

A Global Cost Sharing Scheme to Prompt Innovation in Environmental Technology¹

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Abstract

Green innovation is expected not only to improve global environment but also to restore the global economies. In the present the green innovation seems to be one of the policy instruments to develop national economies. This paper argues that a global cost sharing scheme could promote innovation of environmental technology as well as decrement of carbon in the world scale.

1. Introduction

The financial crisis of 2008-09 slowdowns global economies. The leading economies spend urgent remedies to restore the globally spreading recession actively and cooperatively. Although the fiscal and monetary policies prevent the further deterioration of economic activities, the rises of national debt and financial funds instabilize world economies. Major countries seek outlet strategies from the urgent remedies preventing the great recessions. Although each

¹ This paper is firstly published London Accord
http://www.london-accord.co.uk/index.php?option=com_content&view=article&id=225&Itemid=61 and revised some misprints in this version.

country firstly aims at reconstruction of the own domestic economy, the large scale cooperative remedies for the global crisis make the effect to support many countries mutually. The effort to expand economic activities could not continue for a long term considering budget restrictions and distortion on the market economy. Since the outlet strategy appears to focus domestic economies, the international mutual effect is afraid of being extinguished. The innovation is expected to preserve global economies. An autonomous recovering process should be supported by a series of innovation in the new field. The innovation of environmental technology to remedy global environmental problems is expected to perform a prominent propelling power in the vitalization of global economies. The innovation could achieve the reallocation of resources to save the cost of the climate change not only in a particular country but in the global view.

Tanaka (2009) proposes the model to analyze the global sustainable framework. This model analysis makes clear that global economic activities are influenced by the coefficients of altruism for stakeholders and risk managements. To maintain global economic societies in the good condition we should construct a series of policies to impact the two types of coefficients positively. This paper focuses on the international cost sharing scheme to promote innovation of environmental technology. Hoel (1990) and (1997) argue the voluntary solution for Transboundary Pollution. Kirchsteiger and Puppe(1994) consider the optimal provision of public goods through the scheme of income redistribution. Tanaka (1998) demonstrates that the transboundary pollution is improved by constructing unilateral income transfer scheme between two

countries. Tanaka (2010) extends the model of Tanaka (1999) to global innovation strategy and proposes the international redistribution scheme to promote innovation of environmental technology. By improving the 2010 model analysis this paper makes clear the international framework to promote environmental technology².

The main results of this paper are stated as follows. We formulate the cost sharing subsidy system to prompt the innovation of environmental technology in the two country economies. The system should offer differential rates to the particular types of individuals. The construction of the cost sharing subsidy scheme progresses the innovation of environmental technology in both countries toward optimal decrement of carbon. This paper is organized as follows. The section 2 introduces the structure of the cost sharing scheme which propels the innovation of environmental technology by the international subsidy system. The section 3 proves that differential rates of subsidy initiate a various types of technology to improve global environment effectively. The section 4 focuses on the international transfer scheme and suggests that the international system could improve the decrement of carbon largely.

2. The structure of the model

In this paper we propose an efficient cost sharing mechanism

²UNEP: United Nations Environment Programme proposes Global Green New Deal.

<http://www.unep.org/greeneconomy/LinkClick.aspx?fileticket=ciH9RD7XHwc%3D&tabid=1393&language=en-US>. Carrillo-Hermosilla et al (2009) investigate theoretical framework of eco-innovation.

between two countries which consist of advanced and emerging ones. It is assumed for the implication that the country 1 is an advanced economy and that the country 2 is an emerging economy. Although this framework is constructed by two economies, the consequences obtained here are extended for the global multiple economies. Tanaka (1999) argues that a scheme including redistribution of income is effective to decrease of emission of CO₂ by using transboundary pollution model. The model is explained briefly as follows. Two countries decrease emission of CO₂ by using an international transfer system to promote innovation of environmental technology. Each of the country one and two obtains s and k individuals to emit CO₂. Each individual i obtains income m_i . He or she consumes x_i unit of composite goods and pays cost g_i to decrease carbon. x_i and g_i are measured the price of unit. Each country introduces governmental support systems to promote decrement of carbon. The government compensates δ_i ($0 \leq \delta_i \leq 1$) ratio of the cost of curtailment g_i . δ_i is decided by considering the degree of innovating effects. For each i the distinct rate is adapted by the government. The two counties promote the innovation in the technology of the carbon decrement cooperatively. The tax payment of the country 1 is not only a source of the environmental policies but also transferred to the country 2 as the found to prompt technical innovation of carbon decrement. On the contrary the tax revenue of the country 2 is used as the source of carbon decrement policies only for own country. t_{11} and t_{12} are the individual burden rate of country 1 to country 1 and 2. t_{22} and t_{21} are the individual burden rate of country 2 to country 2 and 1. t_{11}, t_{12}, t_{22} are positive but t_{21} is negative. Between the two countries

the individual of country 1 offers the fund for the environmental innovation and the individual of country 2 simply accepts the tariff.

The total amounts of carbon decrement of country 1 and 2 are denoted by G_1 and G_2 . G_1 and G_2 are defined by

$$G_1 = \sum_{i=1}^s g_i, G_2 = \sum_{j=s+1}^{s+k} g_j \quad (1)$$

The total amount of carbon decrement for the two countries expressed by

$$G = G_1 + G_2. \quad (2)$$

We suppose that the Nash conjecture $\frac{\partial g_h}{\partial g_t} = 0$ holds for any h, t

($1 \leq h, t \leq s+k, h \neq t$). The utility functions of representative individual i and j are denoted by $u_i(x_i, G)$ and $u_j(x_j, G)$. In this functions x_i, g_i, x_j, g_j are decision variables.

When the two countries achieve the agreement with total decrement of emission, cooperative attempts to decrease emission might be proposed. As the country 1 increases the decrement of emission in own county at the large scale, the country is obliged to confront with relatively high cost option. The country 1 seems to seek for more advantageous decrement of emission in the country 2 as well as the country 1. By the above reasoning we suppose that the transfer from the country 1 to the country 2 to promote innovation of environmental technology is assumed to increase monotonously with the innovation in the country 1 expressed by G_1 . Simplifying the analysis the burden on the individual of the country 1 must cover a part of the decrement cost G_2 in the country 2. The burden for each individual of the country 1 to facilitate innovation of environmental technology in the

international transfer scheme is supposed to satisfy the linier form $\theta_{22}G_2$. θ means the rate of burden in the individuals of the country 1 to promote innovation of environmental innovation of the country 2. It is assumed simply that the relations $t_{12} = \theta_{22}$ and $t_{21} = -\theta_{22}$ hold.

3. Policies for the differential rate of subsidy

The income constraints are stated by

$$x_i + (1 - \sigma_i)g_i = m_i - t_{11}G_1 - \theta_{22}G_2, \quad i = 1, \dots, s, \quad (3)$$

$$x_j + (1 - \sigma_j)g_j = m_j + \left(\frac{s}{k}\theta - 1\right)t_{22}G_2, \quad j = s+1, \dots, s+k. \quad (4)$$

It is assumed that the individual i is a resident in the country 1 and that j is a resident in the country 2. The individuals i and j decide x_i, g_i, x_j, g_j by considering the international transfers

$\theta_{22}G_2$ and $\frac{s}{k}\theta_{22}G_2$. The consumptions of goods and the decrements of CO₂ emission of individuals are affected by the total decrement of the country 2. In this model the international transfer from the country 1 to the country 2 is supposed to initiate innovation of environmental technology in the country 2. The budgetary equilibrium conditions for the two countries are described by

$$\sum_{i=1}^s \sigma_i g_i = s t_{11} G_1, \quad (5)$$

$$\sum_{j=s+1}^{s+k} \sigma_j g_j = (k + \theta s) t_{22} G_2. \quad (6)$$

The left side of (5) and (6) imply the total benefits of the scheme. The right side means the fund or the source of the scheme. The advanced country 1 considers the cost benefit of decrement of

emission in the two countries. (6) states that the transfer $\theta_{22}G_2$ from the country 1 to the country 2 is affected by the decrement of emission in the country 1.

Considering the income constraint (3) the utility function of individual in the country 1 is transformed into

$$u_i(m_i - (1 - \sigma_i)g_i - t_{11}G_1 - \theta_{22}G_2, G) \text{ for } i (i=1, \dots, s).$$

The optimal consumption condition of the first order for the decrement of emission is written by

$$\frac{\frac{\partial u_i}{\partial G}}{\frac{\partial u_i}{\partial x_i}} = 1 - \sigma_i + t_{11}. \quad (7)$$

Under the condition of decreasing the marginal rate of substitution, the following proposition 1 is assured.

Proposition 1. As the own burden for the innovation effort $t_{11} - \sigma_i$ becomes smaller, the amount of innovation g_i grows. $t_{11} - \sigma_i$ is the incentive policy instrument to prompt innovation of environmental technology.

The marginal rate of substitution (7) is not necessary to be identical for different individuals. The individuals seem to adopt the suitable type of facility to introduce the renewable energy by considering their living conditions. The rate of electricity price t_{11} is determined uniformly for the community, but the financial aid for the investment σ_i is differentiated by depending on which technology is adopted.

By employing figure 1 the financial aid system with differential rates activates various efforts to decrease emission of CO₂. For the

simplicity the total decrement of the country 2 is assumed to be constant. The country 1 is composed by two types of individual i and j . The total amount of emission decrement G expressed in (2) is rewritten by

$$G = g_i + g_j + G_2. \quad (8)$$

It is supposed that the marginal rate of substitution of i is greater than the rate of j . The line CK shows a single rate of aid. Two rates draw the lines CK and DL. Comparing the surpluses of the two individuals it is ensured that the surplus of i (area ACFE) is larger than surplus of j (area BCF) in the case of the single rate.

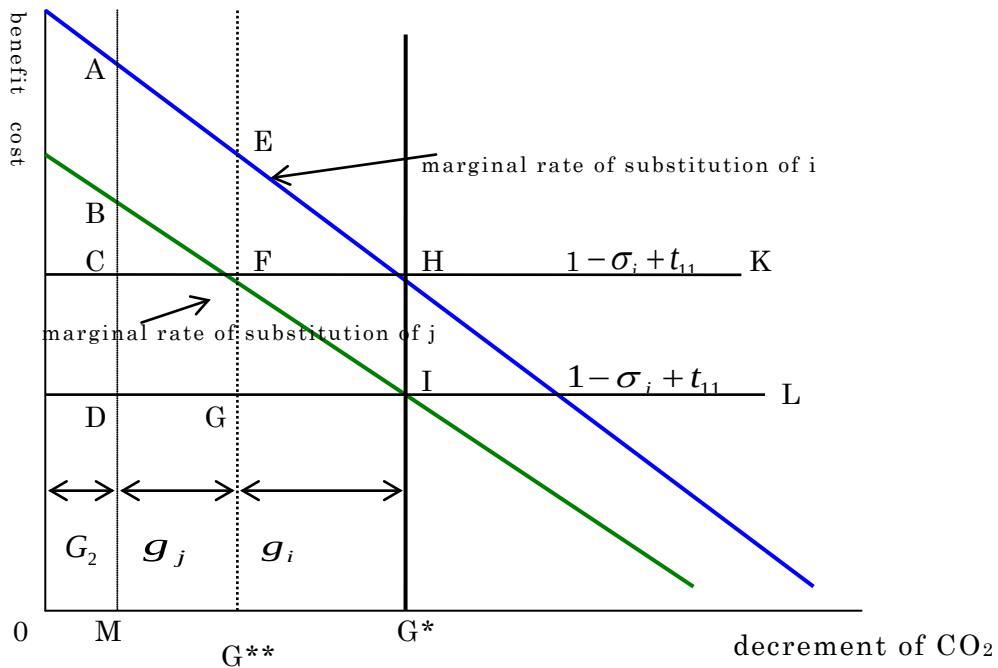


Figure 1. Differential rates of subsidy for individuals

It is efficient that the individual i mainly contributes to decrease emission of CO₂ using financial aid. The expression

$$G_1 = g_i$$

is satisfied. The single rate of financial aid makes effect to promote the innovation supported by consumption of type i . The type i exhibits high evaluation for revolution of new technology in the field of environment. But it is more likely that the other type of innovation driving from the consuming behavior of j is developed only partially in this financial aid.

In the two rates of financial aid individuals i and j could contribute cooperatively by the limit of G^{**} . It is possible that the surplus of individual j (area BDGF) is larger than the surplus of i (area ACFE). The individual j contributes the decrement under the limit G^{**} and that the individual i contributes to decrease the emission beyond the limit. We obtain the relation

$$G_1 = g_i + g_j.$$

The burden of the cost is assigned to the type i and j as follows. To simplify the reasoning the part of cost depicted by the area CDGF are supposed to be exempted for i . It is assumed that the amount is charged to j . the alternation of contribution from the type i to j in the decrement of CO₂ improves net social benefit depicted by the triangle BCF. The two rates system is more effective to activate innovation inducing consumptions in the both types of individuals i and j and to make efforts of emission decrement than the single rate system. The single rate system focuses on the prominent technology in the present. But the multi rates system is expected to be effective mechanism to initiate innovation in the field of environmental technology. We could argue that this result is applicable for the multiple rates system. Noticing that the innovational process means the revolution in the complex of technology we could conclude the proposition 2.

Proposition 2. Differential rates of financial aid to improve various environmental technology of decreasing CO₂ emission could activate innovation of environmental technology.

4. An international transfer scheme on the environmental technology innovation

In this section we consider an effective international transfer scheme to improve environmental technologies to decrease CO₂ emission. To simplify the following analysis we identify that individuals 1 and 2 are individuals possessing the average utility and decrease of emission in each country. The consumption, decrement of emission and income of the individual of the country 1 and the country 2 are denoted by x_1, g_1, m_1 and x_2, g_2, m_2 . The relation

$$g_1 = \frac{G_1}{s}, \quad g_2 = \frac{G_2}{k} \quad (9)$$

are satisfied. Reminding the definition,

$$g_i = g_1, i=1, \dots, s, \quad g_j = g_2, j=s+1, \dots, s+k$$

the individuals in each country obtain the cooperative conjecture for $i, j=1, \dots, s$, or $=s+1, \dots, s+k$,

$$\frac{dg_i}{dg_j} = 1, i \neq j.$$

In this paper we consider the unilateral transfer scheme from the advanced country 1 to the emerging country 2.

The social welfare function is defined by

$$W = \sum_{i=1}^{s+k} u_i(x_i, G).$$

Using (3) and (9), G is rewritten by

$$G = sg_1 + kg_2.$$

W is replaced by

$$\begin{aligned} & su_1(m_1 - (1 - \sigma_1)g_1 - t_{11}sg_1 - \theta kt_{22}g_2, sg_1 + kg_2) + \\ & ku_2(m_2 - (1 - \frac{s\theta}{k})kt_{22}g_2 - (1 - \sigma_2)g_2, sg_1 + kg_2). \end{aligned} \quad (10)$$

To maximize social welfare the expression (10) is differentiate with regard to g_1 , g_2 . The first order condition of maximization is stated by (11) and (12).

$$\frac{\partial W}{\partial g_1} = -s((st_{11} + 1 - \sigma_1)\frac{\partial u_1}{\partial x_1} - s\frac{\partial u_1}{\partial G}) + ks\frac{\partial u_2}{\partial G} = 0. \quad (11)$$

$$\frac{\partial W}{\partial g_2} = s(-\theta kt_{22}\frac{\partial u_1}{\partial x_1} + k\frac{\partial u_1}{\partial G}) - k\frac{\partial u_2}{\partial x_2}((1 - \frac{s\theta}{k})kt_{22} + (1 - \sigma_2)) + k\frac{\partial u_2}{\partial G} = 0. \quad (12)$$

(11) is transformed to

$$\frac{\frac{\partial u_1}{\partial G}}{\frac{\partial u_1}{\partial x_1}} = \frac{1}{s}(1 - \sigma_1) + t_{11} - \frac{k}{s}\frac{\frac{\partial u_2}{\partial G}}{\frac{\partial u_1}{\partial x_1}}. \quad (13)$$

$$\frac{\frac{\partial u_2}{\partial G}}{\frac{\partial u_2}{\partial x_2}} = ((1 - \frac{s\theta}{k})kt_{22} + (1 - \sigma_2)) + s\theta t_{22}\frac{\frac{\partial u_1}{\partial x_1}}{\frac{\partial u_2}{\partial x_2}} - s\frac{\frac{\partial u_1}{\partial G}}{\frac{\partial u_2}{\partial x_2}}. \quad (14)$$

(13) and (14) imply the cooperative policy for the two countries. The following the transformations of (13) and (14) make clear the policy implication.

$$\frac{\frac{\partial u_1}{\partial G}}{\frac{\partial u_1}{\partial x_1}} + \frac{k}{s}\frac{\frac{\partial u_2}{\partial G}}{\frac{\partial u_1}{\partial x_1}} = \frac{1}{s}(1 - \sigma_1) + t_{11}. \quad (15)$$

$$\frac{\frac{\partial u_2}{\partial G}}{\frac{\partial u_2}{\partial x_2}} + s \frac{\frac{\partial u_1}{\partial G}}{\frac{\partial u_2}{\partial x_2}} = ((1 - \frac{s\theta}{k})kt_{22} + (1 - \sigma_2)) + s\theta_{22} \frac{\frac{\partial u_1}{\partial x_1}}{\frac{\partial u_2}{\partial x_2}}. \quad (16)$$

The second terms of left sides of (15) and (16) mean the total marginal benefits of the other country evaluated by each country. The left side of (15) and (16) describe the total marginal benefits evaluated by the country 1 and 2. Each country should decide own pricing policy for promote environmental innovation considering marginal benefits of the other county as well as own country individuals. Comparing the left sides of (7) and (15) regional cooperative scheme represents greater marginal benefit than independent one county innovation scheme. Noticing that marginal cost exhibited by the right side of (15) is smaller than the right side of (7), this cost sharing scheme is effective to increase decrement of emission of the carbon in the country 1.

Suppose that the marginal utility of emerging country is greater than that of advanced country. It is ensured that the inequality

$$\frac{\partial u_2}{\partial x_2} > \frac{\partial u_1}{\partial x_1}$$

is satisfied. In this case

$$s\theta_{22}(\frac{\frac{\partial u_1}{\partial x_1}}{\frac{\partial u_2}{\partial x_2}} - 1) < 0$$

is obtained. To increase the rate of transfer θ from country 1 to 2 decreases the marginal cost of country 2 exhibited in (16). Noticing that the marginal benefit is decreasing (16) implies that the optimal decrement of emission increases by rising the rate θ . The transfer might make effect promote innovation of environmental

technology in the country 2. The result obtained above is stated in Proposition 3. Although the result obtained above is the optimal condition, the system to attain the condition is proposed. The scheme stated in this model is effective to decrease carbon emission globally.

Propositon 3. The unilateral cost sharing scheme among the participating countries to promote innovation of environmental technology could lead global environment to the optimal condition. In this condition decrements of CO₂ improve in not only the advanced countries but also the emerging countries.

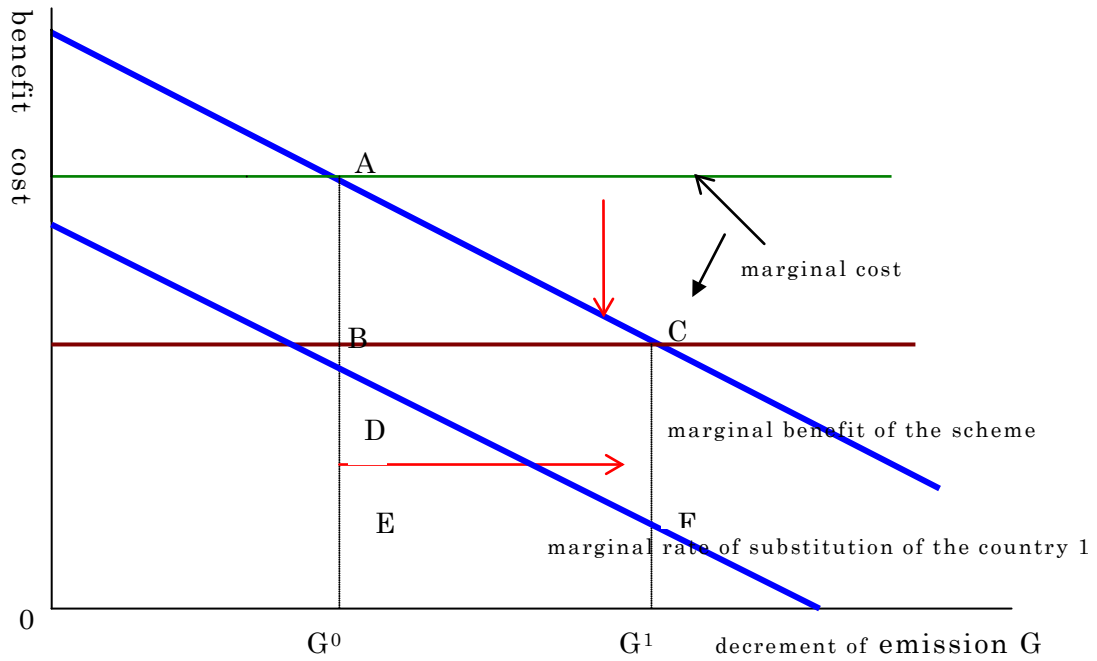


Figure 2. the decrement of emission in the advanced countries

Figure 2 depicts the main results of this section in the country 1. (15) shows that the individuals in country 1 consider the marginal benefit of scheme and the marginal cost of the individual. In

cooperative community the marginal benefit rises and marginal cost lowers. Consequently, the equilibrium point A shift to the point C in the figure. From the shift decrement of emission is ensured. Regarding the country 2, similar reasoning could be applied in different marginal benefit and cost. Finally the decrement of emission exhibited by G^1 in the Figure 2 is obtained.

5. Conclusion

The cost sharing scheme proposed in this paper is assumed to be founded by the cooperative framework in some regional countries. It has been supposed that the innovation strategy obtains the policy to enforce competitiveness of the national leading industries. This paper focuses on the cooperative benefits of innovation and argues that innovation and sustainability could be compatible in the global community by this cost sharing scheme. In the dominant aspect, to prompt innovation each country should develop various types of energy technology. The optimal emission decrement is attained by balancing the marginal benefit of the region evaluated by each country to marginal cost of decreasing emission in each country. In international view the transfer system among some neighborhood countries must be constructed to achieve the solution for the global environmental problems.

In this paper the transfer between the two countries is characterized by the lump sum tax for the advanced country and subsidy to decrement cost in the emergent country. The framework could be supported by another international transfer mechanism. In particular, Onstwedder and Mainelli (2010) propose the system of carbon bond. The carbon bond obtains an excellent characteristic

of fund for the innovation of renewable energy technology. The carbon bond could be a feasible alternative in the cost sharing scheme presented in this paper. It clarifies the mechanism that the cost sharing scheme could promote innovation of environmental technology in not only the advanced country but also the emerging country in this country. Remaining that this mechanism functions better, the scheme could be effective to construct international framework of sustainability.

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Acknowledgments

It should be noted that this essay could not exhibit comprehensive mechanism of innovation of environmental technology but investigate only the effective cost sharing scheme to promote the innovation. I greatly appreciate that Professor Mainelli instructs me to develop the model analysis to some more significant issues such as the role of trade, the role of the carbon markets and the importance of the green intellectual property. I expect to have an opportunity to discuss the problems systematically.