(\zeta)) + \frac{a(\gamma_D(\zeta))}{\gamma_D(\zeta)} \right\}$$

$$= ra(\gamma_D(\zeta)) \left\{ \zeta + \frac{1}{\gamma_D(\zeta)} \right\},$$

where use was made of $\zeta = z(\gamma_D(\zeta))$. 

Figure 2: Competitive relation between the commodity price and the emission permit price
2.2.2 Relative Supply Curve

Insofar as the country is in incomplete specialization, the zero-profit condition 
\( p = c(r, 1) \) gives the demand price of the emission permit, which we express by \( r_D(p) \).

Given this demand price for the emission permit \( r_D(p) \), the factor market clearing conditions below determines the equilibrium output of each good.

\[
a(r_D(p))X^* + Y^* = L \\
e(r_D(p))X^* = Z
\]

This set of equations yields the equilibrium relative supply of good X to good Y, i.e.,

\[
\chi^S(p, \zeta) = \frac{X^*}{Y^*} := \frac{\zeta}{a(r_D(p))(z(r_D(p)) - \zeta)}.
\]

(2)

In view of (2), it is straightforward to confirm that incomplete specialization is possible only when there holds \( \zeta < z_R \).

Without loss of generality, we assume

**Assumption 2** *The government imposes the per-capita emission quota \( \zeta < z_R \).*

Under this assumption, for \( r_D(p) \in (\gamma_D(\zeta), \gamma_R) \), (2) implies that the relative supply of good X is strictly increasing in the relative price \( p \), for \( r'_D(p) > 0 \) and \( r'(r) < 0 \). Given the commodity price \( p \), the permit price is determined subject to the unit cost curve in the second quadrant, which determines the emission intensity of good-X production in the third quadrant and the equilibrium output of each good in the first quadrant.

When the commodity price is less than \( p_K (= \gamma_R \epsilon_R + a_R) \), the permit price becomes also less than \( \gamma_R \), making the emission intensity constant at \( z_R \). Until the permit price becomes equal to zero, the outputs as well as the relative supply stay constant, i.e., \( \chi^K = \frac{\zeta}{a_R(z_R - \zeta)} \). This is because the economy is at the kinky point along the production possibility frontier. Once the permits become free, the economy is just Ricardian, so that at the resulting relative price \( p_R := a_R \) the relative supply can take any value over \([0, \chi^K]\).
On the other hand, when the commodity price is as high as \( p = p_D \), the relative supply of good X becomes infinite, i.e., the economy completely specializes in good X. The associated point along the unit-cost curve is shown by point \( D \), i.e., the critical point for diversified production. The associated relative commodity price, denoted by \( p_D \) given by (1), depends on \( \zeta \). We express this relation by the function \( p_D(\zeta) \).

### 2.3 National Welfare

The national welfare of the country is measured by the utility enjoyed by the representative household with the following utility function,

\[
U = U \left( u(X^c, Y^c), Z^W \right)
\]

where \( X^c \) denotes the consumption of good X, \( Y^c \) the consumption of good Y, \( u(\cdot) \) the subutility function, and \( Z^W \) the world total emission of GHG. We may impose the following assumption on the household’s utility function.

**Assumption 3** The household’s utility function satisfies the following properties.

\( A \, 3-1: U(u, Z^W) \) is (i) strictly increasing in the subutility \( u \) (ii) strictly decreasing in \( Z^W \), and (iii) twice continuously differentiable.

\( A \, 3-2: u(X^c, Y^c) \) is (i) strictly increasing in the consumption of each good, (ii) twice-continuously differentiable, and (iii) homothetic. It also satisfies (iv) \( \lim_{X^c \to 0} \frac{\partial u(X^c, Y^c)}{\partial X^c} = +\infty \) and \( \lim_{X^c \to +\infty} \frac{\partial u(X^c, Y^c)}{\partial X^c} = 0 \) where \( \chi^C := X^c / Y^c \).

Given Assumption 3, the expenditure share of good X depends only on its relative price \( p \). Hereafter we denote the expenditure share of good X by \( \delta_X(p) \) and that of good Y by \( \delta_Y(p) \), and assume \(^1\)

\(^1\)One should note that this assumption is equivalent to the condition that the price elasticity of the demand for good X exceeds unity.
Assumption 4. The expenditure share of good $X$ is decreasing in the relative price $p$.

This assumption implies that the relative demand for good $X$, $\chi^D(p)$, is in fact given by $\delta_X(p)/\delta_Y(p)$, which is strictly decreasing in the relative price $p$.

### 2.4 Autarky Equilibrium

Let us first explore the autarky equilibrium. The autarky equilibrium is governed by

$$\chi^S(p, \zeta) = \chi^D(p), \quad \text{or} \quad \frac{\zeta}{a(r_D(p)) (z(r_D(p)) - \zeta)} = \frac{\delta_X(p)}{\delta_Y(p)}.$$ 

Assumption 3 implies that the demand for good $X$ relative to good $Y$, i.e., the relative demand for good $X$ depends only on the relative price $p$. This relative demand is described by the downward sloping curve $D$ in Figure 3.

There are possible equilibria, i.e., $A_i (i = 1, 2, 3)$ for each relative demand curve $D_i$. The emission quota is strictly binding at $A_1$, while it is strictly unbinding at $A_3$. At $A_2$, it is just binding.
3 Commodity-Trade Liberalization: Two-Country Model

In this section, we consider a two-country (home and foreign countries) model where both countries introduce GHG emission regulations. We first examine a symmetric technology case in which the countries have the same production technology but impose different GHG emission quotas on domestic production activities. We show that commodity trade liberalization may expand the world output of the dirty good, leading to the worsening in the global environment quality. Second, we consider an asymmetric technology case in which the countries differ in the production technology, i.e., one country has the more emission-intensive technology than the other. In contrast to the symmetric case, the commodity trade liberalization may result in a reduction in the world GHG emissions. In fact, we show that the commodity trade improves the global environment quality regardless whether the distribution of the emission quotas is favorable or not for the country using the more emission-intensive technology. In the following, foreign variables and parameters are distinguished by asterisk.

3.1 Symmetric Case

Let us first consider the symmetric case in which the two countries have the same production technology but they differ only with respect to the evaluation on the external damages from global warming. Such a difference in the perception over the environmental damage leads to a different choice of the emission quotas by each government. Without the loss of generality, we assume that the per-capita emission quota of the home country is smaller than that of the foreign country,

\[ \frac{Z}{L} < \frac{Z^*}{L^*}. \]

This assumption implies that the foreign country’s relative supply curve is located right to the home country’s (see Figure 4). It also implies that,
under the same commodity demand condition, the foreign country has a comparative advantage in good X given each country’s emission quota policy.

Figure 5 shows the world trading equilibrium when the two countries liberalize the commodity trade given the emission quota chosen in autarky. In Figure 5, the home country’s relative supply curve is given by $S$, the foreign country’s by $S^*$ and the world relative supply curve by $S^T$, while the three downwards sloping curves $D_i (i = 1, 2, 3)$ are possible relative demand curves showing the relative demand for each country as well as the world. Points $A_i (i = 1, 2, 3)$ show the associated autarky equilibrium for the home country and $A_i^*$ the foreign counterpart. The world trading equilibrium is then shown by point $T_i$. Note that for each possible case, the foreign country has a comparative advantage in good X.

Let us inquire into each equilibrium more in detail. When the relative demand curve is given by $D_1$, each country faces the binding emission quota at both the autarky equilibrium and the commodity-trading equilibrium, because the two countries incompletely specialize in both goods. The world GHG emission does not change before and after the commodity-trade liberalization.

When the relative demand curve is given by $D_2$, the emission quota is strictly binding for the home country and just binding for the foreign coun-
try. After the commodity-trade liberalization, the two countries incompletely specialize in both goods and produce at the kinky point on the production possibility frontier. This implies that the emission quotas are just binding for both countries. Again, we have no change in the world GHG emissions.

Lastly as with the relative demand curve $D_3$, the situation is a little different. After free trade in commodities, the home country would produce both goods or specialize in producing good $Y$, while the foreign country would produce both goods. Only the home country gains from commodity trade since the world relative price at the free trade equilibrium is the same as the autarky price of the foreign country. Clearly, the free trade in commodities expands the world production of good $X$, increasing the world GHG emissions. If we take into account the effects of increased emission, the commodity trade hurts the foreign country but it may or may not benefit the home country.

3.2 Asymmetric Case

Now consider the asymmetric case in which the technologies differ between the two countries. Let us first take a specific case shown by Figure 6. Later
on, we shall explain the details of the production structure. Given the world relative demand curve, which is the same as each country’s, $A$ shows the home country’s autarky equilibrium and $A^*$ the foreign counterpart, while $T$ shows the world free commodity-trading equilibrium. The foreign country has a comparative advantage in good X, and it expands good X production after trade. The home country completely specializes in good Y after trade. Note that before the commodity trade liberalization the emission quotas are binding for both countries, while after trade the quota is still binding for the foreign country but it is not for the home country. In fact, it produces none of good X, so that the emissions by the home country before trade are totally eliminated after trade. Therefore, both countries gain from both the commodity trade liberalization and the improved global environment.

Let us now specify the technology difference in producing good X between the countries.

**Assumption 5** The production technologies for producing good X in the home and foreign countries satisfy

$$A\, 5-1: \ e_R < e_R^* \text{ and } a_R > a_R^* \ ,$$
Figure 7: Unit-cost curves and relative supply curves in the asymmetric technology case

A 5-2: $e(r_D(p)) < e^*(r_D^*(p))$ and $a(r_D(p)) > a^*(r_D^*(p))$ for all $p$.

This assumption implies that when both countries are diversified in free trade, then the emission intensity in good X production is higher in the foreign country than in the home country, i.e., $z(r_D(p)) < z^*(r_D^*(p))$. The unit-cost curves of the two countries are then shown in the second quadrant of Figure 7. Curve $p_RH$ represents the home country’s unit-cost curve and curve $p_R^*F$ the foreign counterpart. They intersect with each other only once. In the third quadrant, the corresponding factor intensity curves are illustrated. Assumption 5 also implies that $z(r) < z^*(r)$ for the given permit price $r$, i.e., the foreign country’s production of good X is relatively more emission intensive than the home counterpart. Also, in the first quadrant of Figure 7, the relative supply curves are drawn. If the home per-capita emission quota $\zeta$ is sufficiently smaller than the foreign one $\zeta^*$, the foreign country has a
Figure 8: The commodity trade equilibrium in the case in which the home country has the relatively larger size of emission quota than the foreign country.

This result on the double gains from trade does hold even in a case in which the home country has the relatively larger per-capita emission quota than the foreign country. Figure 8 shows the commodity trade equilibrium in this case. Since the per-capita emission quota of the home country ζ is sufficiently greater than that of the foreign country ζ*, χ^K is greater than χ^K*, i.e., the home country has the greater capacity for the relative output of good X than the foreign country. This implies that the home country has a comparative advantage in good X when the relative demand for good X is
sufficiently large such as $D_2$.

However, the home country may not have a comparative advantage in good $X$ when the relative demand for the dirty good is not so large as $D_2$. If the demand curve is $D_1$, then the foreign country has a comparative advantage in the dirty good. This is because the foreign country has the lower comparative labor costs in good $X$. Given the relative demand curve $D_1$, the home country specializes in good $Y$ and the foreign country produces both goods at the commodity trade equilibrium. As a result, each country benefits from additional gains from a reduction in the global emission. That is, the commodity-trade liberalization generates the double gains from trade even when the home country has the greater per-capita emission quota than the foreign country. This result suggests that the commodity-trade liberalization improves the global environment quality regardless if the more generous emission quota is given or not to the country using the more emission-intensive technology. We can state this result as follows.

**Proposition 1** If the country using the less emission-intensive technology completely specializes in good $Y$ (the clean good) after commodity-trade liberalization, then both countries get better off because of gains from commodity trade and the improved global environment.

### 4 Emission Permit Trade After Commodity-Trade Liberalization

Let us now consider the welfare effect of emission-permit trade after the commodity-trade is liberalized. As we have already discussed, the commodity-trade liberalization may give rise to the double gains to the world, i.e., standard gains from commodity trade and additional one from an improvement in the global environment quality. In this section, we examine whether or not the permit trade generates further improvements in the global environment, providing additional benefits for the world. After the permit trade, the country having a comparative advantage in the dirty good can expand its output by importing emission permits. As a result, the permit trade liberalization
will increase the global GHG emissions. In fact, we show that the country exporting the dirty good may suffer double losses from emission-permit trade: the worsening of the terms of trade and the deterioration of the global environment quality.

4.1 World Integrated Equilibrium

When emission-permit trade is liberalized, the commodity prices and the emission permit prices would be equalized between the two countries at equilibrium, which we call the world integrated equilibrium. We shall consider the case in which the home and foreign countries are asymmetric in the production side, i.e., they have the same production technology in the neneraire, but different technologies in the production of good $X$. In Figure 9, $S^T$ is the world relative supply curve under commodity trade, which is the same as the one illustrated in Figure 6. That is, we consider the situation in which the foreign country initially has the greater per-capita emission quota than the home country. If both countries open the markets for emission permits, the world relative supply curve is drawn as $S^T_K$. Let us first explain how to construct $S^T_K$. We assume that either country has sufficiently large labor force to absorb the world total amount of emission permits. To be more precise, the following conditions are satisfied,

$$Z^W < \min\{z_R L, z^*_R L^*\},$$

where $z_R = e_R/a_R$, $z^*_R = e^*_R/a^*_R$, and $Z^W = Z + Z^*$. This condition implies that the emission quota binds if the total amount of permits is allocated to either country.

If $p \in (p^*_R, p^*_K)$, the foreign country offers the higher permit price and imports all of permits issued by the home country. Then, the home country is specialized in goods $Y$ and the foreign country produces both goods. The world relative supply of good $X$ is represented by

$$\chi^W_2 = \frac{\zeta^W}{a_R(z^*_R - \zeta^W)}$$
Figure 9: The world integrated equilibrium

where $\zeta^W = Z^W / L^W$. Before permit-trade liberalization, the relative output of good $X$ is $\chi_1^W = \frac{Z^* / L^W}{\alpha^*(z^* - Z^*/L^*)}$, which is smaller than $\chi_2^W$. Clearly, the permit trade expands the world relative output of the dirty good.

If $p \in (p_K^*, \tilde{p})$, then either country is engaged in the same production pattern as in the previous case, but the substitution of labor for emissions works in the foreign production of good $X$. The higher price of good $X$ leads to the higher price of permits, which promotes the substitution of labor for emission and expands the production of the dirty good.

When the price of good $X$ reaches $\tilde{p}$, commodity production is diversified at either country. Then, both countries offer the same price for emission permits, and the allocation of permits across the countries is not determined without the demand side condition. As the home country employs more of permits, the world relative output of good $X$ increases due to the home country’s higher productivity in emission permits. When the home country
uses all of permits, the relative output is maximized at

\[ \chi_3^W = \frac{\zeta^W}{a(\bar{r})z(\bar{r}) - \zeta^W}. \]

Clearly, the foreign country produces only good \( Y \) since it exports all of permits.

If \( p \in (\bar{p}, p_D(\frac{Z^W}{L})) \), then the substitution of labor for emission works and an increase in the price of the dirty good raises the relative output along the home country’s production possibility frontier. When \( p \) is equal to or greater than \( p_D(\frac{Z^W}{L}) \), complete specialization arises, i.e., the home country produces the dirty good and the foreign country does the clean good. Then, the world relative output of the dirty good is

\[ \chi_4^W = \frac{Z^W}{e(r_D(\frac{Z^W}{L}))L^*}. \]

### 4.2 Welfare Effects of Permit Trade

Next, let us examine the impact of permit-trade liberalization on the welfare of countries. Suppose that the world relative demand for good \( X \) is given by \( D_1 \). Then, at the commodity-trade equilibrium \( T_1 \), the home country produces good \( Y \) only, and the foreign country produces both goods. As we have shown in Proposition 1, there are double gains from trade, i.e., both countries benefit from commodity trade due to the standard gains from trade and the improvement of the global environment. However, in this section, we shall show that liberalization in permit trade may cause double losses from trade.

When both countries liberalize permit trade as well as commodity trade, the equilibrium is determined at \( T^K_1 \). Before the permit trade, the foreign country’s production of the dirty good is constrained by the emission quota. The permit trade allows the foreign country to expand the production of the dirty good by importing emission permits. Since the home country specializes in the clean good, the global GHG emissions increase due to the permit-trade liberalization.
Let us first examine the welfare effect of permit trade on the foreign country. The welfare effect can be decomposed into three effects. First, the import of permits benefits the foreign country because the less expensive permits become available. This is called the volume-of-trade-effect in permit trade. Also, a decline in the price of the dirty good negatively affects the welfare of the foreign country due to the worsening of the terms of trade measured in goods. This is called the terms-of-trade effect in commodity trade. Furthermore, the expansion of the world production of the dirty good leads to the worsening of the global environment. This can be called the emission-volume effect on the global environment. Those results imply that the foreign country suffers from the double losses from trade: the worsening of the terms of trade and the global environment. However, the home country can benefit from the permit trade if gains from the improvement in the terms of trade overwhelms losses from the worsening of the global environment.

We can summarize the above results as follows:

**Proposition 2** After the permit-trade liberalization, the country using more emission-intensive technology is allowed to expand the output of the dirty good by importing emission permits. As a result, the global environment deteriorates because of an increase in the world output of the dirty good. Then, the country suffers double losses from the permit trade: the worsening of the terms of trade in commodities and the deterioration of the global environment.

Next, suppose that the commodity demand curve is given by $D_2$. Then, the emission permit quota is bidding for both countries before and after the liberalization of permit trade. Since the total level of the global emissions does not change, the permit trade does not worsen the global environment. The home country imports permits and expands the production of the dirty good. Since the home country has the higher productivity of emission permits, the world relative output of the dirty good increases, resulting in a reduction in the price of the dirty good. If the pattern of commodity trade

\[2\text{See Appendix for the algebraic derivation of the gains or losses from permit trade.}\]
remains the same as the one at the commodity-trade equilibrium, the permit trade hurts the foreign country but benefits the home country. However, the permit trade may cause the reversal of the pattern of commodity trade. That is, the home country can be an exporter of the dirty good. When such a reversal arises, the welfare effect of the permit trade would be ambiguous.

4.3 Initial Distribution of Permits and Welfare Effects of Permit Trade

There is a distributional question of which country should be given the larger quota when permit trade starts. In this section, we examine this issue in terms of the welfare effect of permit trade. So far, we have considered a situation in which the foreign country has the greater size of per-capita emission quota and it exports the dirty good at the commodity-trade equilibrium. Instead, we shall examine a case in which the home country has the greater per-capita emission quota than the foreign country. This situation has been illustrated in Figure 8. We assume that other things are equal, and thus the total level of emission permits is constant.

Before the liberalization of permit trade, the world relative supply curve is illustrated as $S^T_0$ in Figure 10. $S^T_0$ has shifted to the left of $S^T$ for $p \in (p_R^*, p_R)$. In this price range, the home country specializes in good Y and thus an increase in the emission quota does not affect its relative output. In the foreign country, a decline in the emission quota reduces the relative output of good X, leading to a reduction in the world relative output of good X. Meanwhile, if $p > p_R$, the world relative supply curve moved to the right as compared to the previous situation. In this price range, transfer of the emission quota from the foreign country to the home country expands the world relative output of good X. The reason is straightforward. The home country has the less emission intensive technology in good X than the foreign country, which implies that the home country’s productivity of emission permits is higher than the foreign country’s. Thus, the transfer of the emission quota improves the efficiency of the world production of the

\[3\] See Appendix for the proof.
dirty good, increasing the relative output of good X in the world.

First, let us consider a case with the relative demand curve $D_1$. Then, the commodity trade equilibrium is determined at $T_0'$. As shown in Figure 8, before the permit trade, the home country specializes in the clean good and the foreign country produces both goods. The permit trade allows the foreign country to expand the output of the dirty good, increasing the global GHG emissions. Again, the foreign country suffers double losses from the permit trade, the worsening the terms of trade in commodities and the deterioration of the global environment quality. This result implies that Proposition 2 does hold even when the home country initially has the greater per-capita emission quota than the foreign country.

Second, suppose that the relative demand is given by $D_2$. Then, the commodity-trade equilibrium is determined at $T_0''$. As illustrated in Figure
8, the home country has a comparative advantage in good X. The emission quotas at both countries are binding before and after the liberalization of permit trade, and thus the quality of the global environment remains the same. As before, the welfare impact of the permit trade consists of the two effects: the terms-of-trade effect in goods and the volume-of-trade effect in permits. At the commodity-trade equilibrium, the home country exports the dirty good and permits, and the foreign country exports the clean good. If the trade pattern remains the same after the permit trade liberalization, the home country benefits from the permit trade since both the terms-of-trade and the volume-of-trade effects positively affect the home welfare. However, the foreign country loses from the permit trade since both effects negatively affects the foreign welfare.⁴

Recall that the permit trade hurts the foreign country when it has the sufficiently large quota of emission permits and exports the dirty good at the commodity-trade equilibrium. Here, we assume that the foreign country does not have the sufficiently large size of emission quota and imports the dirty good. However, once again, the foreign country loses from the permit trade. The permit trade may hurt the county using the more emission-intensive technology regardless if the country is given the larger or smaller per-capita emission quota.

5 Conclusion

In this paper, we have examined the welfare effect of international trade in emission rights. The commodity-trade liberalization benefits both countries due to the double gains from trade: the standard gains from trade and the improvement of the global environment. After the commodity-trade liberalization, global trade in emission permits does not guarantee further gains for the countries. The permit trade allows the country using the more emission-intensive technology to import permits, and it raises the world output of the dirty good. As a result, the world emission level increases and the global envi-

⁴See Appendix.
ronment deteriorates. In fact, the country having the more emission-intensive technology suffers double losses from the permit trade: the worsening of the terms of trade and the deterioration in the global environment quality.

We have also examined the distributional question of emission quotas among countries. The distribution of quotas might not affect the level of global emissions. The permit trade deteriorates the global environment quality irrespective of which country is given the larger emission quota. Also, the country using the more emission-intensive technology loses from the permit trade regardless whether the distribution of emission quotas is generous or not for the country. This result suggests that a country using environmentally less advanced technology strongly opposes to global trade in emission permits.

References


Appendix: Algebra on the Welfare Effects of Permit Trade

Taking a derivative of the sub-utility function of the home country, we have

\[ du = u_X dX^C + u_Y dY^C, \]  

(A1)

where \( u_i \) is the marginal utility of good \( i = X, Y \). Dividing the both side of (A1) with \( u_Y \), we can obtain a change in the real income in terms of good \( Y \).

\[ d\tilde{u} = \left( \frac{u_X}{u_Y} \right) dX^C + dY^C. \]  

(A2)

With the use of the first order condition in the utility maximization problem, we can rewrite (A2) as

\[ d\tilde{u} = p^H dX^C + dY^C, \]  

(A3)

where \( p^H \) denotes the domestic price of good \( X \). Let \( p^W \) and \( r^W \) denote the world price of good \( X \) and the world price of permits, respectively. Then,
the budget constraint for the home country is

\[ p^W X^C + Y^C = p^W X + Y + r^W (Z - Z^D) \]  \hspace{1cm} (A4)

where \( Z^D \) is the home employment of emission permits. The profit maximization conditions imply that

\[ p^H dX + dY = -r^H d(Z - Z^D), \]  \hspace{1cm} (A5)

where \( r^H \) denotes the domestic price of permits. Using (A3), (A4) and (A5), we can derive a change in the real income of the home country as follows:

\[
d \bar{u} = (X - X^C)dp^W + (Z - Z^D)dr^W
\]

\[ + \left( p^W - p^H \right) d(X - X^C) + (r^W - r^H) d(Z - Z^D). \]  \hspace{1cm} (A6)

On the RHS, the first two terms are the terms-of-trade effects measured in good \( X \) and permits, respectively. The last two terms are the volume-of-trade effects measured in good \( X \) and permits, respectively. If we evaluate (A6) at the commodity-trade equilibrium, \( p^H = p^W \) and \( Z = Z^D \) hold. Thus, we can simplify (A6) as

\[
d \bar{u} = (X - X^C)dp^W + (r^W - r^H) d(Z - Z^D). \]  \hspace{1cm} (A7)

Similarly, we can derive the foreign counterpart as

\[
d \bar{u}^* = (X^* - X^{*C})dp^W + (r^W - r^F) d(Z^* - Z^{*D}). \]  \hspace{1cm} (A8)

When the world relative demand curve is given by \( D_1 \), the foreign country exports good \( X \) for the imports of good \( Y \) and permits. With (A8), we can derive gains from permit trade for the foreign country. Since the price of good \( X \) falls, the terms-of-trade effect measured in good \( X \) negatively affects the welfare of the foreign country. At the same time, the foreign price of emission permits declines, the volume-of-trade effects measured in permits positively affects the welfare of the foreign country.
On the other hand, if the demand curve is $D_1$, the home country exports good $Y$ and permits for the import of good $X$. Using (A7), we can confirm that the home country gains from the permit trade since both the terms-of-trade effect in good $X$ and the volume-of-trade effect in permits have the positive impacts on the home welfare.

Next, suppose that the relative demand curve is represented by $D_2$, and the trade pattern in commodity does not change due to permit trade. If the foreign country initially has the greater per-capita emission quota than the home country, then the home country exports good $Y$ and imports permits as well as good $X$. Again, the home country gains from permit trade since both the terms-of-trade effect and the volume-of-trade effect are positive. On the other hand, the foreign country exports both good $X$ and permits for the import of good $Y$. The foreign country loses from the permit trade since both the terms-of-trade effect and the volume-of-trade effect negatively affect the foreign welfare. Similarly, we can show that the permit trade benefits the home country but hurts the foreign country when the home country is given the sufficiently greater per-capita emission quota than the foreign country.