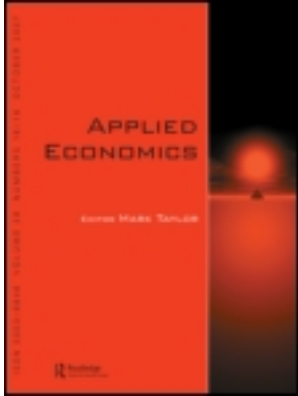


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Publisher: Routledge

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Applied Economics

Publication details, including instructions for authors and subscription information:
<http://www.tandfonline.com/loi/raec20>

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Published online: 18 Jun 2009.

To cite this article: Ming-Chung Chang & Jin-Li Hu (2011) Inconsistent preferences in environmental protection investment and the central government's optimal policy, Applied Economics, 43:6, 767-772, DOI: [10.1080/00036840802599891](https://doi.org/10.1080/00036840802599891)

To link to this article: <http://dx.doi.org/10.1080/00036840802599891>

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Inconsistent preferences in environmental protection investment and the central government's optimal policy

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Environmental protection plans cannot succeed without full cooperation among related units. However, inconsistent investment preferences toward environmental protection increase the damage to the environment. This article employs the contract mechanism to analyse environmental protection effects when the central government directly subsidizes the local governments. The results reveal that subsidies from the central government are not only unable to solve the problem of the inconsistent investment preferences among the central and local governments but also induce the free-riding behaviour of local governments. Because of the free-riding behaviour of the local governments, there is no such equilibrium in which the central government prefers the sequential investment mode while the local governments prefer the simultaneous investment mode.

I. Introduction

Many studies suggest that the government should subsidize environmental protection activities. Hence, governments all over the world expend sizable budgets to subsidize the natural resource sectors such as agriculture, energy, water, forestry and fisheries (OECD, 1998, 1999; van Beers and de Moor, 2001). However, many environmental protection activities cannot succeed without the full cooperation among different countries' governments.

Many real examples can illustrate the importance of collaboration in environmental protection. For instance, the Dead Sea is a well-known tourist spot, but it is also disappearing. The main reason for the Dead Sea to be literally on the verge of death is an interception in the upstream of the Jordan River by

the bordering countries of Israel, Jordan and Palestine for agricultural irrigation purposes. However, the countries bordering the Dead Sea are planning to save the Dead Sea (DWNEWS, 2006). Besides, the lakes Ohrid and Prespa are the largest natural reservoirs in Europe. However, they are being damaged by the pollution from agricultural wastewater that is passing through them. Macedonia and Albania have thus signed a contract to protect them (Environment News Service, 2003).

The Tamsui River in Taiwan is a boundary river between Taipei county and Taipei city, and the renovation of the Tamsui River requires a joint collaboration on the part of the Taipei county government, the Taipei city government and the central government in Taiwan. In this case, the cooperation in relation to environmental protection

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is formed by two local governments and a central government. Because of the inconsistent investment preferences in environmental protection among the central and local governments, subsidies from the central government may induce social welfare losses.

This article applies the game-theoretic approach to analyse the environmental protection effects when the central government directly subsidizes the local governments. We also examine how direct subsidies from the central government affect the local governments' environmental protection behaviour. Our direct subsidy method is different from those in standard public economics: the traditional public economics theories often analyse the subsidy as a negative tax (Atkinson and Stiglitz, 1980). The subsidy by way of the negative tax can be seen as an indirect subsidy. Hence the central government can use a direct subsidy to affect the environmental protection investment outcomes of the local governments.

The previous literature regarding environmental protection subsidies consists of general and partial equilibrium analyses. The general equilibrium modelling requires many assumptions regarding the behaviour of consumers and sectors, as well as many parameters that need to be estimated (see also Burniaux *et al.*, 1992). Although the partial equilibrium analysis is restricted to a single sector, the single-sector effects of specific subsidies in a partial equilibrium framework can also provide good intuition and insight in environmental economics (Larsen and Shah, 1992; Ostbye, 1998; Giosa *et al.*, 1999; International Energy Agency, 1999; van Beers *et al.*, 2007). The previous studies, however, do not use the contract mechanism to analyse the effect of environmental protection. By contrast, this article employs the contract mechanism to analyse the environmental protection effects when the central government directly subsidizes the local governments in a partial equilibrium framework.

There arises the problem of the inconsistent investment preferences of contracting parties when an investor cannot obtain the investment gain (Hart and Moore, 1988) or when the investment contract is incomplete (Grout, 1984; Grossman and Hart, 1986; Hart and Moore, 1988). The problem of inconsistent investment preference can be solved by formal fixed-wage contracts (MacLeod and Malcomson, 1993), renegotiation on contract content (Aghion *et al.*, 1994), simple option contracts (Nöldeke and Schmidt, 1995), or increasing collateral over time (Neher, 1999). We employ the models of Smirnov and

Wait (2004a, b) to discuss the central and local governments' environmental investment preferences and the optimal policy to maximize the social welfare. We find that the environmental protection subsidy from the central government is unable to achieve the socially optimal point because of free-riding behaviour among local governments. It is possible that the investment preference in environmental protection is inconsistent between the central and local governments. The penalty for violating the environmental protection contract induces the consistent investment preference between the central and local governments.

The remainder of this article is organized as follows: Section II consists of the model setup and the process for calculating the sub-game perfect Nash equilibrium. Section III discusses investment preference inconsistency among the central government and local governments. Section IV resolves the problems caused by inconsistent investment preferences. Section V concludes the article.

II. Model Setup

We employ a two-period, three-stage model with two local governments (GOV *A* and GOV *B*) and one central government. In the first stage, the central government chooses a subsidy to optimize the environmental protection effect. In the second stage, two local governments decide either to adopt the simultaneous mode or the sequential investment mode. In the third stage, two local governments decide the optimal environmental protection investment quantities. We characterize the sub-game perfect Nash equilibrium and adopt backward induction to calculate the solution to this game.

Two local governments' investment quantities are defined as m_A and m_B . Following the formulation of Smirnov and Wait (2004a), we define the environmental protection effect function as $E = \beta m_A^{1/2} + \beta m_B^{1/2}$, where $\beta > 0$, $m_i \geq 0$ and $i = A, B$.¹ This functional form indicates that there is a positive relationship between the environmental protection investment quantity and the environmental protection effect. Moreover, the marginal effect of investment is negative, i.e. $\partial E / \partial m_i > 0$, $\partial^2 E / \partial m_i^2 < 0$. This functional form also indicates that there are independent relationships among the environmental protection investors. Furthermore, if all investors are engaged in the environmental protection's

¹ Smirnov and Wait (2004a) used a similar function to analyse the optimal collaborative investment-timing and the influence of the hold-up problem on the social welfare. The setup for their function was $E = \sum \beta_i \ln m_i$, where $i = A$ or B .

investment, then there will be a significant environmental protection effect. The parameter β is the coefficient of the environmental protection effect.

Because the central government pursues the optimal environmental protection effect, it plays a role of subsidizing the local governments' environmental protection investment. Assume that the central government only subsidizes the local governments in the first period and then does not provide any subsidy in the second period. Under the subsidy case, if the central government subsidizes local government i , then local government i 's total investment quantity is $m_i + s$, where s is the subsidy from the central government and $s \geq 0$. We also assume that GOV A invests in two periods and GOV B starts to invest either in the first period or in the second period. If both local governments start to invest in the first period, then this is defined as the simultaneous investment mode; if both local governments start to invest in different periods, i.e. GOV A starts to invest in the first period and GOV B starts to invest in the second period, then this is defined as the sequential investment mode.

Regardless of whether the simultaneous investment mode or the sequential investment mode is adopted, the coefficient of the environmental protection effect in the first period is β . In the second period the coefficient of the environmental protection effect is β^{SI} ($=\beta + \varepsilon^{SI}$) in the simultaneous mode, and the coefficient of the environmental protection effect is β^{SE} ($=\beta + \varepsilon^{SE}$) in the sequential investment mode, where $\varepsilon^{SI} > \varepsilon^{SE} > 0$. The parameter ε^j is an externality in the environmental protection investment, where $j = SI$ or SE . Furthermore, $\varepsilon^{SI} > \varepsilon^{SE} > 0$ indicates that the externality in the simultaneous investment mode is larger than that in the sequential investment mode.

Many political economists have proposed that the central government should establish a reward system to encourage the local government to achieve a good performance. Hence we assume that if the environmental protection effect is more significant, then the local government can obtain a bigger reward. Besides, the reward is also a function of the proportion of the population. Define the parameter u as the proportion of the population in the area of GOV A and the proportion of population $1 - u$ in the area of GOV B , where $u \in [0, 1]$. Following the idea of Grossman and Helpman (1994), we assume that the local government maximizes the revenue function.

Solution in the third stage

In this stage, the local government decides the optimal environmental protection investment quantity.

Simultaneous investment mode. According to the model setup, in the first period the revenue functions of GOV A and GOV B are $R_{A1}^{SI} = u[\beta(m_{A1} + s^{SI})^{1/2} + \beta(m_{B1} + s^{SI})^{1/2}] - m_{A1}$, and $R_{B1}^{SI} = (1 - u)[\beta(m_{A1} + s^{SI})^{1/2} + \beta(m_{B1} + s^{SI})^{1/2}] - m_{B1}$, where s^{SI} is a subsidy from the central government in the case of the simultaneous investment mode. In the second period, the revenue functions of GOV A and GOV B are $R_{A2}^{SI} = u[\beta^{SI}m_{A2}^{1/2} + \beta^{SI}m_{B2}^{1/2}] - m_{A2}$, and $R_{B2}^{SI} = (1 - u) \times [\beta^{SI}m_{A2}^{1/2} + \beta^{SI}m_{B2}^{1/2}] - m_{B2}$. We obtain the two local governments' optimal investment quantities in the first period as $m_{A1}^{SI} = (u\beta/2)^2 - s^{SI}$ and $m_{B1}^{SI} = ((1 - u)\beta/2)^2 - s^{SI}$. The optimal investment quantities in the second period are $m_{A2}^{SI} = (u\beta^{SI}/2)^2$ and $m_{B2}^{SI} = ((1 - u)\beta^{SI}/2)^2$. Hence the reduced forms of GOV A 's and GOV B 's revenue functions for the two periods, i.e. $R_i^{SI} = R_{i1}^{SI} + rR_{i2}^{SI}$, are:

$$R_A^{SI} = \frac{2u - u^2}{4}[\beta^2 + r(\beta^{SI})^2] + s^{SI} \quad (1)$$

$$R_B^{SI} = \frac{1 - u^2}{4}[\beta^2 + r(\beta^{SI})^2] + s^{SI} \quad (2)$$

where r is the discount factor, and $r \in [0, 1]$.

Sequential investment mode. In the first period, the revenue functions of GOV A and GOV B are $R_{A1}^{SE} = u[\beta(m_{A1} + s^{SE})^{1/2} + \beta(s^{SE})^{1/2}] - m_{A1}$, and $R_{B1}^{SE} = (1 - u)[\beta(m_{A1} + s^{SE})^{1/2} + \beta(s^{SE})^{1/2}]$, where s^{SE} is a subsidy from the central government in the case of the sequential investment mode. In the second period, the revenue functions of GOV A and GOV B are $R_{A2}^{SE} = u[\beta^{SE}m_{A2}^{1/2} + \beta^{SE}m_{B2}^{1/2}] - m_{A2}$, and $R_{B2}^{SE} = (1 - u)[\beta^{SE}m_{A2}^{1/2} + \beta^{SE}m_{B2}^{1/2}] - m_{B2}$. The optimal investment quantities that we obtain in the first period are $m_{A1}^{SE} = (u\beta/2)^2 - s^{SE}$ and $m_{B1}^{SE} = 0$. The optimal investment quantities in the second period are $m_{A2}^{SE} = (u\beta^{SE}/2)^2$ and $m_{B2}^{SE} = [(1 - u)\beta^{SE}/2]^2$. Hence the reduced forms of GOV A 's and GOV B 's revenue functions for the two periods, i.e. $R_i^{SE} = R_{i1}^{SE} + rR_{i2}^{SE}$, are:

$$R_A^{SE} = u\beta\sqrt{s^{SE}} + s^{SE} + \frac{u^2\beta^2 + r(2u - u^2)(\beta^{SE})^2}{4} \quad (3)$$

$$R_B^{SE} = (1 - u) \left[\beta\sqrt{s^{SE}} + \frac{u\beta^2}{2} + r(1 + u) \left(\frac{\beta^{SE}}{2} \right)^2 \right] \quad (4)$$

We find that in the first stage the environmental protection investment quantity of the local government is a decreasing function of the central government's subsidy. The more subsidies there are from the central government, the less that a local government will invest. Subsidies for the environmental protection investment from the central government cause

the local governments to adopt free-riding behaviour. Hence we obtain the following proposition:

Proposition 1: *Subsidies for the environmental protection investment from the central government cause the local governments to exhibit free-riding behaviour.*

Solution in the second stage

In this stage we attempt to find the optimal investment mode, which is either the simultaneous investment mode or the sequential investment mode. Because GOV *A* invests in the first period, GOV *B* is the key decider of the investment mode. If $R_B^{SI} > (<) R_B^{SE}$, then the optimal investment mode is simultaneous (sequential). By letting $R_B^{SI} - R_B^{SE} > 0$, the condition must be satisfied as follows:

$$(1-u)\beta^2 + r(1+u)[(\beta^{SI})^2 - (\beta^{SE})^2] + 4\left(\frac{s^{SI}}{1-u} - b\sqrt{s^{SE}}\right) > 0 \quad (5)$$

The first item and the second item on the left-hand side of Equation 5 are positive. If the third item on the left-hand side of Equation 5 is positive, then $s^{SI} > (1-u)\beta\sqrt{s^{SE}}$. This implies that if the subsidy in the simultaneous investment mode is large, then the local governments prefer the simultaneous investment mode. On the contrary, if the subsidy in the sequential investment mode is large enough to cover the first term and the second term, then the local governments prefer the sequential investment mode. Hence the local governments' investment preference is affected by the magnitude of the investment subsidy from the central government and the magnitude of the investment externality.

Solution in the first stage

In this stage, the central government decides the optimal investment subsidy.

Simultaneous investment mode. In this stage the central government chooses the optimal subsidy to maximize the environmental protection effect, i.e. $E^{SI} = E_1^{SI} + rE_2^{SI}$, where $E_1^{SI} = \beta(m_{A1}^{SI} + s^{SI})^{1/2} + \beta(m_{B1}^{SI} + s^{SI})^{1/2}$, and $E_2^{SI} = \beta^{SI}(m_{A2}^{SI})^{1/2} + \beta^{SI}(m_{B2}^{SI})^{1/2}$. The optimal subsidy for the central government is $s^{SI*} = 0$. The reduced form of the environmental protection effect for the two periods is:

$$E^{SI} = \beta^2/2 + (r/2)(\beta^{SI})^2 \quad (6)$$

Sequential investment mode. In this mode, the function of the environmental effect for the two periods is $E^{SE} = E_1^{SE} + rE_2^{SE}$, where $E_1^{SE} = \beta(m_{A1}^{SE} + s^{SE})^{1/2} + \beta(m_{B1}^{SE} + s^{SE})^{1/2}$, and $E_2^{SE} = \beta^{SE}(m_{A2}^{SE})^{1/2} + \beta^{SE}(m_{B2}^{SE})^{1/2}$. The optimal subsidy for the central government is $s^{SE*} = (u\beta/2)^2$. The reduced form of the environmental protection effect for the two periods is:

$$E^{SE} = u\beta^2 + (r/2)(\beta^{SE})^2 \quad (7)$$

From Equations 6 and 7, if $E^{SI} > E^{SE}$, then the central government prefers the simultaneous investment mode. On the contrary, if $E^{SI} < E^{SE}$, then the central government prefers the sequential investment mode. The condition that the central government prefers the simultaneous mode is:

$$E^{SI} - E^{SE} = [(1/2) - u]\beta^2 + (r/2)(\beta^{SI} + \beta^{SE})(\beta^{SI} - \beta^{SE}) = [(1/2) - u]\beta^2 + (r/2)(2\beta + \varepsilon^{SI} + \varepsilon^{SE}) \times (\varepsilon^{SI} - \varepsilon^{SE}) > 0 \quad (8)$$

Substituting $s^{SI*} = 0$ and $s^{SE*} = (u\beta/2)^2$ into Equation 5 and rearranging it, we obtain the condition that the local government prefers the simultaneous investment mode as follows:

$$R_B^{SI} - R_B^{SE} = (1-3u)\beta^2 + r(1+u)(\beta^{SI} + \beta^{SE})(\beta^{SI} - \beta^{SE}) = (1-3u)\beta^2 + r(1+u)(2\beta + \varepsilon^{SI} + \varepsilon^{SE}) \times (\varepsilon^{SI} - \varepsilon^{SE}) > 0 \quad (9)$$

III. Inconsistent Preferences in the Environmental Protection Investment

In this section, we examine the problem of an inconsistent investment preference in environmental protection.

It can be easily checked from Equations 8 and 9 that if $\varepsilon^{SI} - \varepsilon^{SE} = 0$ then the intercept terms of the curves $E^{SI} - E^{SE} = 0$ and $R_B^{SI} - R_B^{SE} = 0$ are 1/2 and 1/3, respectively. Furthermore the slope of the curve $E^{SI} - E^{SE} = 0$ is always larger than the slope of the curve $R_B^{SI} - R_B^{SE} = 0$. In other words, there is no intersection between the curve $E^{SI} - E^{SE} = 0$ and the curve $R_B^{SI} - R_B^{SE} = 0$. The relationship between the two curves in the geometric figure can be shown in Fig. 1.

In Fig. 1, regimes I and III are areas in which the central government and the local governments have the same investment preference. In regime I (III), both of them prefer the simultaneous (sequential) investment mode. However, regime II is a preference inconsistent area. In this area, the central government prefers the simultaneous investment mode and the

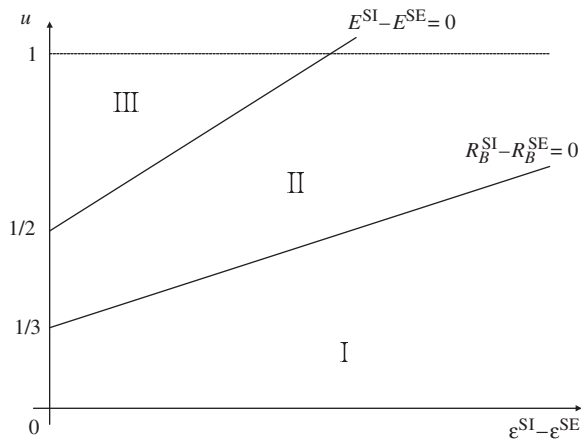


Fig. 1. Investment preference in environmental protection

local governments prefer the sequential investment mode. Hence we have the following proposition:

Proposition 2: *It is possible to have inconsistent preferences in the environmental protection investment between the central government and the local governments; besides, the equilibrium where the central government prefers the sequential investment mode and the local governments prefer the simultaneous mode does not exist because of the free-riding behaviour of the local governments.*

In Fig. 1, we also find that when the externality of the simultaneous investment mode is large, the central government prefers the simultaneous investment mode. If the proportion of the reward that the local government *B* obtains (i.e. $1 - u$) is small, then the local governments prefer the sequential investment mode. Hence if the externality of the simultaneous investment mode is large and the proportion of the reward that the local government *B* obtains is small, then both of them have an inconsistent investment preference. We then have the following proposition:

Proposition 3: *The investment preference inconsistency is the cause of a small proportion of the reward that the critical local government obtains and the greater externality in the simultaneous investment mode.*

IV. Solution of the Inconsistent Preferences in the Environmental Protection Investment

In a contract mechanism, the penalty can punish the player that violates the contract in order to ensure that the contract can work. In Fig. 1, regime II is an

area of inconsistent preferences in environmental protection investment. In regime II, GOV *B* selects the sequential investment mode. However GOV *B*'s preference violates the central government's preference. Hence the central government should set a penalty to make GOV *B* invest in the first period.

In regime II, the payoff for GOV *B* in the sequential investment mode is higher than that in the simultaneous investment mode, i.e. $R_B^{SE} > R_B^{SI}$. If two local governments agree on a simultaneous investment contract and the penalty that violates the contract is $Z \geq R_2^{SE} - R_2^{SI}$, then GOV *B* will abide by the simultaneous investment contract. Hence the central government can encourage the local governments to negotiate a simultaneous investment contract and to set a penalty for solving the problem regarding the inconsistent investment preference.

V. Conclusion

This study uses a two-period, three-stage game to discuss the issue of the inconsistent preference in environmental protection investment. We find that if the central government increases its subsidy in relation to environmental protection investment, then the local government will decrease its investment in environmental protection. In other words, the local governments exhibit free-riding behaviour in their environmental protection investment, and the central government's investment preference is affected by the externality of the investment mode. If the externality of the simultaneous investment mode is large, then the central government will prefer the simultaneous investment mode. Hence, it is possible to have an inconsistent investment preference between the central government and the local governments. The reasons that give rise to the inconsistent investment preference between the central government and the local governments are the large externality that arises from the simultaneous investment mode and the small proportion of the reward that the critical local government obtains. However there is no such equilibrium in which the central government prefers the sequential investment mode and the local governments prefer the simultaneous investment mode.

Acknowledgements

The first author gratefully acknowledges the financial support provided by Taiwan's National Science Council (NSC 95-2415-H-424-001).

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