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預料到的污染排放標準政策之長短期經濟效果分析

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行政院國家科學委員會補助專題研究計畫 ■成果報告 □期中進度報告

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中文摘要及關鍵詞

近年來，為了滿足民眾愈來愈強烈的環保意識，眾多的環保相關政策因而相繼地施行，因此，環境經濟學者投入了相當多的心力研究環保政策對於總體經濟的影響。既存文獻大多將研究的焦點放在討論環境政策如何影響總體經濟的長期均衡上，然而，關於環保政策對於經濟體系短期動態調整的相關討論，一直是被忽略的部份。觀察民主社會運作的模式可以發現，環境政策在執行之前，必定經過冗長的立法程序、繁雜的預算編列審查過程，與特定長度的緩衝期。也就是說，政策從訊息宣告到實際執行的過程會出現一段時間上的落差(lag)。根據理性預期的理論可以得知，當訊息情報被揭露出來時，民眾會立即將此訊息納入它的情報集合(information sets)中，修正她的預期，進而改變她的行為，引發經濟體系的調整。是以，政策在實際施行前就已經開始影響經濟體系的運作了。

本研究設計了一個理論分析模型，在模型中我們加入了環保的特質，藉此分析*預料到*的污染排放標準政策如何影響經濟體系的長期均衡與短期調整現象。根據我們的研究得知，愈嚴格的污染排放標準對於經濟體系長期的消費水準與資本存量的影響是不確定的。而且，當排放標準政策將改變的消息一旦曝光後，民眾的消費與投資行為就開始發生改變，故經濟體系的資本數量因此受到影響而改變。

英文摘要及關鍵詞

Abstract

This paper develops an intertemporal optimization growth model embodying the nature of the environment, and examines the long-run and the transitional responses to an anticipated rigorous emission standard. Based on our analysis, a rigorous emission standard has an ambiguous impact on both the steady state consumption and capital. But, a lower in the emission standard may accumulate the stock of productive capital before the environmental policy implement.

Key words: Emission standard; anticipated policy; transitional dynamic.

報告內容

Anticipated emission standard policy and transitional dynamics

1. Introduction

Typically, serious environmental damage has accompanied this rapid growth in many economies. As a result, many pollution control instruments, (e.g., emission charge, emission trading, emission standard, etc.) are adopted for preventing environment degeneration. Environmental economists are usually predilection for the use of the emission tax to control pollution externality. However, the ideal Pigouvian tax leaves a serious problem in practice since we are inability to measure the marginal damage of pollution. As a result, the emission standard policy is often adopted for preventing environment degeneration.[1,2]

The purpose of this paper is to try to set a *theoretical* model to examine both the long-run and short-run macroeconomic effects to a rigorous emission standard. In order to incorporate the nature of environment in to analysis model, we first discuss the nature of the environment. The existing literatures usually investigate the impact of the environment on the economy from demand side and supply side. For the demand side effect, peoples usually prefer a clean environment. A rise in the quality of the environment enhances the utility of the representative agent. As a result, Huang and Cai (1994), Ligthart and van der Ploeg (1994), Nielsen et al. (1995) and Schou (2002) introduce environmental quality into the utility function to capture the amenity effect of a clean environment. On the other hand, Nielsen et al. (1995), Bovenberg and Smulders (1995), Musu (1996), Schneider (1997), Bovenberg and de Mooij (1997) and Gottinger (1999) point out that the public must extract some environmental resources as an input for production. The extractive use of the environment will produce emissions. Under the zero extraction cost assumption, emissions can be viewed as a proxy for the extractive use of the environment.[3] Based on this consideration, we take the demand-side effect and supply-side effect of the environment into our analysis framework.

In addition, observing the fact that environmental authorities usually undertake policies with a pre-announcement, it seems that the analysis dealing with *anticipated* policies may be more realistic in the real world. However, most, if not all, existing environment literatures are concerned with the effects of permanent changes in environmental policy, but ignore the transitional dynamics. Based on such a consideration, this paper develops an intertemporal optimization model embodying the nature of environment, and uses it to examine the *announcement* effect of the emission standard on the steady-state impact and the transitional responses of macroeconomics.

The rest of the paper is organized as follows. A macroeconomic model with emission standard is outlined in section 2. Section 3 examines the short-run and long-run impact of the emission standard shock. Finally, section 4 summarizes the main findings of the analysis.

2. The Model

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[1] The vast body of literature has made a comparison between emission taxation policy and emission standard policy. For a more complete review, see Helfand (1999).

[2] "The approach to pollution control adopted by the federal government has by and large been based upon the use of standards, both ambient and emission (or effluent)." (Harford (1978, p. 26) In addition, as illustrated by Helfand (1999) that the United States prefers the mandated standards rather than tax for controlling pollution, while pollution tax is often adopted rather than emission standard in Europe for maintaining clean environment.

[3] As documented by Nielsen et al. (1995, p.188) that "our treatment of pollution as an input reflects the idea that the services provided by the natural environment (including its function as a waste sink) enable the firm to increase its level of output for any given input of other factors."

Consider an economy consisting of a representative household and a government. The household produces a single composite commodity, which can be consumed, accumulated as capital, provided as abatement expenditure, and paid for as a lump-sum tax. The government collects its tax revenue and provides public abatement to lessen pollution damage.

The representative household derives positive utility from consumption, c and derives negative utility from pollutants, P. The objective of the representative household is to maximize the discounted sum of future instantaneous utilities:

$$\int_0^\infty U(c,P)e^{-\rho t}dt\,, \tag{1}$$

where U is the utility function and ρ is the subjective time preference rate. Following Keeler et al. (1971) and Tahvonen and Kuuluvainen (1991) and Gradus and Smulders (1993), to satisfy the requirement that private consumption yields a positive but diminishing marginal utility and that the pollution damage yields a negative and increasing marginal utility, we impose the restrictions $U_c > 0$, $U_P < 0$, $U_{cc} < 0$ and $U_{PP} > 0$. Moreover, $U_{cc}U_{PP} - U_{cP}^2 > 0$ is imposed to ensure that the utility function is concave in the quantities c and P.

At each instant of time, the representative household is bound by a flow constraint linking capital accumulation to any difference between its disposable income and expenditure. The household budget constraint can be described as:

$$\dot{k} = f(k,P) - c - a - t - \delta k\,, \tag{2}$$

where the overdot denotes the rate of change with respect to time, a is the abatement expenditure, t is a lump-sum tax, δ is the depreciation rate, and $f(k,P)$ is the production function. As indicated by Alfsen et al. (1992), Brendemoen and Vennemo (1994), and van Ewijk and van Wijnbergen (1995), that the environmental pollution lowers both the productivity of labor by harming the public's health and the productivity of physical capital by depreciating the productive equipment. We hence follow their pace to incorporate aggregate environmental quality into the production function to capture productive services of the environment. To ensure positive, but diminishing, marginal productivity of capital, the restrictions $f_k > 0$ and $f_{kk} < 0$ are imposed. In addition, we assume $f_P < 0$ and $f_{PP} > 0$ to ensure that the impact of pollution on private production is negative. Moreover, $f_{kP} > 0$ ($f_{kP} < 0$) implies pollution is a complement (substitute) for the capital stock in production.

The main source of pollution is the firm's emission of pollutants. Specifically, emission is an inevitable by-product of production, but can be lessened by devotion to abatement. In common with existing literature, the flow of emission is specified to be positively related to private capital and negatively related to private abatement and public abatement, M. In addition, firms face an emission standard $\bar{e}$ that cannot be exceeded. As a result, the household faces following restriction:

$$e(k,a,M) \le \bar{e}\,, \tag{3}$$

where $e_k > 0$, $e_a, e_M < 0$, $e_{kk} < 0$, $e_{aa}, e_{MM} > 0$. In addition, we assume the cross effects are insignificant, i.e., $e_{ka}, e_{kM}, e_{aM} = 0$.

Total pollution emissions are given by the sum of emissions by the firms. Under symmetric equilibrium and normalized to one, we have

$$P = e(k,a,M)\,, \tag{4}$$

Following Ligthart and van der Ploeg (1994), Michel and Rotillon (1995), Elbasha and Roe (1996), and Bovenberg and de Mooij (1997), we assume that the household treats environmental pollution as given since the household feels that its activities are insignificant in affecting pollution. Given knowledge of the emission standard, the representative household chooses both consumption and abatement expenditure to maximize the discounted sum of utility defined in equation (1), subject to equations (2) and (3). The current-value Hamiltonian function H is thus given by:

$$H = U(c,P) + \lambda[f(k,P) - c - a - t - \delta k] + \phi[\bar{e} - e(k,a,M)],$$

where λ is the co-state variable which can be interpreted as the shadow value of private capital stock, measured in utility terms, ϕ is the Lagrange multiplier associated with emission.

The optimal conditions necessary for this optimization problem are given by:

$$U_c(c,P) = \lambda, \tag{5a}$$

$$-e_a\phi = \lambda, \tag{5b}$$

$$-\dot{\lambda} + \rho\lambda = [f_k(k,e) - \delta]\lambda - e_k\phi, \tag{5c}$$

together with equations (2) and (3), and the transversality condition $\lim_{t\to\infty} \lambda k e^{-\rho t} = 0$. Equation (5a) defines that the co-state variable λ is equal to the marginal utility of consumption. Equation (5b) describes that the marginal benefit of abatement must equal to the marginal cost. The differential equation (5c) is the Euler equation.

The government is assumed to collect lump-sum tax revenue to finance its public abatement expenditure. Assuming that the government balances its budget at any moment, the government's budget constraint thus can be expressed as:

$$t = M. \tag{6}$$

Plugging equation (6) into (2), the resource constraint for the whole economy is given by:

$$\dot{k} = f(k,P) - c - a - M - \delta k. \tag{7}$$

We can easily derive the following instantaneous relationship from equation (3):

$$a = a(k, \bar{e}, M), \tag{8}$$

where, $a_k = -e_k / e_a > 0$, $a_{\bar{e}} = 1/e_a < 0$, and $a_M = -e_M / e_a < 0$.

Using equations (3), (4), and (5a)-(5c), the optimal change in consumption is given by:

$$\dot{c} = \frac{U_c}{U_{cc}}[\rho + \delta - f_k(k,P) - \frac{e_k}{e_a}]. \tag{9}$$

At the steady-growth equilibrium, the economy is characterized by $\dot{k} = \dot{c} = 0$, and k and c are at their stationary levels, namely k^* and c^*. Substituting equation (8) into (7) and (9), and then linearizing the resulting equations around the steady-state equilibrium, we have:

$$\begin{pmatrix} \dot{c} \\ \dot{k} \end{pmatrix} = \begin{pmatrix} 0 & a_{12} \\ -1 & a_{22} \end{pmatrix} \begin{pmatrix} c - c^* \\ k - k^* \end{pmatrix} + \begin{pmatrix} a_{13} \\ a_{23} \end{pmatrix} d\bar{e}, \tag{10}$$

where $a_{12} = -U_c(e_a^2 f_{kk} + e_a e_{kk} - a_k e_k e_{aa}) / U_{cc} e_a^2$, $a_{13} = -U_c a_{\bar{e}} (f_{kP} e_a^3 - e_k e_{aa}) / U_{cc} e_a^2$, $a_{22} = f_k - \delta - a_k > 0$, $a_{23} = a_{\bar{e}}(f_P e_a - 1)$,.

Let s_1 and s_2 be the two characteristic roots of the dynamic system. From equation (10), we then have:

$$s_1 + s_2 = a_{22} = f_k - \delta + a_k, \tag{11a}$$

$$s_1 s_2 = \Delta = a_{12} = \frac{-U_c}{U_{cc} e_a^3}(e_a^3 f_{kk} + e_a^2 e_{kk} + e_k^2 e_{aa}), \tag{11b}$$

As addressed in the literature of dynamic rational expectation models, including Burmeister (1980), Buiter (1984), and Turnovsky (1995), the dynamic system has a unique perfect-foresight equilibrium if the number of unstable roots equals the number of jump variables. Since the dynamic system reported in equation (10) has one jump variable c, in what follows we impose $\Delta = a_{12} < 0$ to assure such a unique perfect-foresight equilibrium.

We now consider the steady-state effect of a rise in the emission standard. It follows from equation (9) with $\dot{k} = \dot{c} = 0$ that the following steady-state relationship is derived:

$$\frac{\partial c^*}{\partial \bar{e}} = -\frac{U_c}{\Delta U_{cc} e_a^3}[(e_k e_{aa} - f_{kP} e_a^3)(f_k - \delta - a_k) + (f_P e_a - 1)(e_a^2 f_{kk} + e_a e_{kk} - a_k e_k e_{aa})], \quad (12a)$$

$$\frac{\partial k^*}{\partial \bar{e}} = \frac{U_c}{\Delta U_{cc} e_a^3}(f_{kP} e_a^3 - e_k e_{aa}). \quad (12b)$$

Obviously, a rigorous emission standard has an ambiguous impact on both the capital stock and consumption. Intuitively, the lower emission standard will reduce pollution damage, leading to a decrease (increase) in the marginal productivity of private capital. This will discourage (encourage) the household to investment. On the other hand, a lower in the emission standard will induce higher abatement expenditure to avoid that emission exceeds a more rigorous level. This will lower the marginal benefit of investment and hence discourage capital accumulation. The net effect of a lower in emission standard on the stock of capital depends upon the relative strength of these two effects. It is clear from equation (12b) that a rigorous emission standard will raise (lower) the steady-state capital stock if the degree of substitution between the capital stock and pollution damage in production function is sufficiently small (large).[4]

Next, we can describe the dynamic behavior of the system by means of a phase diagram. From equation (11b), we know that $s_1 s_2 = \Delta < 0$. For expository convenience, in what follows let s_1 be the negative root and s_2 be the positive root (i.e., $s_1 < 0 < s_2$). It follows from equation (10) that the general solution for k and c can thus be expressed as:

$$c = c^* + A_1 e^{s_1 t} + A_2 e^{s_2 t}, \quad (13a)$$

$$k = k^* + \frac{s_1}{a_{12}} A_1 e^{s_1 t} + \frac{s_2}{a_{12}} A_2 e^{s_2 t}, \quad (13b)$$

where A_1 and A_2 are as yet undetermined coefficients. A graphical solution of the system is provided in Figure 1. From equation (10), the $\dot{k} = 0$ locus is upward sloping, and the $\dot{c} = 0$ locus is a vertical line.[5] Furthermore, the SS curve and UU curve represent the stable and unstable branches, respectively. As indicated by the direction of arrows, the SS curve is upward sloping and steeper than the $\dot{k} = 0$ locus, while the UU curve is downward sloping.[6]

3. Dynamics of a Shock in Public Abatement Expenditure

By using a graphical apparatus like Figure 1, this section proceeds to trace the possible adjustment patterns of the consumption and capital in response to an anticipated shock in the emission standard. The experiment we conduct is that, at time $t = 0$ the authority announces that the emission standard will permanently rise from $\bar{e}_0$ to $\bar{e}_1$ at $t = T$ in the future.

From equation (10) we have:

$$\left.\frac{\partial k}{\partial \bar{e}}\right|_{\dot{c}=0} = -\frac{a_{13}}{a_{12}} \gtrless 0; \text{ as } a_{13} \gtrless 0, \quad (14a)$$

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4 It is clear from equation (12b) that $\partial k^* / \partial \bar{e} \gtrless 0 \quad if \quad f_{\mathrm{kp}} \gtrless e_k e_{aa} / e_a^3$.

5 From equation (10), the slope of the $\dot{k} = 0$ locus and $\dot{c} = 0$ locus are $(\partial c / \partial k)|_{\dot{c}=0} = -a_{12} / a_{11} = \infty$ and $(\partial c / \partial k)|_{\dot{k}=0} = -a_{22} / a_{21} > 0$, respectively.

6 It is clear from equations (13a) and (13b) that $(\partial c / \partial k)|_{SS} = s_1 / a_{12} > 0$, $(\partial c / \partial k)|_{UU} = s_2 / a_{12} < 0 > 0$, $(\partial c / \partial k)|_{SS} - (\partial c / \partial k)|_{\dot{k}=0} = s_1(a_{22} - s_2) / s_1 a_{22} > 0$.

$$\left.\frac{\partial k}{\partial \bar{e}}\right|_{\dot{k}=0} = -\frac{a_{23}}{a_{22}} \gtrless 0 \text{; as } a_{23} \lessgtr 0, \tag{14b}$$

In response to a lower in $\bar{e}$, both the $\dot{k}=0$ locus and $\dot{c}=0$ locus may shift either rightward or leftward.

To trace the component of a_{13}, and a_{23}, we find that key role to determine the sign of a_{13}, and a_{23} are f_{kP} and f_P.[7] Specifically, $a_{13}>0$ ($a_{13}<0$) will be true if the substitution between pollution damage and capital is relatively large (small), and $a_{23}>0$ ($a_{23}<0$) will be taken place when the negative production externality of pollution is sufficiently small (large). Thus, in what follows four cases will be considered: (1) f_{kP} and f_P are relatively large ($a_{13}>0$ and $a_{23}>0$); (2) f_{kP} and f_P are relatively small ($a_{13}<0$ and $a_{23}<0$); (3) f_{kP} is relatively large and f_P is relatively small ($a_{13}>0$ and $a_{23}<0$); and (4) f_{kP} is relatively small and f_P is relatively large ($a_{13}<0$ and $a_{23}>0$).

(1) The f_{kP} and f_P are relatively large ($a_{13}>0$ and $a_{23}>0$) case

Under the situation where f_{kP} is relatively large and f_P is relatively small, $a_{13}>0$ and $a_{23}>0$ will result. We now use Figure 2 to study the adjustment process of the economy in response to an anticipated shock in the emission standard. In Figure 2 the initial equilibrium where $\dot{k}=0(\bar{e}_0)$ intersects $\dot{c}=0(\bar{e}_0)$ is established at E_0; the initial capital stock and consumption are k_0 and c_0, respectively. From equations (14a) and (14b), we know that $\dot{k}=0(\bar{e}_0)$ shift rightward to $\dot{k}=0(\bar{e}_1)$ and $\dot{c}=0(\bar{e}_1)$ shift leftward to $\dot{c}=0(\bar{e}_0)$ in response to an anticipated permanent lower in emission standard. The new steady-state equilibrium is at point E_*, with k and c being k^* and c^*, respectively.

Before proceeding to study the economy's dynamic adjustment, three points should be addressed. First, for expository convenience, in what follows 0^- and 0^+ denote the instant before and after the policy announcement, respectively, while T^- and T^+ denote the instant before and after the policy implementation, respectively. Second, during the dates between 0^+ and T^-, the emission standard remains at its initial level $\bar{e}_0$, and point E_0 should be treated as the reference point that governs the dynamic adjustment of k and c. Third, since the public knows that the emission standard will increase from $\bar{e}_0$ to $\bar{e}_1$ at the moment of T^+, the transversality condition requires the economy to move to a point on the convergent stable branch associated with $\bar{e}_1$, $SS(\bar{e}_1)$, at that instant of time.

Based on these understanding, we now use Figure 2 to illustrate the dynamic adjustment in response to an anticipated lower in the emission standard. We firstly draw a line connecting the initial steady state E_0 and new steady state E_*. This line is named the LL locus. As is evident in Figure 2, the relative steepness between the LL schedule and the convergent branch $SS(\bar{e}_1)$ is ambiguous. If the $SS(\bar{e}_1)$ locus is flatter than the LL line, namely $SS_1(\bar{e}_1)$, then at

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[7] It is clear from the definition of a_{13} and a_{23} that:

$$a_{13} \gtrless 0 \quad if \;\; f_{kP} \gtrless \frac{e_k e_{aa}}{e_a^3},$$

$$a_{23} \gtrless 0 \quad if \;\; f_P \gtrless \frac{1}{e_a}.$$

the instant of policy announcement, c will immediately fall from c_0 to c_{0+}, while k is fixed at k_0 since it is predetermined. Accordingly, the economy will instantaneously jump from point E_0 to a point like E_{0+} on impact. From time 0^+ to T^-, as the arrows indicate, consumption continues to decrease and the stock of capital continues to increase. At time T^+, as the emission standard lower, the economy exactly reaches point E_T on the convergent stable path $SS_1(\bar{e}_1)$. Subsequently, from T^+ onwards, both k and c will continue to fall as the economy moves along the $SS_1(\bar{e}_1)$ curve towards its stationary equilibrium E_*

On the other hand, if the $SS(\bar{e}_1)$ locus is steeper than the LL line, namely $SS_2(\bar{e}_1)$, then at the instant 0^+, c will discontinuously raise from c_0 to c_{0+}^1 and the economy will immediately jump from point E_0 to a point like E'_{0+} on impact. From 0^+ to T^-, as the arrows indicate, c continues to increase and k continues to decrease. When $\bar{e}$ actually decreases at time T^+, the economy exactly reaches the point E'_T on the convergent stable path $SS_2(\bar{e}_1)$. Thereafter, from T^+ onwards, both k and c will continue to fall as the economy moves along the $SS_2(\bar{e}_1)$ curve towards its stationary equilibrium E_*.

(2) The f_{kP} and f_P are relatively small ($a_{13} < 0$ and $a_{23} < 0$) case

Figure 3 depicts the transitional dynamic of an environmental policy shock under the situation that f_{kP} is relatively small and f_P is relatively large. In Figure 3, the initial equilibrium where $\dot{k} = 0(\bar{e}_0)$ intersects $\dot{c} = 0(\bar{e}_0)$ is established at E_0; the initial capital stock and consumption are k_0 and c_0, respectively. In response to an anticipated permanent lower in , shift rightward to $\dot{c} = 0(\bar{e}_1)$, while $\dot{k} = 0(\bar{e}_0)$ shift leftward to $\dot{k} = 0(\bar{e}_1)$. The new steady-state equilibrium is at point E_*, with k and c being k^* and c^*, respectively.

We firstly draw the LL locus which connects the initial steady state E_0 and new steady state E_*. As is evident in Figure 3, if the $SS(\bar{e}_1)$ locus is flatter (steeper) than the LL line, namely $SS_1(\bar{e}_1)$ ($SS_2(\bar{e}_1)$), then at the instant of policy announcement, c will immediately rise (fall) from c_0 to c_{0+} (c'_{0+}), while k is fixed at k_0 since it is predetermined. Accordingly, the economy will instantaneously jump from point E_0 to a point like E_{0+} (E'_{0+}) on impact. From time 0^+ to T^-, as the arrows indicate, consumption continue to increase (decrease), while the stock of capital continues to decumulate (accumulate). At time T^+, as the emission standard falls, the economy exactly reaches point E_T (E'_T) on the convergent stable path $SS_1(\bar{e}_1)$ ($SS_2(\bar{e}_1)$). Subsequently, from T^+ onwards, both k and c will continue to rise as the economy moves along the $SS_1(\bar{e}_1)$ ($SS_2(\bar{e}_1)$) curve towards its stationary equilibrium E_*

(3) The f_{kP} is relatively large and f_P is relatively small ($a_{13} > 0$ and $a_{23} < 0$) case

In Figure 4, the initial equilibrium where $\dot{k} = 0(\bar{e}_0)$ intersects $\dot{c} = 0(\bar{e}_0)$ is established at E_0; the initial capital stock and consumption are k_0 and c_0, respectively. Upon a permanent lower in $\bar{e}$, both $\dot{k} = 0(\bar{e}_0)$ and $\dot{c} = 0(\bar{e}_0)$ shift leftward to $\dot{k} = 0(\bar{e}_1)$ and $\dot{c} = 0(\bar{e}_1)$, $\dot{k} = 0(\bar{e}_1)$ intersects $\dot{c} = 0(\bar{e}_1)$ at point E_*, with k and c being k^* and c^*, respectively. As depicted in Figure 4, two adjustment patterns are possibly present depending upon the length of lead-time between policy announcement and implementation T.

At the instant 0^+, c will immediately raise from c_0 to c_{0+}, while k is fixed at k_0 since it is predetermined. In consequence, the economy will vertically jump from point E_0 to different points between E_0 and D in response to different values of T. If the value of T is smaller (larger), c_{0+} overshoots (undershoots) its long-run value c^*, and hence, the economy instantaneously jumps from point E_0 to E_{0+} (E'_{0+}) on impact. Since point E_{0+} (E'_{0+}) lies vertically above point E_0, from 0^+ to T^-, as the arrows indicate, c continues to increase and k continues to decrease, and the economy moves from E_{0+} (E'_{0+}) to E_T (E'_T) as the arrows indicate. At time T^+, when the pollution standard is enacted, the economy exactly reaches point E_T (E'_T) on the convergent stable path $SS(\bar{e}_1)$. Thereafter, from T^+ onwards, both k and c continue to decrease (increase) as the economy moves along the $SS(\bar{e}_1)$ curve towards its stationary equilibrium E_*.

(4) The f_{kP} is relatively small and f_P is relatively large ($a_{13} < 0$ and $a_{23} > 0$) case

Figure 5 depicts the situation where f_{kP} and f_P are relatively small. In response to an lower in $\bar{e}$, $\dot{k} = 0(\bar{e}_0)$ and $\dot{c} = 0(\bar{e}_0)$ shift rightward to $\dot{k} = 0(\bar{e}_1)$ and $\dot{c} = 0(\bar{e}_1)$, $\dot{k} = 0(\bar{e}_1)$ intersects $\dot{c} = 0(\bar{e}_1)$ at point E_*, with k and c being k^* and c^*, respectively. It is clear from Figure 5, two adjustment patterns are possibly present depending upon the length of lead-time between policy announcement and implementation T. At the instant 0^+, c will immediately fall from c_0 to c_{0+}, while k is fixed at k_0 since it is predetermined. In consequence, the economy will vertically jump from point E_0 to different points between E_0 and D in response to different values of T. If the value of T is smaller (larger), c_{0+} overshoots (undershoots) its long-run value c^*, and hence, the economy instantaneously jumps from point E_0 to E_{0+} (E'_{0+}) on impact. Since point E_{0+} (E'_{0+}) lies vertically above point E_0, from 0^+ to T^-, as the arrows indicate, c continues to fall, while k continues to increase, and the economy moves from E_{0+} (E'_{0+}) to E_T (E'_T). At time T^+, when the pollution standard is enacted, the economy exactly reaches point E_T (E'_T) on the convergent stable path $SS(\bar{e}_1)$. Thereafter, from T^+ onwards, both k and c continue to increase (decrease) as the economy moves along the $SS(\bar{e}_1)$ curve towards its stationary equilibrium E_*.

4. Concluding Remarks

This paper uses a theoretical framework to analyze both the long-run and short-run impact on macroeconomic performance to this *anticipated* rigorous emission standard. Based on our analysis, it finds that a rigorous emission standard has an ambiguous impact on both the steady state consumption and capital. But, a lower in the emission standard may accumulate the stock of productive capital before the environmental regulation implement.

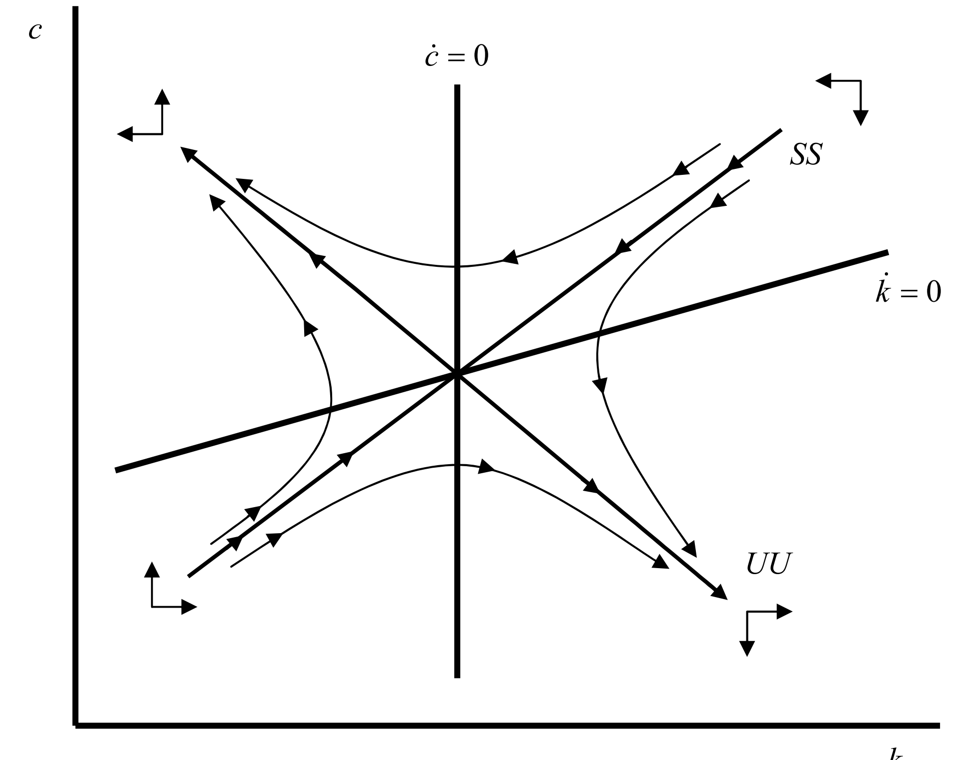

Figure 1 Phase diagram $f_{ke} > 0$.

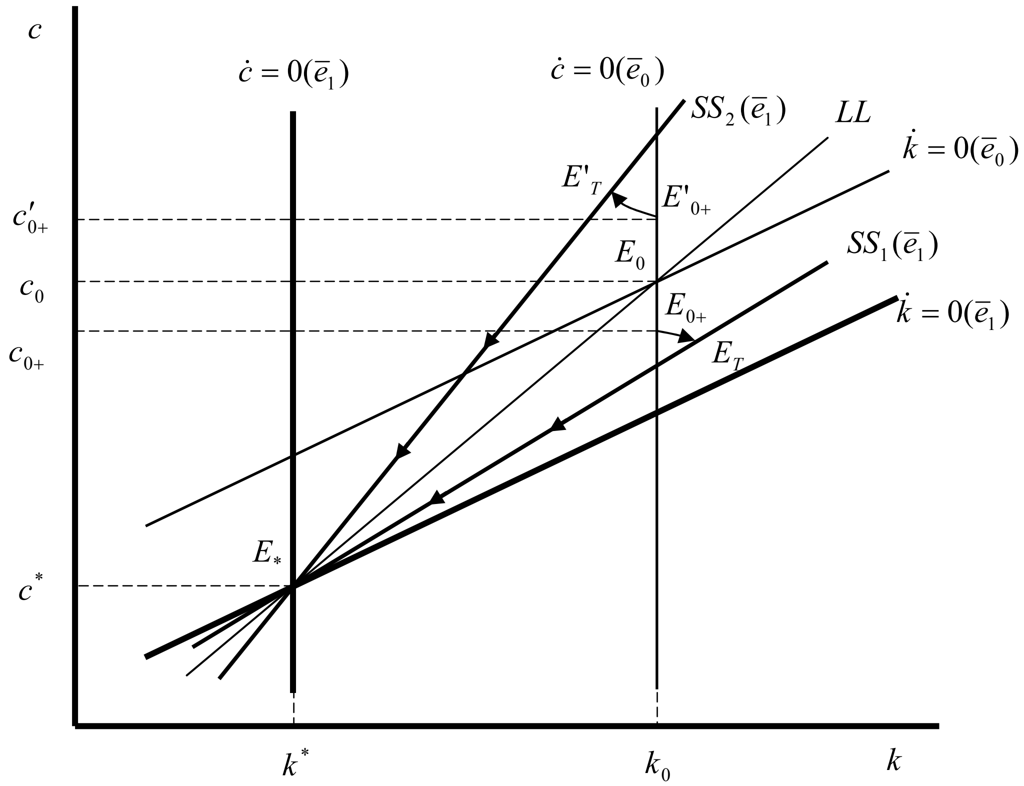

Figure 2 The f_{kP} is relatively large and f_P is relatively small.

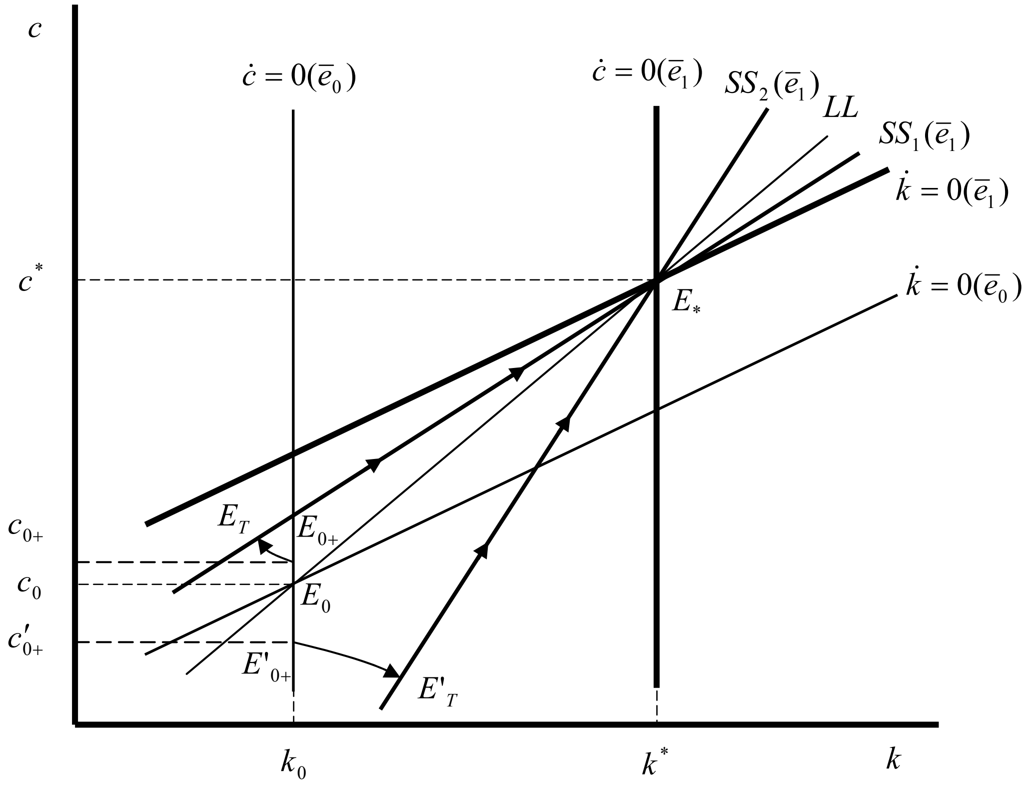

Figure 3 The f_{kP} is relatively large and f_P is relatively large.

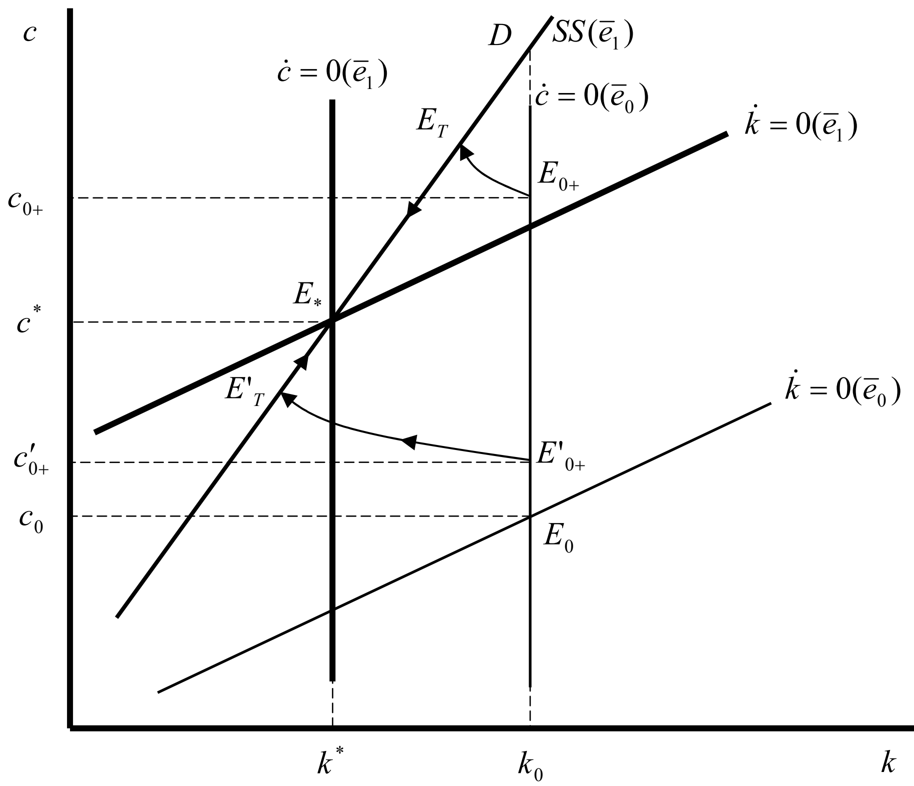

Figure 4 The f_{kP} and f_P are relatively large.

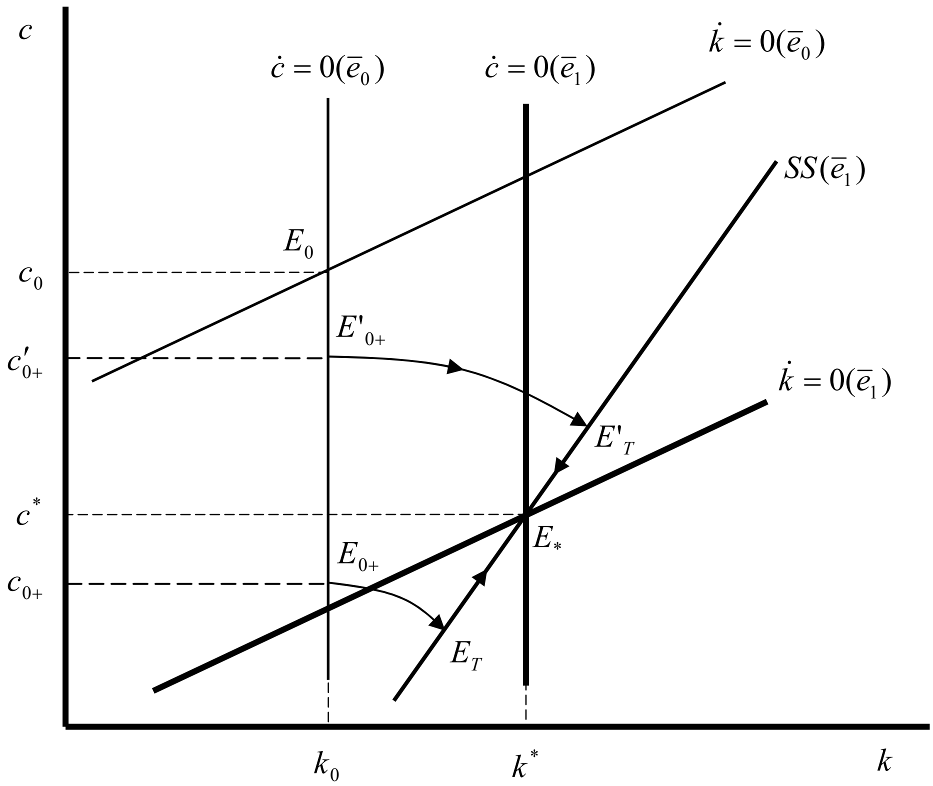

Figure 5 The f_{kP} and f_P are relatively small.

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計畫成果自評

1. 在執行計畫時，我們發現只要依計畫書的構想，當代表性個人考量政府所設定的污染排放限制時，的確會左右經濟體系的消費、產出與投資，進而影響總體經濟的均衡。更重要的是，「預期」在經濟體系的確扮演著相當重要的角色，當私部門事先知道政策將改變的訊息時，他將會改變他的行為方式，造成總體經濟產生波動。由於既存文獻缺乏關於預料到的污染排放管制對於經濟成長影響的探討。是以，本研究的結果確實可以彌補既存環境經濟學文獻發展中的不足，確有其學術價值，也適合於發表於著名的國際學術期刊。

2. 本計畫的成果已經撰寫成學術論文，我們將聽取專家學者意見並稍做修正後，投稿國際學術期刊。