The Transfer of Emissions Abatement Technology and Environmental Policies

〔研究論文〕

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1. Introduction

The cooperation of developed and developing countries is indispensable for the correspondence to transboundary pollution and global warming. Then, developed countries have supported abatement activities in developing countries.[1)] Among these activities, the transfer of pollution or emissions' abatement technology is one of the practical measures. Actually, an introduction of cleaner technologies (e.g., energy conservation technology to coke oven) has been promoted under the assistance of advanced countries. The main purpose of this paper is analyzing the effect of such a technology transfer on emissions discharged from the recipient country.

There are several researches for the abatement technology's transfer. Stranlund (1996) notes the strategic relation with respect to choosing the level of an abatement activity, and examines whether the technology transfer from a technologically advanced country to its less-advanced rival is implemented. Itoh and Tawada (2003) analyze the welfare effect of the technology transfer based on the Ricardian two-country model a la Copeland and Taylor (1999). By using the expenditure and revenue functions, Takarada (2005) generalizes the model of Itoh and Tawada (2003) so that the case of incomplete specialization could be analyzed.[2)] Since we statically analyze the effect of the technology transfer, this paper is closely related to Takarada (2005). However, our research differs in the following two points, while we examine only the recipient country under the assumption of a small open economy.[3)]

Firstly, we consider an endogenous emissions tax. World Bank (2016) shows that about 40 national jurisdictions and over 20 cities, states, and regions have already implemented carbon pricing through carbon tax or emission trading system. Hence, as a first step, we reveal the relation between an emissions tax and the transfer of emissions abatement technology in a small open economy without the terms of trade effect. Analyzing the policy response of a recipient's government is a very important part of our analysis, because we are interested in future handling of environmental policies in emerging and developing countries. Then, in order to explore how the technology transfer changes the level of an emissions tax in the recipient country, we treat the tax rate as an endogenous variable.

Secondly, we describe the pollution abatement technology in a more general form. In Itoh and Tawada (2003) and Takarada (2005), the amount of emissions per unit of a dirty good's output is given by a parameter. Since a decrease in the parameter means a progress of abatement technology,

except for the technical progress, a reduction of emissions is practiced only by reducing the output of a dirty good. We consider the situation where emissions can be decreased by hiring more factors of production for abatement activities under a certain level of the output of dirty goods. That is, we rearrange the description of the parameter with respect to the abatement technology.[4)]

Within this framework, we derive the following results. (I) if an increase in real income swells the marginal external damage, in other words, the marginal willingness to pay for reducing emissions (clean environment is a normal good in this case), the optimal emissions tax rate may be decreased with the technology transfer. Then, (II) the total amount of emissions is also reduced with the transfer because such a transfer increases the recipient's total revenue, then augments the marginal willingness to pay.

The rest of the paper is organized as follows. We set up our model in Section 2. Section 3 examines the effect of the transfer of emissions abatement technology on the recipient's emissions tax rate. Then, considering the results of Section 3, Section 4 explores whether the technology transfer reduces the total amount of emissions. We present some concluding remarks in Section 5.

2. Model

We consider a small open country that receives emissions-reduction technology. There are two goods (X and Y), and two primary factors (labor and capital) which are inelastically supplied at $\bar{L}$ and $\bar{K}$. Both goods are produced with a constant returns to scale technology. A good X generates emissions (Z) during its production process. Along with Copeland and Taylor (2003, Ch2), we suppose that this sector allocates a fraction θ, $(0\leq\theta\leq 1)$ of these factors to abatement activity. In this case, the net production function of this good is represented as $X=(1-\theta)F(L_x, K_x)$ and then emissions as a by-product are assumed as $Z=(1-\theta)^{1/\alpha}F(L_x, K_x)$. That is, $Z=F$ if abatement activity is not performed at all $(\theta=0)$. Moreover, $\alpha,(0<\alpha<1)$ is the parameter which expresses the degree of emissions' intensity.[5)] From these functions, we obtain the specified production function which involves emissions as an input:

$$X=Z^{\alpha}F(L_x, K_x)^{1-\alpha}. \tag{1}$$

Hence, in our model, the transfer of emissions abatement technology corresponds to a decrease in α.[6)] On the other hand, good Y is a clean good, and is produced with labor and capital:[7)]

$$Y=H(L_y, K_y). \tag{2}$$

In the following analysis, we designate a good Y as the numeraire and express the relative price of a good X as p. Suppose that the recipient's government imposes on an emissions tax (τ). Given factor endowments, the relative price, and the emissions tax, the revenue function (G) which means the maximum value of net revenue produced by the private sector is defined as

$$\begin{aligned} G(p, \tau, \alpha, \bar{L}, \bar{K})\equiv & \\ \max_{L_i, K_i, Z}\{ & pZ^{\alpha}F(L_x, K_x)^{1-\alpha}+ \\ & H(L_y, K_y)-\tau Z \mid \bar{L}\geq L_x+L_y, \\ & \bar{K}\geq K_x+K_y\}, \ (i=x, y). \end{aligned} \tag{3}$$

Then, from envelope theorem of the function, we can obtain the following relations for the partial differentiation of G with respect to τ and α.[8)]

$$G_{\tau}(p, \tau, \alpha, \bar{L}, \bar{K})=-Z<0, \tag{4}$$

$$G_\alpha(p, \tau, \alpha, \bar{L}, \bar{K}) = -pX\ln\left(\frac{F}{Z}\right) < 0. \quad (5)$$

Noting $Z \leq F$, from (4) and (5), we find that α increases this country's total revenue, while τ decreases it. The technology transfer declines the emission intensity of the production of a good X. It means that the emissions tax payment are reduced with the transfer even if the fraction θ regarding abatement activity does not change. Hence, the total revenue is increased with the transfer.

We take a representative consumer in the recipient country. Emissions are a pure public bad for the consumer. The utility function is strongly separable with respect to consumption goods and the negative externality caused by emissions. That is, $U = u(C_x, C_y) - \phi(Z_T)$, where Z_T denotes the total amount of emissions, and then $\phi(Z_T)$ means the damage function. We assume that $\phi(Z_T)$ has the following properties: $\phi'(Z_T) > 0$, $\phi''(Z_T) > 0$. Hence, the expenditure function that represents the minimum expenditure on final goods' consumption is described as follows:

$$E(p, \tilde{U}) \equiv \min_{C_x, C_y}\{pC_x + C_y \mid U + \phi(Z_T) \leq u(C_x, C_y)\}, \quad (6)$$

where we define $\tilde{U} \equiv U + \phi(Z_T)$.

Suppose that the revenue of the recipient's government from an emissions tax is redistributed to the domestic households in a lump-sum fashion. In this case, the recipient's budget constraint requires

$$E(\tilde{U}) = G(\alpha, \tau) + \tau Z. \quad (7)$$

This equation means that consumer expenditure is equal to the net value of output plus emissions tax revenue in the country.[9] Given the level of foreign emissions (Z^*), the total amount of emissions is written as follows:

$$Z_T = Z + Z^*. \quad (8)$$

Considering $G_\tau = -Z$ from (4), in (7) and (8), endogenous variables are U and Z_T.

Noting $dZ^* = 0$, a change in the total amount of emissions is expressed as

$$dZ_T = dZ = -G_{\tau\tau}d\tau - G_{\tau\alpha}d\alpha. \quad (9)$$

As shown in Copeland and Taylor (2003), the revenue function G is convex in p and τ. It means that emissions are decreased with an increase in the emissions tax, that is,

$$G_{\tau\tau} = -\frac{\partial Z}{\partial \tau} \geq 0. \quad (10)$$

Moreover, from Young's theorem,

$$-\frac{\partial Z}{\partial \alpha} = G_{\tau\alpha} = G_{\alpha\tau} = -pX\left[\left(\alpha\ln\left(\frac{F}{Z}\right) - 1\right)\left(\frac{\partial Z/\partial\tau}{Z}\right) + \left\{1 + (1-\alpha)\ln\left(\frac{F}{Z}\right)\right\}\left(\frac{\partial F/\partial\tau}{F}\right)\right], \quad (11)$$

where $\partial F/\partial\tau = F_L(\partial L_x/\partial\tau) + F_K(\partial K_x/\partial\tau)$. In (11), noting $\partial Z/\partial\tau \leq 0$, $G_{\alpha\tau} < 0$ can be obtained if $\alpha\ln(F/Z) \leq 1$ and $\partial F/\partial\tau > 0$. In this case, although an increase in the emissions tax swells the total input of primary factors in the emissions generating sector, a part of these factors engages in abatement activities. Hence, emissions from this sector decrease. The technology transfer may enhance this impact by reducing emissions' intensity in the production of a good X. Considering this point, we suppose $\partial Z/\partial\alpha > 0$ in the following analysis.

On the other hand, totally differentiating (7), then substituting (9) into it, the change in the utility level is written as

$$E_{\tilde{U}}\,dU = (E_{\tilde{U}}\phi' - \tau)G_{\tau\tau}d\tau + Ad\alpha, \quad (12)$$

where A is defined as follows:

$$A \equiv G_\alpha + (E_{\tilde{U}}\phi' - \tau)G_{\tau\alpha}. \tag{13}$$

In (12), $E_{\tilde{U}}$ denotes the inverse of the marginal utility of income. In addition, $E_{\tilde{U}}\phi'$ represents the marginal willingness to pay for emissions reduction and is referred as the marginal external damage. Noting $G_{\alpha\tau}(=G_{\tau\alpha})<0$, we find that from (12) and (13), both an increase in the emissions tax and the technology transfer enhance the recipient's welfare as long as the emissions tax rate is lower than the marginal damage $(E_{\tilde{U}}\phi' \geq \tau)$.

3. The effect on the level of emissions tax

In this section, to analyze the effect of the transfer of abatement technology on the level of an emissions tax, we treat the tax as an endogenous variable. Assuming that the tax is imposed at a level that maximizes recipient's welfare, the first order condition is given by

$$\frac{dU}{d\tau} = \frac{G_{\tau\tau}}{E_{\tilde{U}}}\left(E_{\tilde{U}}(\tilde{U})\phi'(Z_T) - \tau\right) = 0. \tag{14}$$

That is, the optimal emissions tax rate is equal to the marginal damage. Here, we denote the first order condition in (14) by $U_\tau(\alpha, \tau) = 0$, then examine the effect of an decrease in α on the optimal emissions tax rate.

From $U_\tau(\alpha, \tau) = 0$, the relation between the emissions tax level and the transfer is derived as

$$\frac{d\tau}{d\alpha} = -\frac{U_{\tau\alpha}}{U_{\tau\tau}}. \tag{15}$$

Considering (4) and (14), the partial derivatives $U_{\tau\tau}$ and $U_{\tau\alpha}$ are given by the following equations, respectively:

$$U_{\tau\tau} = -\frac{G_{\tau\tau}}{E_{\tilde{U}}}\{(E_{\tilde{U}\tilde{U}}\phi'^2 + E_{\tilde{U}}\phi'')G_{\tau\tau} + 1\} < 0, \tag{16}$$

$$U_{\tau\alpha} = -\frac{G_{\tau\tau}}{E_{\tilde{U}}}\{E_{\tilde{U}}\phi''G_{\tau\alpha} + E_{\tilde{U}}^{-1}E_{\tilde{U}\tilde{U}}\phi'G_\alpha(\rho_{\alpha\tau} - 1)\}, \tag{17}$$

where $U_{\tau\tau} < 0$ from the second-order condition of welfare maximization. In addition, by using (11) and (14), we denote the elasticity of G_α with respect to τ as $\rho_{\alpha\tau}$. The elasticity is defined as

$$\rho_{\alpha\tau} \equiv \frac{\tau G_{\alpha\tau}}{G_\alpha} > 0. \tag{18}$$

Substituting (16) and (17) into (15), we obtain as follows:

$$\frac{d\tau}{d\alpha} = \frac{E_{\tilde{U}}^{-1}E_{\tilde{U}\tilde{U}}\phi'G_\alpha(1-\rho_{\alpha\tau}) - E_{\tilde{U}}\phi''G_{\tau\alpha}}{(E_{\tilde{U}\tilde{U}}\phi'^2 + E_{\tilde{U}}\phi'')G_{\tau\tau} + 1}. \tag{19}$$

The sign of $E_{\tilde{U}\tilde{U}}$ depends on whether the marginal utility of income is increasing function or decreasing. Since $E_{\tilde{U}}\phi'$ expresses the marginal willingness to pay for reducing emissions, the sign is closely related to the influence of an increase in real income on the willingness to pay. If an increase in real income swells it, in other words clean environment is a normal good, it becomes $E_{\tilde{U}\tilde{U}} > 0$. Hence, we suppose $E_{\tilde{U}\tilde{U}} \geq 0$ in the following analysis.[10] Then, noting $G_{\alpha\tau}(=G_{\tau\alpha}) < 0$, we can derive the following relation between the optimal emissions tax and the technology transfer.

Proposition 1: *Suppose that the recipient's government executes the optimal emissions tax. In this case, if (i)* $E_{\tilde{U}\tilde{U}} = 0$ *or (ii)* $E_{\tilde{U}\tilde{U}} > 0$ *and* $\rho_{\alpha\tau} \geq 1$ *is satisfied, the transfer of emissions abatement technology reduces the emissions tax rate. That is,* $d\tau/d\alpha > 0$.

In (19), we can confirm that the tax level is influenced in two ways. First, the technology transfer directly reduces the emissions tax level, because the transfer decreases the amount of

domestic emissions. Second, the emissions tax is also affected through a change in the marginal damage. The marginal damage in other words, the marginal willingness to pay for reducing emissions is swelled with an increase in real income if $E_{\tilde{U}\tilde{U}} > 0$. In such a case, the second effect also acts to ease the emissions tax level because clean environment is a normal good, then the technology transfer reduces emissions.[11)]

4. The effect on the total amount of emissions

On the basis of the results obtained in Section 3, we examine the effect of the technology transfer on the total amount of emissions. Considering (19), a change in the total emissions is described by:

$$\frac{dZ_T}{d\alpha}\left(=\frac{dZ}{d\alpha}\right)= -\frac{(E_{\tilde{U}\tilde{U}}\phi' G_\alpha G_{\tau\tau}+E_{\tilde{U}} G_{\tau\alpha})}{E_{\tilde{U}}\{(E_{\tilde{U}\tilde{U}}\phi'^2+E_{\tilde{U}}\phi'')G_{\tau\tau}+1\}}. \quad (20)$$

Noting the second-order condition of welfare maximization, the denominator of the right-hand side of the equation in (20) is positive. Therefore, if $E_{\tilde{U}\tilde{U}} \geq 0$, the total amount of emissions is apparently decreased with the technology transfer.

Proposition 2: *Suppose that the recipient's government charges the optimal emissions tax. In this case, if $E_{\tilde{U}\tilde{U}} \geq 0$, the transfer of emissions abatement technology decreases the total amount of emissions. That is, $dZ_T/d\alpha > 0$.*

The technology transfer directly reduces the total emissions. In addition, if $E_{\tilde{U}\tilde{U}} \geq 0$, the transfer raises the recipient's real income, then increases the marginal willingness to pay for reducing emissions. Since the transfer increases the recipient's revenue ($G_\alpha < 0$), the total emissions are also reduced through an increase in the marginal willingness to pay although the emissions tax rate is decreased with the transfer.

5. Concluding remarks

We examine the effect of the transfer of emissions abatement technology on the recipient's emissions tax rate and the total amount of emissions. Considering that the tax rate is endogenously determined, a change in the marginal damage along with an increase in real income plays an important role in this model. Since marginal damage means the representative consumer's willingness to pay for reducing emissions, the total emissions definitely decrease in the case where an increase in the income raises the marginal willingness to pay.

In this paper, we assume a small open economy regarding the recipient. However, e.g., China will introduce environmental taxes for the purpose of reducing air and water pollution, waste products, and sound noise from 2018. Therefore, we need to extend our model to investigate the case of a large country with the terms of trade effect. Under this framework, we will investigate the impact of the technology transfer on the level of environmental policy, the total amount of pollution emissions.

Notes

1) There are many researches for foreign aid in the case where negative externality exists. E.g., see Copeland and Taylor (1995), Chao and Yu (1999), Hatzipanayotou, Lahiri, and Michael (2002), Naito (2003), and Abe, Sugiyama, and Kiyono (2012).
2) By using same functions, Copeland (1994) examines the gradual reform of environmental and trade policies in a small open economy. Moreover, Turunen-Red and Woodland (2004) investigate the feasibility of Pareto-improving multilateral reforms of environmental taxes in a model involving multi countries

and goods.

3) Although Itoh and Tawada (2003) and Takarada (2005) suppose that pollution discharged from a dirty industry decreases the productivity of a clean industry, we assume that pollution is harmful to consumers.
4) Nimubona and Rus (2015) consider the green technology transfer which supports public abatement activity in developing countries, and reveal the donor's optimal grant level for assisting the transfer. They also investigate the impact of stricter border tax adjustment on the optimal grant level, cross-border pollution emissions, and both countries' welfare.
5) See Copeland and Taylor (2003, Ch2) for more general and detailed discussions of the production and abatement technologies.
6) From (1), $\ln X = \alpha \ln Z + (1-\alpha)\ln F$. Thus, we can obtain $\partial X/\partial \alpha = -X \ln(F/Z)$
7) Ishikawa and Kiyono (2006) compare emission quotas, emissions taxes, and emission standards in the model where two goods are produced using labor and greenhouse gases are discharged during the production of both goods.
8) In this paper, subscripts of functions denote the partial derivative of these functions with respect to corresponding variables. Noting the first order conditions for (3), (4) and (5) are derived from envelope theorem. Similarly, we also obtain $G_{\hat{p}} = X$ (See Dixit and Norman 1980, Ch2).
9) Hereafter, we abbreviate the relative price of the good in the revenue and expenditure functions based on our small country's assumption. We also omit factor endowments in the revenue function.
10) As shown in Abe, Sugiyama and Kiyono (2012), if the utility function is additively separable in negative externality and homogeneous of degree one with respect to consumption bundles, its expenditure function becomes a linear function with respect to the utility level including the external damage. That is, $E_{\hat{U}\hat{U}} = 0$ in such a case.
11) If $E_{\hat{U}\hat{U}} = 0$, the second effect does not work. $d\tau/d\alpha > 0$ is determined only from the direct effect.

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