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Clean Development Mechanism, Technological Diffusion Effect and Economic Growth

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Abstract

The reduction of GHG emission has become an important issue in the world since 1992. The 「clean development mechanism」 has been proposed allowing the non-Annex I countries to join the joint-implementation project in 1997 Kyoto Protocol. However, there are a few researches that deal with it till now.

It is believed that the issues of pollution abatement, technological diffusion effects, and economic growth have trilateral relationships. But most studies talked about two issues among them only. Keeler & Zeckhauser (1971), Brock (1977), Tahvonen & Kuulu-Vainen (1991), Huang & Chen (1993), and Huang & Lee (2000) believed that pollution abatement would affect the economic growth. Milliamn & Prince (1989) and Goulder & Ma-Thai (2000) concluded that pollution control could generate technological diffusion effects. Barro & Sala-I-Martin (1995, 1997) employed the optimal control model to discuss the relationships between technological diffusion effects and economic growth.

This study applies the optimal control theory that is similar to Barro & Sala-I-Martin (1997) and Goulder & Ma-Thai (2000) applied. It is to discuss the impacts of technological diffusion effects on economic growth of the investing country and the host country, respectively, under the clean development mechanism. Four conclusions are obtained as follows:

1. The investing country has higher economic growth rate with more CO_2 emission under the clean development mechanism.
2. The country with advanced technology of CO_2 abatement usually has higher economic growth rate. This is because the country can accumulate intermediate inputs easily and is treated as the source of technological progress and the reason of increasing economic growth rate.
3. The sum of two countries' CO_2 emission can reach the proposed level under CDM. Meanwhile, each country can also promote economic growth rate respectively. The investing country gets all CERs from the host country and then increases its products and economic growth rate under CDM. The host country can obtain technological diffusion effect that induces the higher growth rate by applying the advanced CO_2 abatement technology.
4. In terms of stable equilibrium, the increasing rate of economic growth for the host country is higher than that in the investing country. Two countries' economic growth rates will converge to the same level finally. However, the nominal output level of investing country is always higher than that of the host country under CDM.

Key words: Clean Development Mechanism, Technological Diffusion Effect,

1. Introduction

The reduction of GHG emission has become an important issue in the world since 1992. But, the non-Annex I countries have been proposed to join the clean development mechanism (CDM), which is similar to the joint-implementation project (JI) 1997's Kyoto Protocol. Even though Taiwan is not a member of the UNFCCC, she should also have obligation to reduce the GHG emission, especially CO_2. This study employs the optimal control theory to form a theoretical model that is similar to Barro & Sala-I-Martin (1997) and Goulder & Mathai (2000) applied. The purpose of this study is to find the impacts of technological diffusion effects on economic growth of the investing country (Annex I countries) and the host country (non-Annex I countries) under CDM.

2. Literature Review

Baumol & Oates (1971, 1988) concluded that the policies of carbon tax (CT) and tradable emission permits (TEP) were economic efficiency solutions for CO_2 reduction. Chang (1998) believed that TEP would be better than CT for fulfilling the target of CO_2 reduction. TEP has become an important policy for GHG abatement in the world (Huang & Lee, 2000). CDM and JI are similar to TEP in terms of definition. However, the former two policies trade the GHG emission permits by transferring advanced abatement technology between the investing country and the host country.

It is believed that the issues of pollution abatement, technological diffusion effects, and economic growth have trilateral relationships. But most studies usually deal with two issues among them only. Keeler & Zeckhauser (1971) believed that pollution would generate negative social utility. Therefore, the pollution abatement could increase social utility level. Meanwhile the levels of economic growth, consumption, capital accumulation and pollution would decrease under Golden Age Equilibrium. Brock (1977) and Tahvonen & Kuuluvainen (1991) obtained the same conclusions. Huang and Chen (1993) applied the endogenous growth model to prove that the trade-off existed between economic growth and environmental quality in the developed countries.

Milliamn & Prince (1989) and Goulder & Mathai (2000) concluded that the abatement of pollution could generate technological diffusion effects. Thus, the economy could be beneficial from those effects. And the countries had the incentives to apply the new abatement technology accordingly.

Barro & Sala-I-Martin (1995, 1997) employed the optimal control model to discuss the relationships between technological diffusion effects and economic growth. They identified that the new pollution abatement technology of developed countries was the key of world economic growth. But the economic growth of developing countries would converge to the same level as the developed countries after applying the new technology. Yang (1999) concluded that the minimum abatement cost could be fulfilled under CDM. However, there were trade-off between cost efficiency and equity in monopoly instead of perfect competition.

3. Emission Quota and Economic Growth

Two-countries' model, namely the investing country and the host country, has been established in this study. Three assumptions are as follows:

1. Only the investing country has the advanced abatement technology.
2. Two countries both have zero population growth rates.
3. The market of intermediate products for new abatement technology is monopolistic competition. The market of final products for consumption is perfect competition.

3.1 The Model

3.1.1 Investing Country

The social planner of the investing country tries to maximize the social utility. The social instantaneous utility function is:

$$U_1(C_1,S_1)=\frac{\left(C_1 / S_1^{\beta}\right)^{1-\sigma}-1}{1-\sigma}$$

Where C_1 and S_1 are level of general consumption and stock of CO_2 emission respectively. In general, C_1 is treated as 'goods', while S_1 is 'bads'. Thus, $U_C > 0$, $U_{CC} < 0$, $U_S < 0$, and $U_{SS}>0$ must be true. $1/\sigma$ [1] indicates the intertemporal substitution

[1] The common intertemporal consumption function of constant substitution elasticity as：
$U_1(C_1,S_1)=\frac{C_1^{1-\sigma}-1}{1-\sigma}$, which its intertemporal substitution elasticity is $\frac{1}{\sigma}$.

elasticity which is between zero and one. β is the disgust degree of CO_2 stock. The higher β represents the more disgust of CO_2 stock. The production function of the investing country is defined as AK model as follows:

$$Y_1 = A_1 K_1$$

Where A_1 is the given parameter of production technology, and K_1 is capital input which includes physical capital, human capital and stock of knowledge[2]. The investing country is assumed to provide the innovative technology for CO_2 emission abatement. It is assumed that CO_2 emission is the side-product of production no matter what kind of capital input applied, so, the level of CO_2 emission (E_1) is a function of K_1 as follows:

$$E_1 = K_1^{1-\alpha}\left[\int_0^{N_1} X_{1\ j}^{\alpha} dj\right]^{\alpha-1}$$

Where X_{1j} is the intermediate input j, which has N_1 kinds of specialized[3], applied in the innovative technology for CO_2 emission abatement. So, $E_K > 0$, $E_{KK} < 0$, $E_X < 0$, and $E_{XX} > 0$ must be fulfilled. The term of α is the input coefficient of capital and intermediate input, where $0 \le \alpha \le 1$. By substituting K_1 with E_1, the production function of the investing country, that is a function with constant return to scale[4] for the accumulation of innovative technology (N_1), can be changed as follows:

$$Y_1 = A_1 E_1^{\frac{1}{1-\alpha}}\left[\int_0^{N_1} X_{1\ j}^{\alpha} dj\right]$$

The social budget constraint is defined as:

$$Y_1 = C_1 + \eta_1 \dot{N}_1 + N_1 X_1$$

Where the Y_1 is the final physical product that is also equal to the real income. The expenditure of general consumption is C_1. The term of η_1 is the expenditure of

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[2] It is not necessary to distinguish the technologic innovation comes from the physical capital, human capital, or stock of knowledge.

[3] The firm that produces the intermediate goods has a department of R＆D to do the innovative technology.

[4]The production function can be expressed as : $Y_1 = A_1 E_1^{\frac{1}{1-\alpha}} N_1 X_1^{\alpha}$. When N_1 growth t times, Y_1 does it, so Y_1 has constant return to scale with N_1.

each innovation, which must equal to the present value of profit[5]. It is assumed that the market of intermediate input is monopolistic competition. So $\eta_1 \dot{N}_1$ is the amount of outlay devoted to R&D. And N_1X_1 is the amount of expenditure on intermediate goods. This study assumes that all of R&D are devoted to the innovative technology of CO_2 abatement. All of the intermediate goods are non-durable goods and the final goods too. For simplifying the model, it is assumed that $P_y = 1$.

The change of CO_2 stock over time is:

$$\dot{S}_1 = E_1 - bS_1$$

Where b is the natural decay rate of CO_2, and $0 \le b \le 1$.

The complete model for the investing country can be set up as follows:

$$\max_{\{C_1, S_1, N_1\}} \quad U_1 = \int_0^{\infty} \frac{\left(C_1 \big/ S_1^{\beta} \right)^{1-\sigma} - 1}{1-\sigma} \cdot e^{-\rho t} dt \tag{3.1}$$

$$s.t. \quad \dot{N}_1 = \frac{1}{\eta_1} \left\{ A_1 \cdot E_1^{\frac{1}{1-\alpha}} \cdot \left[\int_0^{N_1} X_{1\ j}^{\alpha} dj \right] - C_1 - N_1 \cdot X_1 \right\} \tag{3.2}$$

$$\dot{S}_1 = E_1 - bS \tag{3.3}$$

$$E_1 = \overline{E}_1 \tag{3.4}$$

$$\lim_{t \to \infty} N_1(t)\mu_1(t) = 0 \tag{3.5}$$

$$\lim_{t \to \infty} S_1(t)\lambda_1(t) = 0 \tag{3.6}$$

Where C is the control variable, but N and S are state variables. The preference rate of time is a constant ρ. And $\overline{E}_1$ is the given endowment of CO_2 emission for investing country.

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[5] That is, $\eta_1 = \pi_1 \cdot \int_0^{\infty} e^{-rt} dt$, where π_1 is the profit of the firm that produces the intermediate goods.

3.1.2 Host Country

There is also a social planner who plans to maximize the social utility in the host country. The complete model can be represented as follows:

$$\max_{\{C_2, S_2, K_2\}} \quad U_2 = \int_0^{\infty} \frac{\left(C_2 / S_2^{\beta} \right)^{1-\sigma} - 1}{1-\sigma} \cdot e^{-\rho t} dt \tag{3.7}$$

$$s.t. \qquad \dot{K}_2 = A_2 K_2 - C_2 - \delta K_2 - G_2 \tag{3.8}$$

$$\dot{S}_2 = E_2 - b S_2 \tag{3.9}$$

$$E_2 = K_2^{1+\alpha} G_2^{-\alpha} \tag{3.10}$$

$$\lim_{t \to \infty} N_2(t) \mu_2(t) = 0 \tag{3.11}$$

$$\lim_{t \to \infty} S_2(t) \lambda_2(t) = 0 \tag{3.12}$$

Most variables of this model, such as ρ, a, b, and α, are defined same as it in the investing country's model. The host country is assumed to be the Non-Annex I country without innovative technology of CO_2 abatement. So the social budget constraint is changed to $Y_2 = C_2 + \dot{K}_2 + \delta K_2 + G_2$. Where C_2 is the expenditure for consumption goods. The term of δ is the depreciation rate of capital, thus, $\dot{K}_2 + \delta K_2$ is the accumulation of capital investment which is independent with CO_2 abatement. G_2 is defined as the expenditure of CO_2 abatement. By the definition, $E_K > 0$, $E_{KK} > 0$[6], $E_G < 0$, and $E_{GG} > 0$ must be true. $\overline{E}_2$ is not existed since the host country has no obligation for fulfill the endowment CO_2 emission.

3.2 Derivation of Model

[6] The marginal change of CO_2 emission is increasing with the capital of the host country ($E_{KK} > 0$), but that is decreasing for the investing country ($E_{KK} < 0$). The difference comes from the investing country posses innovative technology of CO_2 abatement, and the host country do not have such effect.

3.2.1 Investing Country

The complete model of investing country can be formulated as the present value of Hamiltonian equation as follows:

$$H = \frac{\left(C_1 / S_1^{\beta} \right)^{1-\sigma} - 1}{1-\sigma} \cdot e^{-\rho t} + \frac{\mu_1}{\eta_1} \left[A_1 \cdot \overline{E}_1^{\frac{1}{1-\alpha}} \cdot N_1 \cdot X_1^{\alpha} - C_1 - N_1 \cdot X_1 \right] + \lambda_1 \left[\overline{E}_1 - bS_1 \right]$$

Where μ_1 and λ_1 are the Hamiltonian multiplier of equation (3.2) and (3.3), that are the shadow prices of N_1 and S_1. By applying the maximum principle, the change rates of shadow prices of N_1 and economic growth are:

$$-\frac{\dot{\mu}_1}{\mu_1} = \frac{1}{\eta_1} \cdot \left(\frac{1-\alpha}{\alpha} \right) \cdot \alpha^{\frac{1}{1-\alpha}} \cdot A_1^{\frac{1}{1-\alpha}} \cdot \overline{E}_1^{\frac{1}{(\alpha-1)^2}} \tag{3.13}$$

$$\begin{aligned} \frac{\dot{C}_1}{C_1} &= \frac{1}{\sigma} \left[\frac{1}{\eta_1} \cdot \left(\frac{1-\alpha}{\alpha} \right) \cdot \alpha^{\frac{1}{1-\alpha}} \cdot A_1^{\frac{1}{1-\alpha}} \cdot \overline{E}_1^{\frac{1}{(\alpha-1)^2}} - \rho \right] \\ &= \frac{1}{\sigma} (r_1 - \rho) \end{aligned} \tag{3.14}$$

This study concludes that the larger change of μ_1, the smaller value of r_1. It means the shadow price of N_1 increasing larger, the intermediate firm's rate of return will decrease overtime. This study also finds that the change rate of economic growth is affected positively by $1/\sigma$, A_1, and $\overline{E}_1$, but it also has negative effects from η_1 and ρ. If it is assumed that $r_1 = 1/\eta_1 \cdot \left((1-\alpha)/\alpha \right) \cdot \alpha^{\frac{1}{1-\alpha}} \cdot A_1^{\frac{1}{1-\alpha}} \overline{E}_1^{\frac{1}{(\alpha-1)^2}}$, then the economic growth rate is positive when $r_1 > \rho$. The reason is that the demand of intermediate goods increases with the innovative technology for CO_2 abatement. So, the economic growth rate will increase[7] due to the production of intermediate goods increased.

3.2.2 Host Country

For the host country, this study also formulate a Hamiltonian equation in terms of

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[7]From the production function and CO_2 emission function of both countries, respectively, the following balance growth path $\frac{\dot{Y}_i}{Y_i} = \frac{\dot{C}_i}{C_i} = \frac{\dot{N}_i}{N_i} \quad i = 1,2$ can be obtained.

present value as follows:

$$H = \frac{\left(C_2 \Big/ S_2^{\beta} \right)^{1-\sigma} - 1}{1-\sigma} \cdot e^{-\rho t} + \mu_2 \left[A_2 K_2 - C_2 - \delta K_2 - G_2 \right] + \lambda_2 \left[K_2^{1+\alpha} \cdot G_2^{-\alpha} - bS_2 \right]$$

Where μ_2 and λ_2 are the Hamiltonian multiplier of equations (3.6) and (3.7), and they indicate the shadow prices of K_2 and S_2, respectively. By applying the maximum principle, the changing rates of μ_2 and economic growth for the host country are:

$$-\frac{\dot{\mu}_2}{\mu_2} = \left(A_2 - \rho \right) - \left(\frac{1+\alpha}{\alpha} \right) \cdot G_2 \cdot K_2^{-1} \qquad (3.15)$$

$$\frac{\dot{C}_2}{C_2} = \frac{1}{\sigma - \beta(\sigma - 1)} \left[A_2 - \delta - \rho - \left(\frac{1+\alpha}{\alpha} \right) \cdot m \cdot A_2 \right] \qquad (3.16)$$

From the equation (3.15), this study finds that the larger of G_2/K_2, the more fluctuation of $\dot{\mu}_2/\mu_2$. Therefore, when the ratio of CO_2 abatement expenditure in the capital increases, the price of capital goods will rise up more. From equation (3.16), it concludes that the economic growth rate has the same sign with $1/[\sigma - \beta(\sigma - 1)]$ and A_2, but with different sign of δ, ρ, and m (where $m = G_2/Y_2$ is defined as the ratio of CO_2 abatement expenditure to the real income). When $A_2 - \delta - \rho - ((1+\alpha)/\alpha) \cdot m \cdot A_2 > 0$, the economic growth rate is positive. Because α represents the coefficient of capital input, so the larger of α indicates the faster of capital accumulation. If $\alpha > m/(1-m)$ shows that the real income is spent more in capital accumulation than in CO_2 abatement expenditure ratio, then the economic growth rate will be positive.

If the host country does not concern the CO_2 emission, then β=0. There is no more expenditure for CO_2 abatement. Most real income can be used in the capital accumulation. The economic growth rate of host country, that can be formulated as follow equation, will increase more.

$$\frac{\dot{C}_2'}{C_2'} = \frac{1}{\sigma} \left[A_2 - \delta - \rho \right]$$

Based on the above statement, this study concludes that the investing country should enhance the incentive for applying the innovative technology for CO_2 abatement. There is no trade-off between the reduction of CO_2 emission and economic growth. The issue of CO_2 abatement should be ignored for the host country with no innovative technology. Because the host country has to devote higher budget for R＆D which will affect the rate of capital accumulation. Then the economic growth rate of host country will fall.

4. CDM, Technological Diffusion Effect, and Economic Growth

4.1 The Model

The idea of CDM was discussed in early 1990, and Merkus & Jones et. al. were the pioneers for the study (Kuik et. al., 1994). It is believed that the innovative technology for CO_2 abatement is an effective method. But, only the investing country can enjoy this advantage. Thus, CDM was proposed in Kyoto Protocol to allow the non-Annex I countries (host country) could also obtain the same advantage. Usually, the transfer of innovative technology from the investing country to the host country will generate the technological diffusion effects (Kuik et. al., 1994). These effects are defined the total effects resulted by applying the innovative technology for CO_2 abatement widely (Milliman and Prince,1989， Jaffe and Stavins,1995，Barro and Sala-I-Martin,1995,1997). Therefore, this study defines the technological diffusion effect as the promotion of economic growth for host country, after adopting the innovative technology of CO_2 abatement and the collection of the certified emission reduction (CERs) as a return for investing country.

This section also establishes two countries' model to analyze CDM, technological diffusion effect, and economic growth together.

4.1.1 Investing Country

The complete model is similar to the one in the section 3. The difference is that the endowment of CO_2 emission is increased in the investing country. Since this study assumes that the investing country can gather total CERs free[8] as a return from the host country after the transfer of new innovative technology for CO_2 abatement. The allowed level of CO_2 emission in the investing country is:

[8]This is according to the Art.3 and Art.12 in the Kyoto Protocol.

$$E_1' = \overline{E}_1 + R$$

Although the host country is a non-annex I country that has no obligation for CO_2 abatement, the amount of CERs generated by the host country has no limitation. The reason why the host country and investing country would like to settle the agreement under CDM is that the host country can obtain the higher economic growth with new innovative technology for CO_2 abatement. In the meantime, the investing country also can gather all CERs from this deal. Therefore, both countries should expect, at least, some fixed amount of CERs. There are incentives of joining CDM for two countries. For simplifying the model, this study assumes that R is a constant. And the level of CO_2 emission in the host country is also assumed to be a constant ($\overline{E}_2$)[9] that is not required by UNFCCC. The complete model for investing country is:

$$\max_{\{C_1, S_1, N_1\}} \quad U_1 = \int_0^\infty \frac{\left(C_1 / S_1^\beta\right)^{1-\sigma} - 1}{1-\sigma} \cdot e^{-\rho t} dt \tag{4.1}$$

$$s.t. \qquad \dot{N}_1 = \frac{1}{\eta_1}\left[A_1 \cdot E_1'^{\frac{1}{1-\alpha}} \cdot N_1 \cdot X_1^\alpha - C_1 - N_1 \cdot X_1.\right] \tag{4.2}$$

$$\dot{S}_1 = aE_1' - bS_1 \tag{4.3}$$

$$E_1' = \overline{E}_1 + R \tag{4.4}$$

4.1.2 Host Country

After joining CDM, the host country's social budget constraint (Y_2) and CO_2 emission function (E_2) have been changed as:

$$Y_2 = C_2 + \upsilon_2 \dot{N}_2 + N_2 X_2$$

$$E_2 = K_2^{1-\alpha} \cdot \left[\int_0^{N_2} X_{2j}^\alpha dj\right]^{\alpha - 1}$$

Where υ_2 is the cost of innovative technology adopted that should be less than the cost of R&D (η_2). K_2 and X_2 are the capital input and intermediate input with N_2 different kinds of specialized for adopting the innovative technology. The other variables and parameters have the same definition in the section 3. Thus, the complete model of the host country is:

[9]Since increasing CO_2 emission can raise economic growth rate, so, the equality will be bind.

$$\max_{\{C_2, S_2, N_2\}} \quad U_2 = \int_0^{\infty} \frac{\left(C_2 / S_2^{\beta}\right)^{1-\sigma} - 1}{1-\sigma} \cdot e^{-\rho t} dt \tag{4.5}$$

$$s.t. \qquad \dot{N}_2 = \frac{1}{\upsilon_2}\left[A_2 \cdot \overline{E}_2^{\frac{1}{1-\alpha}} \cdot N_2 \cdot X_2^{\alpha} - C_2 - N_2 \cdot X_2 \right] \tag{4.6}$$

$$\dot{S}_2 = a\overline{E}_2 - bS_2 \tag{4.7}$$

$$E_2 = \overline{E}_2 \tag{4.8}$$

4.2 Derivation of the Model

4.2.1 Investing Country

By applying the maximum principle, the economic growth rate of investing country can be derived as follows:

$$\frac{\dot{C}_1}{C_1} = \frac{1}{\sigma}\left[\frac{1}{\eta_1} \cdot \left(\frac{1-\alpha}{\alpha}\right) \cdot \alpha^{\frac{1}{1-\alpha}} \cdot A_1^{\frac{1}{1-\alpha}} \cdot E_1'^{\frac{1}{(\alpha-1)^2}} - \rho \right]$$
$$= \frac{1}{\sigma}\left(r_1' - \rho\right)$$

Where $r_1' = \frac{1}{\eta_1} \cdot \left(\frac{1-\alpha}{\alpha}\right) \cdot \alpha^{\frac{1}{1-\alpha}} \cdot A_1^{\frac{1}{1-\alpha}} \cdot E_1'^{\frac{1}{(\alpha-1)^2}}$, represents the firm's rate of return that produces the intermediate goods in the investing country. Because of $E_1' > \overline{E}_1$, the economic growth rate of the investing country will be higher under the CDM. And it is the reason why the investing country is willing to attend CDM.

4.2.2 Host Country

By applying the maximum principle, the economic growth rate of the investing country can be also derived as follows:

$$\frac{\dot{C}_2}{C_2} = \frac{1}{\sigma}\left[\frac{1}{\upsilon_2} \cdot \left(\frac{1-\alpha}{\alpha}\right) \cdot \alpha^{\frac{1}{1-\alpha}} \cdot A_2^{\frac{1}{1-\alpha}} \cdot \overline{E}_2^{\frac{1}{(\alpha-1)^2}} - \rho \right]$$
$$= \frac{1}{\sigma}\left(r_2' - \rho\right) \tag{4.9}$$

Where $r_2' = \frac{1}{\upsilon_2} \cdot \left(\frac{1-\alpha}{\alpha}\right) \cdot \alpha^{\frac{1}{1-\alpha}} \cdot A_2^{\frac{1}{1-\alpha}} \cdot \overline{E}_2^{\frac{1}{(\alpha-1)^2}}$, represents the firm's rate of return that produces the intermediate goods in the host country. Usually, the cost of adopted innovative technology in host country should be small than the cost of R＆D in investing country, and , $\overline{E}_2$ should also less than $\overline{E}_1$. So, the economic growth rate of host country is lower than it in the investing country. Compared with the previous analysis, the economic growth rate after joining CDM is also increased due to the technological diffusion effects.

4.2.3 Dynamic Path and Convergence

However, it is assumed that the cost of innovative technology adopted by the host country is fixed in the previous discussion. In fact, the cost could be changeable overtime. This study tries to find the dynamic path and convergence of economic growth rate for the host country if the cost of innovative technology adopted is changeable. When the cost of adopting the innovative technology is fixed, then:

$$\upsilon_2(t) = \pi_2 \cdot \int_t^{\infty} \exp\left[-\int_t^s r_2'(\nu) \cdot d\nu\right] \cdot ds$$

Differentiating both side with respects to t, and it finds:

$$r_2'(t) = \pi_2 \big/ \upsilon_2(t) + \dot{\upsilon}_2(t) \big/ \upsilon_2(t) \qquad (4.10)$$

Where r_2' is the firm's rate of return that produces the intermediate goods, and π_2 is the firm's profit. The cost of innovative technology adopted in the host country is the function of ratio of N_2 and N_1 as follows:.

$$\upsilon_2 = \upsilon_2\left(N_2 \big/ N_1\right)$$

This study concludes that υ_2 is an increasing function of N_2/N_1 ($\upsilon_2' > 0$), and $N_2/N_1 < 1$[10]. Thus, the growth rate of N_2 and N_1 will equal to each other[11] in the steady state, and υ_2 will be a constant. The equilibrium economic growth rate of host country $\left(\dot{C}_2 \big/ C_2\right)^*$ will be:

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[10] Since the investing country is the technological leader, thus, $N_1(0) > N_2(0)$. When $N_2 = N_1$, the host country may not adopt innovative technology.

[11] That is, N_2/N_1 will converge to a constant.

$$\left(\frac{\dot{C}_2}{C_2}\right)^* = \frac{\dot{C}_1}{C_1} \Rightarrow r_2'^* = r_1' \Rightarrow \frac{\pi_2}{\upsilon_2^*} = \frac{\pi_1}{\eta_1}$$

Where $r_2'^*$ and υ_2^* are the equilibrium paths of r_2' and υ_2 respectively. It is proved that the technological diffusion effects will lead both countries' economic growth rates to be equal, that implies the rate of return for intermediate input in both countries will also be equal.

The new function can be derived from the above equation as follows:

$$\upsilon_2^* = \eta_1 \cdot \pi_2/\pi_1 = \eta_1 \cdot \left(A_2/A_1\right)^{\frac{1}{1-\alpha}} \cdot \left(\overline{E}_2/E_1'\right)^{\frac{1}{(\alpha-1)^2}} \qquad (4.11)$$

Because $A_2 < A_1$, $\overline{E}_2 < E_1'$, and $\eta_1 < \eta_2$, so

$$\frac{\upsilon_2^*}{\eta_2} = \frac{\eta_1}{\eta_2} \cdot \left(A_2/A_1\right)^{\frac{1}{1-\alpha}} \cdot \left(\overline{E}_2/E_1'\right)^{\frac{1}{(\alpha-1)^2}} < 1$$

$$\Rightarrow \upsilon_2^* < \eta_2$$

It implies that host country has no incentive to innovate the new technology for CO_2 abatement, and the investing country is the perpetual leading country for innovative technology. Because $\left(N_2/N_1\right)^* < 1$ [12], $A_2/A_1 < 1$, and $\overline{E}_2/E_1' < 1$, so $Y_2^* < Y_1^*$, that implies the production level of host country will not equal to the same level as investing country even by adopting the innovative technology.

For simplicity, this study defines the explicit form of υ_2 as:

$$\upsilon_2 = \eta_2 \cdot \left(N_2/N_1\right)^{\omega} \qquad (4.12)$$

Where ω is the power of (N_2/N_1), and let $N_2/N_1 < 1$, $\omega > 0$ (if ω=0, which implies the host country will not adopt innovative technology). By defining $\hat{N} = N_2/N_1$, and substitute equations (4.10), (4.12) into (4.9), the economic growth rate and budget constraint of host country are:

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[12] From equations (4.11) and (4.12), we get $\left(N_2/N_1\right)^* = \left[\left(A_2/A_1\right)^{\frac{1}{1-\alpha}} \cdot \left(\overline{E}_2/E_1'\right)^{\frac{1}{(\alpha-1)^2}} \cdot \left(\eta_1/\eta_2\right)\right]^{\frac{1}{\omega}}$,

since $A_2 < A_1$, $\overline{E}_2 < E_1'$, and $\eta_1 < \eta_2$, thus, $\left(N_2/N_1\right)^* < 1$.

$$\frac{\dot{C}_2}{C_2} = \frac{1}{\sigma} \cdot \left[\frac{\pi_2}{\upsilon_2} + \omega \cdot \frac{\dot{\hat{N}}}{\hat{N}} - \rho \right]$$

$$\frac{\dot{\hat{N}}}{\hat{N}} = \left(\frac{1}{\upsilon_2} \right) \cdot \left[\pi_2 \cdot \frac{1+\alpha}{\alpha} - \theta_2 \right] - \frac{\dot{C}_1}{C_1} \tag{4.13}$$

Where $\theta_2 = C_2 / N_2$. By substituting (4.13) into the function of economic growth rate, it can be:

$$\frac{\dot{C}_2}{C_2} = \frac{1}{\sigma} \cdot \left\{ \frac{1}{\upsilon_2} \cdot \left[\pi_2 \cdot \left(1 + \frac{\omega \cdot (1+\alpha)}{\alpha} \right) - \omega\theta_2 \right] - \rho - \omega \cdot \frac{\dot{C}_1}{C_1} \right\}$$

And the growth rate of θ_2 is:

$$\frac{\dot{\theta}_2}{\theta_2} = \left(\frac{1}{\sigma\upsilon_2} \right) \cdot \left\{ \pi_2 + (\sigma - \omega) \cdot \left[\theta_2 - \pi_2 \cdot \frac{1+\alpha}{\alpha} \right] \right\} - \frac{1}{\sigma} \cdot \left(\omega \cdot \frac{\dot{C}_1}{C_1} + \rho \right) \tag{4.14}$$

By applying the phase diagram, the time path of host country can be showed in Figure 1~4. Figure (1), (2), and (4) have only one upward saddle path, and figure (3) shows that there is a stable equilibrium in the economic system. It concludes that the increment cost of adopting the innovative technology will lead the higher economic growth rate of host country than investing country. When the equilibrium ($\hat{N}^*$) is reached, both countries' economic growth rates will converge to same level.

5. Conclusion

There are four accomplishments obtained in this study as follows:

1. The investing country has higher economic growth rate with more CO_2 emission under the clean development mechanism.
2. The country with advanced technology of CO_2 abatement usually has higher economic growth rate. This is because the country can accumulate intermediate inputs easily and is treated as the source of technological progress and the reason of increasing economic growth rate.
3. The sum of two countries' CO_2 emission can reach the proposed level under CDM. Meanwhile, each country can also promote economic growth rate respectively. The investing country gets all CERs from the host country and then increases its products and economic growth rate under CDM. The host country can obtain

technological diffusion effect that induces the higher growth rate by applying the advanced CO_2 abatement technology.

4. In terms of stable equilibrium, the increasing rate of economic growth for the host country is higher than that in the investing country. Two countries' economic growth rates will converge to the same level finally. However, the nominal output level of investing country is always higher than that of the host country under CDM.

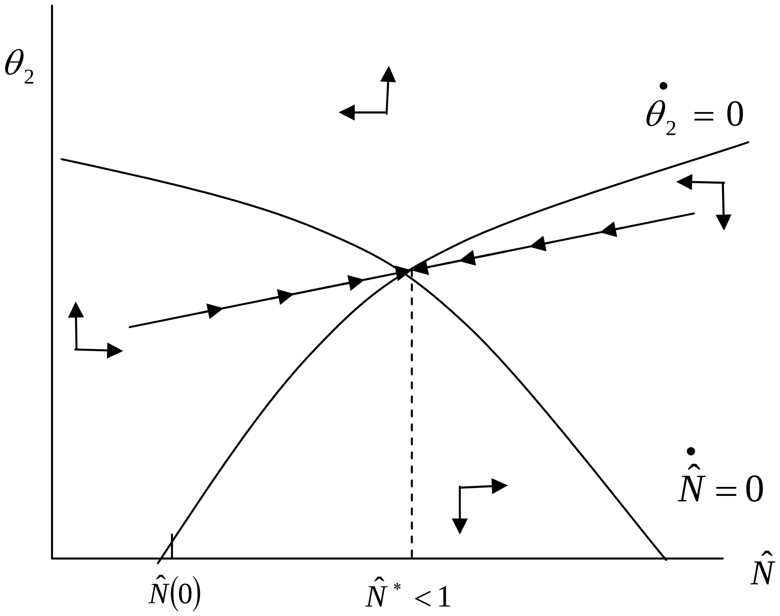

Fig. 1 : Phase Diagram of Host Country -$(\sigma - \omega) > 0$

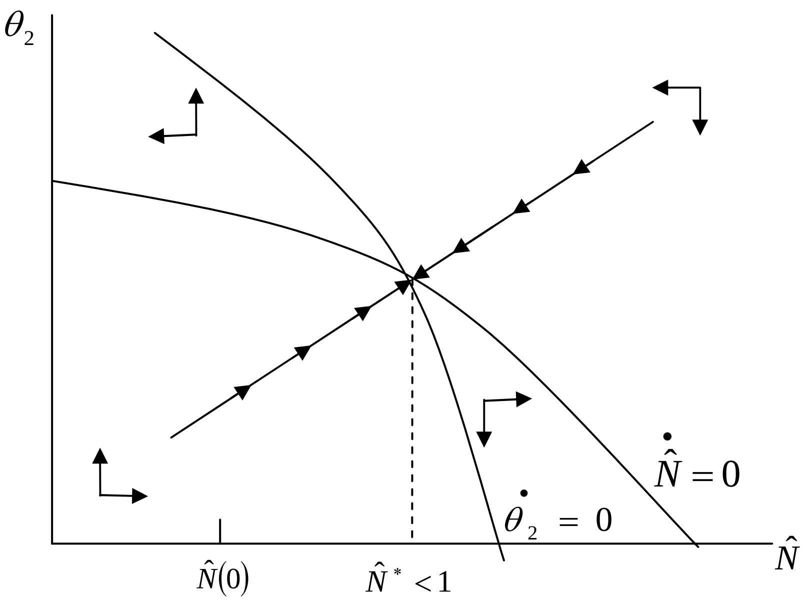

Fig. 2 : Phase Diagram of Host Country - $(\sigma-\omega)<0$, the slope of $\dot{\hat{N}}=0$ is greater than the slope of $\dot{\theta}_2=0$

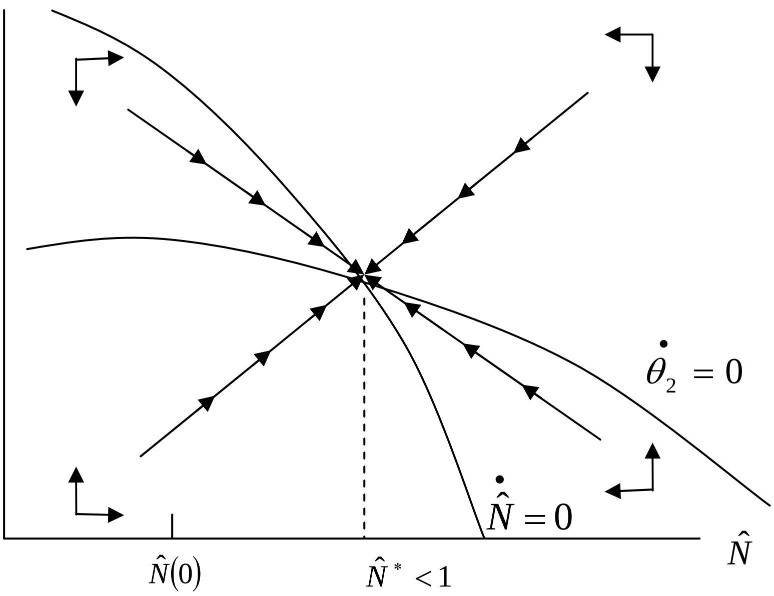

Fig. 3 : Phase Diagram of Host Country - $(\sigma-\omega)<0$, the slope of $\dot{\hat{N}}=0$ is less than the slope of $\dot{\theta}_2=0$

$$\dot{\theta}_2 = 0$$

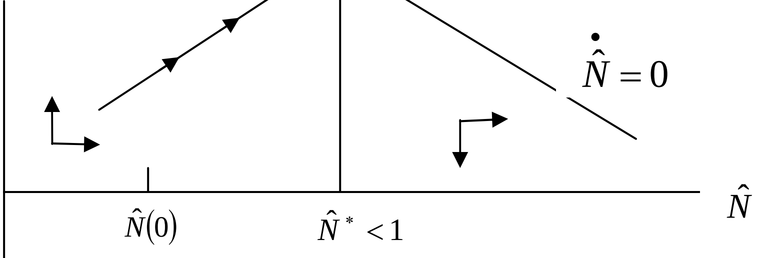

Fig. 4 : Phase Diagram of Host Country $-(\sigma - \omega)=0$

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