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Research on Nonfarm Economic Optimum Growth Model Considering Environmental Pollution

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Abstract: Recently, the rapid development of nonfarm economy resulted in the environment pollution. In order to study the optimum growth rate with the environmental pollution, this study established an economic optimum growth model including the factor of pollution which added the factor of the concentration level of polluting enterprise. The model analyzed the influence of 2 factors on the optimal economy growth which are the concentration level of polluting enterprise and the concentration possibility of polluting enterprise. The result showed the concentration level and the concentration possibility had significant influence on the optimal growth. At last, the study came to the conclusion that the bigger growth rate of concentration level of pollution enterprise, the higher the economic growth rate in the steady-state, at this moment the pollution level of the environment being low.

Key words: Environmental pollution, nonfarm economic, optimal growth, concentration rate, industrial park

INTRODUCTION

In recent years, the nonfarm economy has been developing rapidly; it has made important contributions to the farmers' income growth and employment. In 2010, the farmers' nonfarm income accounted for 62.3% of the rural family income and the nonfarm income has become main source of farmers' income. Besides, the employment in township enterprises reached 158.93 million which accounted for 38.4% of the total population of rural employment. But nonfarm economy has caused serious environmental pollution. Now the environment problem in countryside is becoming more and more serious. So, how to control the pollution in countryside is very important. In order to solve the environmental problem in some areas, the government has established industrial park to concentrate the pollution enterprises and deal with pollution intensively. This study shows that the level of dealing with the pollution is closely related to the number of manufacturers in the industrial park. On the basis of the economic model of Reis (2001), this study takes the proportion of polluting enterprise entering the park among the whole ones as the concentration of polluting enterprise. And the concentration is added into the model. This study analyzes its influence on the optimal growth and environment.

The problem of rural environment pollution has caused much attention from all sectors of society. The domestic research focuses on testing whether there is Environmental Kuznets Curve between environmental pollution and economic growth. Zhao *et al*. (2011) researched the relationship using simultaneous equation model. It turned out that there was inverted U shaped Kuznets Curve. Li *et al*. (2006) established a model of per capita GDP and wastewater emission and showed that the economic growth and environmental pollution complied with environmental Kuznets Curve which was inverted U type. Xia (2011) showed that: According to different samples and environmental indicators, the relationship between the two may not meet environmental Kuznets hypothesis. Han (2010) and Li *et al*. (2008) pointed out that Environmental Kuznets Curve was an objective phenomenon rather than a law.

Foreign literature about the research on this aspect is relatively comprehensive. A large number of researchers studied the way the environmental externalities affect the economic optimum growth, environmental pollution and economic growth. Furtherly, there are lots researches focusing on how to achieve a balance so as to realize the optimal economic growth. Nielsen *et al*. (1995) found a switch from a command-and-control regime toward pollution charges may not only improve the efficiency of environmental regulation but also raise growth without damaging the environment. Yi *et al*. (2012) showed that investment in pollution abatement technology, the pre-emptive effect damages option values to a significant degree, causing investment to take place sooner than in either the single-firm or the coordinated case. Wang (2012) showed that the groundwater environment in karst area may be protected by certain methods, namely

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developing ecological agriculture, reducing the contamination, controlling pollution and developing the monitoring network for groundwater. Withagen (1995) found that optimal growth was not necessarily balanced and negative environmental externalities reduced optimal long-term growth rates. Huang and Cai (1994) showed: If there is a constant rate in consumption and abatement expenditure, pollution stock will grow slowly. Criado *et al.* (2011) showed if the technology progress rate of reducing pollution was high enough; pollution would converge to a limited stable state. Reis (2001) showed discovering a technology that eliminates pollution can increase optimal growth. Masako (2008) showed if agents had persistent habit stock and cared about their habit, more technological progress is required for sustained economic growth. Byrne (1997) showed that growth was dependent on technology improvements. Pollution growth was higher in a decentralized economy and if environmental issues can be controlled effectively, the economy would have positive steady-state growth.

In conclusion, foreign researchers mainly have studied the measures to reduce pollution and improve economic growth. But the current studies do not take the concentration ratio of polluting enterprise into consideration.

METHODOLOGY

This study added the concentration ratio of polluting enterprises to Optimum growth model to study how it affects the environment pollution and the optimal economic growth rate.

RESULTS

This study has concluded that when the growth rate of concentration ratio was higher, the economic growth rate was higher and at this moment the environment has less pollution.

THEORETICAL MODEL

Declaration about model and variable: This study built a simple optimum growth model on the basis of the study of Ana Balcao Reis. Specifically, this study used an AK technology. Then this study would make a description for all variables. It takes U, A, C, K, P, D as utility, productivity, consumption, capital, pollution, the weight of pollution on the utility, respectively. T means the moment of polluting industries realize fully concentrated, similarly $V(K_T)$ means the value of utility from the moment of polluting industries realize fully concentrated, ρ means the intertemporal discount rate. z represents the index of concentration ratio and $z\in[0,1]$. The parameter γ, p and λ represent that the concavity of utility function; probability and shadow price of capital.

Model analysis: This study considers a closed economy. The utility of the representative agent depends on per capita consumption C and on the flow of pollution P. This study shows it using the following equation:

$$\int_0^\infty e^{-\rho t}\left(\log C_t - \frac{DP_t^\gamma}{\gamma}\right)dt, \gamma \geq 1, D > 0 \tag{1}$$

This study defines the production function as Y = AK and depreciation of capital is zero. So:

$$\dot{K}_t = AK_t - C_t \tag{2}$$

This study supposes the flow of pollution is proportional to total production at each moment. That is:

$$P_t = AK_t/a+bz_t \text{ (a, b are constant, b is not zero)} \tag{3}$$

where, z measures the pollution effects of production. An increase in z means a decrease in pollution. This study can understand z as an index of concentration ratio of industries; the greater z means the higher concentration of polluting industries.

If this study ignores pollution externalities, the optimal solution would mean a constant rate of growth A-ρ. This study assumes that A-ρ>0, in this case the economy has positive economic growth.

Now this study determines the optimal solution considering pollution. The solution depends on the behavior of z. This study assumes increase of concentration allows production to occur in a less polluting way. So, the production function is always the same but the pollution implied by a given level of production decreases with concentration increase. Continuous concentration increase means that the index z increases at an exogenous constant rate 1/b F:

$$(a+b\dot{z}_t) = F(a+bz_t) \tag{4}$$

This study also considers a discontinuity in the process of concentration increase. To formalize the possibility of polluting industries realize fully concentrated, this study assumes that there is a constant probability p per unit of time of realizing fully concentrated that allows producing without polluting.

Let, T be a stochastic variable that denotes the moment of the polluting industries realize fully concentrated. In all moments after T the level of pollution is 0. This study assumes that the realization happens with probability pdt in the interval dt. To determine the optimal trajectory for the economy this study maximizes expected utility:

$$U = E\left[\int_0^{\infty}\left(\log C_t - {DP_t^{\gamma}}/{\gamma}\right)dt + \int_T^{\infty} e^{-\rho t}\log C_t dt\right], \gamma \geq 1 \quad (5)$$

Let, $v(K_T)$ be the value of the second term of (5). After T, for all t, P = 0 so, the value of z is irrelevant. So:

$$v(K_T) = \text{Max}\int_T^{\infty} e^{-\rho t}\log C_t dt$$

$$\text{St.}\dot{K}_t = AK_t - C_t,\ K_T \text{ Given}$$

The optimal solution means that at each moment after the realization $C_t = \rho K_t$ and K and C grow at a constant rate A-ρ So:

$$v(K_T) = \frac{e^{-\rho T}}{\rho}\left(\log\rho K_T + {(A-\rho)}/{\rho}\right) \quad (6)$$

By the properties of the Poisson distribution and using condition 6, expected utility can be expressed as:

$$\int_0^{\infty} e^{-\rho t}\left(\log C_t - {DP_t^{\gamma}}/{\gamma}\right)e^{-pt}dt + \int_0^{\infty}\frac{e^{-\rho t}}{\rho}\left[\log\rho K_t + {(A-\rho)}/{\rho}\right]pe^{-pt}dt \quad (7)$$

Merging this type, the objective function can be rewritten as:

$$\int_0^{\infty} e^{-(p+\rho)t}\left(\log C_t - {DP_t^{\gamma}}/{\gamma} + \left[\log\rho K_t + {(A-\rho)}/{\rho}\right]{p}/{\rho}\right)dt \quad (8)$$

This study maximizes 8 in C subject to Eq. 2, 3 and 4 with given K_0 and z_0. The current value Hamiltonian is:

$$H = \log C_t - \frac{D\left({AK_t}/{a+bz_t}\right)^{\gamma}}{\gamma} + \left[\log\rho K_t + \frac{A-\rho}{\rho}\right]\frac{p}{\rho} + \lambda_t[AK_t - C_t]$$

The necessary conditions are:

$$C_t = 1/\lambda_t \quad (9)$$

$$\dot{\lambda}_t = \lambda_t\left(p + \rho - A + {D\left({AK_t}/{a+bz_t}\right)^{\gamma}}/{\lambda_t K_t} - {p}/{(\rho\lambda_t K_t)}\right) \quad (10)$$

And the transversality condition:

$$\lim_{t\to\infty} e^{-(p+\rho)t}\lambda_t K_t = 0 \quad (11)$$

The probability p enters condition 10 in two ways; first it increases the discount factor; second it decreases the effect of a change in capital on its opportunity cost. This last effect happens because an increase in capital increases pollution but it also increases the stock of capital after the realization. So, the utility increases after that moment, it was shown in condition 6.

These conditions characterize the optimal behavior before the realization of fully concentrated. It was known that after the realization capital and consumption grow at a constant rate A-ρ. Now this study characterizes the optimal trajectory and the steady state of the economy before realizing fully concentrated of polluting industries.

For A-ρ>F before the realization K, C and the level of production grow at the constant rate F and the level of pollution is constant at the steady state of the optimal trajectory. The shadow price of capital decreases at the rate F. Taking this into account, conditions 2, 4, 9 and 10 imply that in the steady state it must have:

$$\frac{K}{a+bz} = \left[\frac{(A-\rho-F)(p+\rho)}{D(A-F)\rho}\right]^{1/\gamma}\frac{1}{A} \quad (12)$$

$$C/K = A\text{-}F \quad (13)$$

From Eq. 2 and 4:

$$\left(\frac{\dot{K}}{a+bz}\right)_t = \left[\left(\frac{\dot{K}}{K}\right) - \left(\frac{a+b\dot{z}}{a+bz}\right)\right]\left(\frac{K}{a+bz}\right) = [A-F]\left(\frac{K}{a+bz}\right) - \left(\frac{C}{a+bz}\right) = \left[A - F - \left(\frac{C}{K}\right)\right]\left(\frac{K}{a+bz}\right)$$

So:

$$\left(\frac{\dot{K}}{a+bz}\right)_t = 0 \Leftrightarrow \left(\frac{C}{K}\right) = A - F \quad (14)$$

From Eq. 2, 9 and 10:

$$\left(\frac{\dot{C}}{K}\right)_t = \left[\left(\frac{\dot{C}}{C}\right) - \left(\frac{\dot{K}}{K}\right)\right]\left(\frac{C}{K}\right) = \left[\left(1 + \frac{p}{\rho} - D\left(\frac{AK_t}{a+bz_t}\right)^{\gamma}\right)\frac{C}{K} - (p+\rho)\right]\left(\frac{C}{K}\right)$$

So:

$$\left(\frac{\dot{C}}{K}\right) = 0 \Leftrightarrow \left(\frac{C}{K}\right) = \frac{\rho(p+\rho)}{(p+\rho) - \rho D\left(\frac{AK_t}{a+bz_t}\right)^{\gamma}} \quad (15)$$

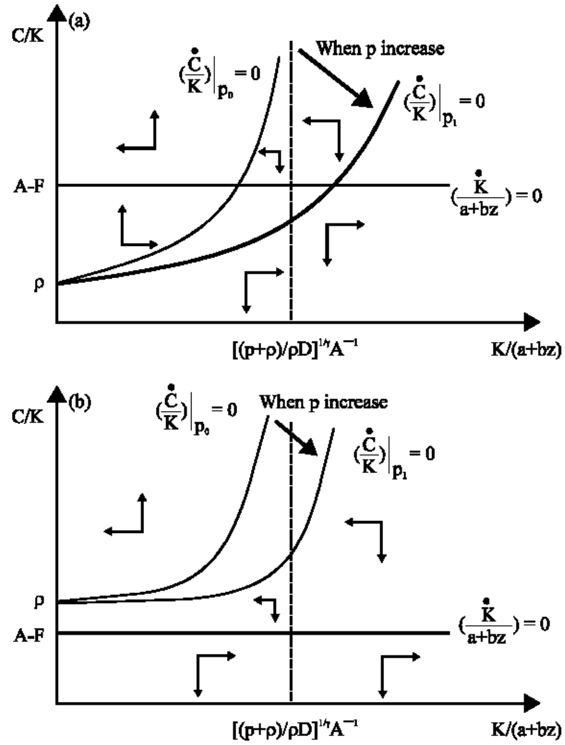

Fig. 1(a-b): (a) Optimal trajectory and steady state of economy and their changes when p increases for A-ρ>F and (b) Optimal trajectory and steady state of economy and their changes when p increases for A-ρ<F

According to Eq. 14 and 15, this study makes the following phase-diagram (Fig. 1). For A-ρ>F, the phase-diagram in Fig. 1a shows that the system is saddle-path stable, converging to the steady state described above, where the rate of growth is F. Figure 1a shows that along the trajectory of convergence to the steady state this study always has that C/K>ρ, implying that the rate of growth of capital is smaller than A-ρ.

For A-ρ<F, Fig. 1b shows that K/a+bz converges asymptotically to 0, implying that K is growing slower than z. C/K converges asymptotically to ρ. The rate of growth of capital and consumption converge to A-ρ, the rate of growth when there is no pollution. A-ρ<F means that the pollution flow is decreasing exogenously at such a high rate that the optimal solution converges to the solution for the economy with no pollution.

Pollution is proportional to K/a+bz, so, the behavior of K/a+bz shown in the phase-diagram is also the behavior of pollution. For A-ρ>F pollution increases or decreases until reaching the steady-state value, depending on the initial value of K/a+bz being higher or lower than its steady-state value. For A-ρ<F, pollution decreases along the whole transition path.

An Increase in p: The probability p can be understood as the subjective probability that polluters into industrial park. The government take appropriate measures may increase the probability. The Fig. 1a and b allow the study of what happens in such case. When p increases, the locus (C/K) rotate to the right and C/K decreases for any positive K/a+bz in the whole optimal trajectory. At any moment the stock of capital, K and Z are given. Thus, the adjustment happens through a decrease in consumption at the moment of the increase in the probability.

CONCLUSION

This study considered the factor of the environmental pollution in an economic optimum growth model. And this study researched the influence of the concentration ratio and the possibility on the optimal growth and environment. This study showed the greater the possibility, economic optimal growth rate would be higher. Also, this study have concluded that when the growth rate of concentration ratio was higher, the economic growth rate was higher in the steady-state and at this moment the environment has less pollution.

According to the analysis of the model, this study put forward the following advices to improve the concentration ratio. First, government should raise people's environmental awareness. Second, build industrial park to improve the concentration ratio of polluting enterprises. Third, because producers need cost to enter the industrial park, as well as the various concerns after entering it, many producers reluctant to enter it. The government should take appropriate measures to encourage polluters into the industrial park. It is essential to lower the entering threshold into the industrial park. At the same time, the rational standard of punishments and subsidies should be established. The reasonable system of regulations and laws about environmental management also need the attention.

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