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Examining the Double Dividend Effect of Energy Tax with the Overlapping Generations Model

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ABSTRACT

This paper constructed a two-period overlapping generations (OLG) model to investigate the effects of the energy tax on environmental quality (the first dividend) and output level (the second dividend) to review the double dividend effect of the energy tax. According to the results of comparative static analysis, we found that the energy tax can improve environmental quality but cannot affect the output level. This suggests that the double effect of the energy tax is not supported in the OLG model. This is because an agent can only survive two periods, and need to give consideration to the consumption level of two-generation and the environmental quality of second-generation for pursuing the maximization of lifetime utility, therefore, the agent must maintain consumption (output) stability, and the double dividend effect does not exist.

Keywords: Energy Tax, Double Dividend Effect, Overlapping Generations Model
JEL Classifications: H23, H24, Q43

1. INTRODUCTION

The influence of the greenhouse effect on global climate change is increasingly significant. While global warming mitigation is urgent, green taxes (such as carbon tax and energy tax) have become one of the potential economic tools for emissions reduction. As the energy tax has great results in Europe, it has almost become an important policy for countries in the world to reduce greenhouse gas emissions, and the review of the double dividend effect of energy tax thus gains increasing importance. The term "double dividend" first appeared in Pearce (1991). The basic concept is to reduce energy consumption by raising the energy tax to achieve environmental protection (the first dividend, hereinafter referred to as D-I) and enhance the efficiency of social resource allocation, improve national welfare, increase gross domestic product or employment quantity (the second dividend, hereinafter referred to as D-II) (Pearce, 1991; Oates, 1993; Bovenberg and de Mooij, 1994a; Carraro et al., 1996; Kuper, 1996; Bosello et al., 2001; Deroubaix and Lévègue, 2006).

There is little noise regarding the theory that energy tax can help improve the environment (D-I is supported). Pigou (1947) was the first to suggest solve pollution problems with environmental taxes (also known as the Pigouvian tax). According to him, the environmental tax can increase the supply cost of energy products, which, in turn, raises product prices through the market mechanism to reduce energy demand and thereby reduce emissions. Compared to D-I that has earned general recognition, the existence of D-II remains inconclusive. In earlier literature, D-II was supported by most scholars. Terkla (1984) proposed that the pollution tax could resolve tax distortions. For example, deducing personal income tax with pollution tax revenue may reduce the excess burden of income tax (such as Bosquet, 2000; Goulder, 1995a and 1995b; Parry and Bento, 2000). Reducing the social insurance fee for employees with pollution tax revenue enables employers to hire more employees to increase employment (such as Deroubaix and Lévèque, 2006; Conrad and Löschel, 2005; Bosello and Carraro, 2001; Bovenberg and de Mooij, 1997; Carraro et al., 1996; Kuper, 1996). In recent years, however, many scholars doubted this dividend. As shown in related literature, there are many factors affecting the existence of D-II, including (1) product market structure (such as Barnett, 1980); (2) tax mutual effect (such as Bovenberg and de Mooij, 1994a, 1994b; Goulder, 1995b; Parry, 1995; Kahn and Farmer, 1999); (3) the necessity of taxation and the reasonability of tax rates (such as Parry, 1995; Bovenberg and Goulder, 1996); (4) selection of tax base (such as Bovenberg and de Mooij, 1994b; Goulder, 1995b; Parry, 1995; Manresa and Sancho, 2005); (5) consumption preference characteristics (such as Kahn and Farmer, 1999; Schwartz and Repetto, 2000; Williams, 2002 and 2003); (6) the imperfect competition on the labor market (such as Carraro et al., 1996; Bosello and Carraro, 2001); (7) non-environmental perspective (such as Goulder et al., 1997; Bovenberg, 1999; Parry and Bento, 2000; Conrad and Löschel, 2005; Bento and Jacobsen, 2007); and (8) cross-generation welfare (such as Chiroleu-Assouline and Fodha, 2005 and 2006). After years of debates, no conclusive result has been made so far. After collating comprehensive arguments in literature related to double dividend, therefore, this paper re-examined the double dividend of the energy tax.

There are three types of double dividend analysis include: (1) Partial equilibrium analysis, such as Tullock (1967), Terkla (1984), Lee and Misiolek (1986), and Pearce (1991); (2) sticky wage model, such as Bovenberg (1998), Bovenberg and Van der Ploeg (1994), Carraro and Soubeyran (1996), Brunello (1996), Carraro et al. (1996), Bayindir-Upmann and Raith (1997), Bovenberg (1997); and (3) static or intertemporal analysis, particularly the computable general equilibrium (CGE) model which was commonly used in recent research, such as Bye (2000), Parry and Bento (2000), and Richter and Schneider (2003). Obviously different from these three types, this paper conducted upon a general equilibrium model with fully operable price mechanism to describe the optimal behavior of households (firms) and market equilibrium conditions for analyze the theoretical effect of the energy tax on double dividend by a two-period overlapping generations (OLG) (hereinafter referred to as OLG) model with micro-foundation, Based on the comparative static analysis of relevant variables, this paper found that the double dividend of the energy tax is not supported.

This paper contains four sections. Section 1 is the introduction describes the research background and research motivations and reviews related literature to mark out the positioning of this study. Section 2 introduces an OLG model covering households and firms, and reviews the double dividend of energy taxes. Section 3 investigates the effects of raising energy taxes on environmental quality and output levels with comparative static analysis to prove if double dividend exists. Section 4 reports the conclusions of this paper, including gathering the research findings and reviewing their economic implications.

2. THEORETICAL MODEL

We assumed the economic system is represented by households, firms with perfect competition, and a government sector. The model was designed as follows:

2.1. Household

Based on the OLG model introduced by Samuelson (1958) and Diamond (1965), assumed that there are two generations in the economic system, including the youth generation (period t) and elderly generation (period t+1), the lifetime utility function of representative agent i is expressed as follows:

$$U_i = \ln c_{i,t}^{Y} + \lambda(\ln c_{i,t+1}^{O} + \delta \ln D_{t+1}) \tag{1}$$

In Equation 1, $c_{i,t}^{Y}$ and $c_{i,t+1}^{O}$ represent respectively the consumption level of the representative agent i in the youth period (period t) and old-age period (period t+1), D_{t+1} is the environmental quality of the old-age period (period t+1), λ is the discount factor, δ is the degree of importance of agents on environmental quality.

Assumed that the representative agent i earns a wage ($w_{i,t}$), she can consume ($c_{i,t}^{Y}$) and save ($s_{i,t}$) in the youth period (period t), and retirement and consumption come from the compound amount of savings ($(1+r_{t+1})s_{i,t}$) in the old-age period (period t+1). Therefore, the budget restraint of representative agent i in the youth period (period t) and old-age period (period t+1) is expressed as follows:

$$\delta c_{i,t}^{Y} + s_{i,t} = w_{i,t} \tag{2}$$

$$c_{i,t+1}^{O} = (1+r)s_{i,t} \tag{3}$$

Where r_{t+1} is the interest rate from periods t to t+1.

Similar to the setting of John (1995) and Ono (1996), it is assumed that environmental quality change and the energy consumption by firms in production are negatively correlated, while environmental quality and the government's environmental governance activity and consumer's green consumption are positively correlated. Environmental quality change in periods t and t+1 is expressed as follows:

$$D_{t+1} = (1-\upsilon)D_t - \eta E_t + \rho H_t \tag{4}$$

Where D_t is the environmental quality in the youth period (period t), E_t is the negative effect of energy consumption by the production of firms on environmental quality, H_t is the environmental efficiency of the agent's pollution reduction activities, $\upsilon \in (0,1)$ is the rate of change of spontaneity (or namely self-purification rate), η is the emission coefficient of firms using energy in production ($\eta \geq 0$), and ρ is the coefficient of environmental quality governance ($\rho > 0$).

2.2. Firm

Assumed that the firm is in a competitive market and hires labor (L), capital (K), and energy (E) to produce, the production function is expressed as follows:

$$Y_t = A_t L_t^{\alpha} K_t^{\beta} E_t^{\gamma} \tag{5}$$

Where Y_t is the output level in period t, A_t is the technical level ($A_t > 0$) in period t, α, β, and γ represent respectively the coefficient of output elasticity of labor, capital, and energy.

The firm's profit function (π) in period t is expressed as follows:

$$\pi_t = Y_t - w_t L_t - r_t K_t - \sigma K_t - (1+\tau)P_t E_t \tag{6}$$

Where $\sigma \in (0,1)$ is the capital depreciation rate, τ is the energy tax rate ($\tau > 0$), and P_t is the energy price.

Using Equation 5, the first order condition of the problem of firm's profit maximization is obtained as follows:

$$\alpha \frac{Y_t}{L_t} = w_t \tag{7}$$

$$\beta \frac{Y_t}{K_t} = r_t + \sigma \tag{8}$$

$$\gamma \frac{Y_t}{E_t} = (1+\tau)P_t \tag{9}$$

Equations 7-9 represent the firm's optimal employment of labor, capital and energy.

2.3. Government Sector

We assumed that the government's mission is to internalize the externality caused by the firm in production by levying the energy tax to prevent environmental quality deterioration. The government's energy tax revenue is expressed as follows:

$$T_t = \tau P_t E_t \tag{10}$$

Where T_t is the energy tax revenue.

2.4. Market-clearing Condition

When the good market is clearing, good demand equals good supply as shown below:

$$Y_t = c_t^Y + c_{t+1}^O + K_{t+1} + (1-\sigma)K_t \tag{11}$$

3. COMPARATIVE STATIC ANALYSIS

Assumed that the government is the subject of environmental governance and levies the energy tax to correct environmental quality deterioration caused by externality in period t to ensure the stability of environmental variables and environmental quality in periods t and t+1. In this case, the governance cost for environmental quality improvement equals tax revenue:

$$M_t = T_t = \tau P_t E_t \tag{12}$$

In the equilibrium, $D_{t+1} = D_t = D$, and make use of Equations 12 and 4 can be expressed as:

$$D_t = -\frac{\eta}{\upsilon} E_t + \frac{\rho}{\upsilon} H_t \tag{13}$$

To derive the solution for utility maximization problem as: Max (1); s.t. (2), (3), (13). The following first order condition is obtained:

$$c_{t+1}^O = \lambda(1+r_{t+1})c_t^Y \tag{14}$$

$$D = \frac{\lambda\delta(\rho\tau P - \eta)}{\upsilon} c_t^Y \tag{15}$$

Equation 14 presents the substitution relationship of the intertemporal (two periods) consumption by representative agent and explains that the intertemporal consumption ratio is the function of discount factor (λ) and interest rate (r_{t+1}). Equation 15 shows the correlation between the optimal environmental quality level and consumption in the previous period (period t).

In Equation 15, because λ, δ, ρ, η, υ, and P are all exogenous variables, the optimal environmental quality level is affected by energy tax rate (τ) and consumption in period t (c_t^Y), a higher energy tax rate enables the government to provide more activities to improve environmental quality to facilitate environmental quality improvement. Also, more current consumption (period t) stimulates the firm to produce more goods to cause more pollution emissions that are unfavorable to environmental quality improvement.

As the capital of the next period (period t+1) comes from the savings of the previous period (period t), i.e. $K_{t+1}=s_t$, to make use of Equation 3 and the condition for steady state equilibrium ($K_{t+1}=K_t=K$), the following equation is obtained:

$$c_{t+1}^O = (1+r)K \tag{16}$$

Given that $r = f'(K) = \alpha A K^{\alpha-1} - \sigma$, the optimal capital employment is:

$$K = \left(\frac{r+\sigma}{\alpha A}\right)^{\frac{1}{\alpha-1}} \tag{17}$$

By substituting Equation 15 with Equation 14, and using Equation 16 and Equation 17, the optimal level of environmental quality (D^*) is:

$$D^* = \left(\frac{r+\sigma}{\alpha A}\right)^{\frac{1}{\alpha-1}} \frac{\delta(\rho\tau P - \eta)}{\upsilon} \tag{18}$$

Using Equations 11, 15-18, the optimal output level (Y^*) is obtained as follows:

$$Y^* = \frac{1+\lambda(1+r+\rho)}{\lambda}\left(\frac{r+\sigma}{\alpha A}\right)^{\frac{1}{\alpha-1}} \tag{19}$$

To further investigate the effects of the energy tax on the optimal environmental quality and output level, by differentiating Equations 18 and 19 with τ, we get:

$$\frac{\partial D^*}{\partial \tau} = \left(\frac{r+\sigma}{\alpha A}\right)^{\frac{1}{\alpha-1}} \frac{\delta\rho P}{\upsilon} > 0 \tag{20}$$

$$\frac{\partial Y^*}{\partial \tau} = 0 \tag{21}$$

From Equations 20 and 21, it is clear that the energy tax can improve environmental quality but will not affect the output level, and the double dividend hypothesis is thus not supported.

4. CONCLUSIONS AND RECOMMENDATIONS

After Samuelson (1958) and Diamond (1965) proposed the OLG model, many scholars have since analyzed different issues with the model, such as economic growth (such as Uhlig and Yanagawa, 1996; Yakita, 2003; Kawamoto, 2009), trade policy effect (such as Bettendorf and Heijdra, 2001), and the existence, uniqueness, and stability of a long-run equilibrium (such as Galor and Ryder, 1989; Konishi and Perera-Tallo, 1997). Inclusion of micro-foundations, being simple to understand, and ease of mathematical operation are the characteristics of the OLG. Given that energy conservation and emission reduction are major global trends, how to achieve "internalization of external costs" with price mechanisms (such as levying energy taxes, carbon taxes, and environmental levies) has become an important issue. This paper thus integrated the energy tax with the OLG to re-verify the double dividend effect of the energy tax.

According to the results of comparative static analysis, we found that in a two-period OLG model, the first dividend of the energy tax (environmental quality improvement) is supported, while the second dividend (output level improvement) is not supported. Investigating the economic intuition behind found that each agent survives only two-period, to maintain consumption in both periods and environmental quality in the second period, the agent must maintain constant consumption in both periods, and the output level remains unchanged. For this reason, the energy tax rate will not affect the output level. We also indirectly verified the argument that a policy tool cannot achieve two policy goals.

This paper attempted to propose a simple and easy to understand theoretical foundation from among a host of related empirical studies to supplement the research of the double dividend in energy taxes. To simplify analysis, however, we eliminated the government's allocation of energy tax revenue, which is the limitation of this study. This limitation can be a topic in future studies.

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