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The impact of natural disasters on economic growth*

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Abstract

This paper studies the impact of natural disasters on economic growth in an endogenous growth model. Production with the use of fossil fuels as input brings about air pollution, which can be one of the causes of climate change. Climate change may be accompanied by natural disasters that causes serious damage to physical capital stock. We assumed that when more polluting inputs are used, the risk of natural disaster is greater, which results in more damage to capital stock. We examine the social planner's problem taking the risk of natural disasters into account. We show that a steady state exists and that it is saddle path stable. In addition, optimal growth with natural disasters is positive but lower than that without pollution and natural disasters.

Keywords: Natural disasters, Two-sector model, Endogenous depreciation of capital stock, Economic growth.
JEL Classification Numbers: O41, O13, E22.

1 Introduction

Over the past decade, an increasing number and magnitude of natural disasters have been observed. According to World Meteorological Organization (2005), there were some of the most destructive hurricanes and typhoons on record in 2004, which claimed more than 6000 lives. Dayton-Johnson (2004) summarizes fatalities and monetary damages for various types of disasters from 1990 to 2002 based on the EM-DAT.[1] In this period, the maximum number of peopled killed by wind storm was 138,866 and that by flood was 30,000. The maximum monetary damages by wind storm was $30 billion and that by flood was $20 billion.[2] Such disasters are caused by global climate change, which is the consequence of human activities: Emissions of greenhouse gases due to human activities continue to affect the climate (IPCC, 2001). Since natural disasters damage physical capital and claim lives, natural disasters may affect economic growth.

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[1] The US Office of Foreign Disaster Assistance/ Centre for Research on the Epidemiology of Disasters International Disaster Database

[2] The damage caused by the latest and the most destructive hurricane Katrina, which devastated along the central Gulf Coast states of the U.S. on August, 2005, is said to be over $100 billion and the death toll stood at 1075(US Department of Commerce NOAA/NESDIS, 2005).

Do natural disasters lower economic growth? Disasters cause serious damage to economic activities in the short term. However, disasters may have a positive effect on economies as well. Skidmore and Toya (2002) investigate the long-run relationships among disasters, capital accumulation, total factor productivity, and economic growth. Their empirical study shows that natural disasters increase the investment in human capital, leading to improvements in total factor productivity, and thus, economic growth. As their hypotheses, disaster risk lowers the expected return to physical capital, and in turn, raises the relative expected return to human capital investment. In endogenous growth models, human capital is the engine of growth. Thus, natural disasters may promote economic growth.

In this paper, we examine the impact of natural disasters on economic growth in an endogenous growth model, introducing the endogenous depreciation of physical capital stock. The mechanism of endogenous depreciation of physical capital stock is as follows: Production with the use of fossil fuels as input brings about greenhouse gases emissions, which is thought to be one of the causes of climate change. Climate change may be accompanied by natural disasters that causes serious damage to physical capital stock. We assumed that the more polluting inputs are used, the greater the risk of natural disaster, that is, damage of capital stock.

We analyze the social planner's problem taking the risk of natural disasters into account. Since the negative externality of pollution is endogenized, the parameter relating to risk of natural disasters does not affect the optimal growth rate. However, the optimal growth with natural disasters is lower than that without pollution and natural disasters, although it is still positive rate. Along the optimal path, the growth rate of physical capital accumulation decreases and the amount of polluting input is constant while the growth rate of human capital stock increases, which leads to reduction in the amount of polluting input per output, otherwise the risk of natural disasters would grow infinitely. Thus, the growh rate decreases at the steady state. We show that steady state exists and that it is saddle path stable.

The rest of this paper is organized as follows. Section 2 describes the model and derives the optimal growth path. Section 3 examines the optimal growth rate and transitional dynamics. The existence of saddle path stable is proved. Concluding remarks appear in Section 4.

2 The Model

The model in this paper is based on the framework of Uzawa (1965) and Lucas (1988) in which there are production sector of goods and education sector. The risk of damage to physical capital stock is introduced into the model and it is caused by natural disasters which are assumed to be inevitable and to depend on the amount of pollution. The emission of pollutants is a by-product of production with polluting inputs such as fossil fuels. The social planner makes savings decisions taking the risk of natural disasters into account. The production technology is given by:

$$Y_t = F(K_t, u_t H_t, P_t) = AK_t^{\alpha}(u_t H_t)^{1-\alpha-\beta} P_t^{\beta}, \tag{1}$$

where A, K_t, H_t, u_t, and P_t denote technology parameter, the amount of physical capital stock, human capital stock, fraction of time devoted to production, and polluting inputs at time t, respectively. The exponents of the production factors are positive and sum to one and $\alpha > \beta$ is assumed. We assume that there is no cost of using the inputs and/or no extraction costs of fossil fuels.

The technology relating to the growth of human capital is defined by:

$$\dot{H}_t = B(1 - u_t)H_t, \tag{2}$$

where B denotes productivity and $1 - u_t$ is a fraction of time devoted to the accumulation of human capital.

The accumulation of physical stock is given by:

$$\dot{K}_t = Y_t - C_t - \delta(P_t)K_t, \tag{3}$$

where $\delta(P_t)$ is the depreciation rate of physical capital stock due to natural disasters, and is specified as follows:

$$\delta(P_t) = \phi P_t, \qquad \phi > 0.$$

The planner maximizes the following utility of the representative household subject to (2) and (3):

$$\int_0^{\infty} \frac{C_t^{1-\theta} - 1}{1 - \theta} e^{-\rho t} dt, \qquad \theta > 1, \tag{4}$$

where C_t is consumption at time t, θ is the reciprocal of the elasticity of substitution, and $\rho > 0$ is the rate of time preference. Setting the current value Hamiltonian of this problem:

$$\mathcal{H} = \frac{C_t^{1-\theta} - 1}{1 - \theta} + \nu_t(AK_t^{\alpha}(u_t H_t)^{1-\alpha-\beta} P_t^{\beta} - C_t - \phi P_t K_t) + \mu_t B(1 - u_t)H_t,$$

where ν_t and μ_t are shadow prices associated with $\dot{K}$ and $\dot{H}$, respectively. The necessary conditions for optimality are:

$$\nu_t = C_t^{-\theta}, \tag{5}$$

$$\mu_t = \frac{(1-\alpha-\beta)Y_t}{B(u_t H_t)} \cdot \nu_t, \tag{6}$$

$$\frac{Y_t}{K_t} = \frac{\phi P_t}{\beta}, \tag{7}$$

$$\frac{\dot{\nu}_t}{\nu_t} = \rho - \alpha\frac{Y_t}{K_t} + \phi P_t, \tag{8}$$

$$\frac{\dot{\mu}_t}{\mu_t} = \rho - \frac{\nu_t}{\mu_t}\frac{(1-\alpha-\beta)Y_t}{H_t} - B(1-u_t). \tag{9}$$

The transversality condition are given by:

$$\lim_{t\to\infty} K_t \nu_t e^{-\rho t} = 0, \tag{10}$$

$$\lim_{t\to\infty} H_t \mu_t e^{-\rho t} = 0. \tag{11}$$

Equation (6) shows the relationship between the shadow price of human capital and physical capital. An increase in human capital decreases the shadow price. Equation (7) or $\beta Y_t / P_t K_t = \phi$ implies that the marginal product of fossil fuels per physical capital is equal to the depreciation rate of capital per a unit of polluting input. From (5) and (7), Euler equation is written by:

$$\frac{\dot{C}_t}{C_t} = \frac{1}{\theta}\left(\frac{\alpha-\beta}{\beta}\phi P_t - \rho\right). \tag{12}$$

The first term in the parentheses is the net of marginal rate of capital which depends on the risk of natural disasters. Substituting (6) into (9) yields:

$$\frac{\dot{\mu}_t}{\mu_t} = \rho - B. \tag{13}$$

Substituting (7) into (3), dynamics of capital stock with (7) is given by:

$$\frac{\dot{K}_t}{K_t} = \frac{1-\beta}{\beta}\phi P_t - \chi_t, \tag{14}$$

where $\chi_t \equiv C_t / K_t$.

3 The Optimum

Let us focus on the optimal growth path. Along the optimal path the growth rate of the economy is defined as:

$$g \equiv \frac{\dot{Y}_t}{Y_t} = \frac{\dot{C}_t}{C_t} = \frac{\dot{K}_t}{K_t}. \tag{15}$$

From (7), P is constant and the dynamics satisfies the following:

$$\frac{\dot{P}_t}{P_t} = \frac{\dot{Y}_t}{Y_t} - \frac{\dot{K}_t}{K_t}. \tag{16}$$

Hence, from (12) and (14), we obtain:

$$\chi^* = \frac{\theta(1-\beta) - (\alpha-\beta)}{\theta\beta}\phi P^* + \frac{\rho}{\theta}. \tag{17}$$

Furthermore, human capital, $\dot{H}_t/H_t = B(1-u_t)$, is constant so that the fraction of time devoted to labour is constant, u^*. Thus, from the production function we obtain u^* as follows:

$$\begin{aligned} \frac{\dot{Y}_t}{Y_t} = \alpha\frac{\dot{K}_t}{K_t} + (1-\alpha-\beta)\frac{\dot{H}_t}{H_t} &= \frac{\dot{K}_t}{K_t} = g, \\ u^* &= 1 - \frac{(1-\alpha)g}{B(1-\alpha-\beta)}. \end{aligned} \tag{18}$$

Consider the arbitrage condition of investment between physical capital and human capital stock. Differentiating logarithmically with respect to time in (6) and substituting (8) and (9) into the derivatives, we obtain the steady state value of P:

$$P^* = \frac{\beta}{\phi(\alpha-\beta)}B - \frac{\beta^2}{\phi(1-\alpha-\beta)(\alpha-\beta)}g \tag{19}$$

Substituting (19) into Euler equation, we obtain the optimal growth rate:

$$g = \frac{B-\rho}{\theta + \frac{\beta}{1-\alpha-\beta}}. \tag{20}$$

Comparing this to the corresponding growth rate in the Uzawa-Lucas model, [3] the growth rate in (20) is discounted more by $\beta/(1-\alpha-\beta)$. Hence, when the economy has the production technology such that the human capital's share of output is large, the economic growth may not be affected by natural disasters so much. In contrast, when the production heavily relies on polluting inputs, the impact of natural disasters may become large. However, the risk of natural disasters does not affect the growth rate since the social planner chooses an optimal path of consumption and polluting input, taking into account the risk of natural disasters.

Let us examine that the optimum satisfies the transversality conditions. (10) and (11) imply that $\dot{K}/K + \dot{\nu}/\nu - \rho < 0$ and $\dot{H}/H - \dot{\mu}/\mu - \rho < 0$. Using the optimum growth rate, we obtain the following:

[3] Without pollution and depreciation of human capital, the growth rate is $g = (1/\theta)(B-\rho)$.

$$\frac{\dot{K}}{K} + \frac{\dot{\nu}}{\nu} - \rho = \frac{\dot{H}}{H} + \frac{\dot{\mu}}{\mu} - \rho = \frac{(1-\alpha-\beta)B(1-\theta) - (1-\alpha)\rho}{\theta(1-\alpha-\beta)+\beta} < 0.$$

Note that the assumption of $\theta > 1$ makes the transversality conditions satisfied.

In order to obtain the optimal values of polluting input, fraction of time devoted to labour, and the ratio of consumption to physical capital, substituting (20) into (19) and (18) yields:

$$P^* = \frac{\beta}{\phi}\left(\frac{B\theta(1-\alpha-\beta)+\beta\rho}{(\alpha-\beta)(\theta(1-\alpha-\beta)+\beta)}\right), \tag{21}$$

$$u^* = 1 - \frac{(1-\alpha)(B-\rho)}{B(\theta(1-\alpha-\beta)+\beta)}, \tag{22}$$

$$\chi^* = \frac{\theta(1-\beta)-(\alpha-\beta)}{\theta}\left(\frac{B\theta(1-\alpha-\beta)+\beta\rho}{(\alpha-\beta)(\theta(1-\alpha-\beta)+\beta)}\right) + \frac{\rho}{\theta}. \tag{23}$$

Consider the effect of change of parameter ϕ. While it does not affect the optimal solution of u^* and χ^*, a larger value of parameter ϕ associated with the risk of natural disasters leads to a lower amount of polluting input. Since an increase in the scale of destroyed physical capital stock due to natural disasters decreases the marginal rate of physical capital stock, which results in a decrease in the incentive to invest in physical capital. From (7), decreased physical capital stock reduces the marginal rate of pollution, which in turn, reduces the amount of polluting inputs.

Following Barro and Sala-i-Martin (1995), consider the transitional dynamics. Using (21), (22), and (23), we obtain the dynamic system for P, u, and χ. Combining (12) with (14) yields the dynamics for χ:

$$\begin{aligned}\frac{\dot{\chi}}{\chi} &= \frac{\dot{C}}{C} - \frac{\dot{K}}{K} \\ &= \frac{(\alpha-\beta)-\theta(1-\beta)}{\theta\beta}\phi(P-P^*) + (\chi-\chi^*)\end{aligned} \tag{24}$$

The dynamics of χ, that is the dynamics of the ratio of consumption to physical capital stock depends on the parameter related to natural disasters.

Differentiating logarithmically with respect to time in (7) and using (14), we obtain the following dynamics for P:

$$\begin{aligned}\frac{\dot{P}}{P} &= \frac{\dot{Y}}{Y} - \frac{\dot{K}}{K} \\ &= \frac{\alpha-1}{\beta}\phi(P-P^*) - \frac{\alpha-1}{1-\beta}(\chi-\chi^*) - \frac{(1-\alpha-\beta)}{1-\beta}B(u-u^*)\end{aligned} \tag{25}$$

Since $Y/K = \phi P/\beta$, this can be cosidered as the dynamics for Y/K, that is, for the gross average product of physical capital, which also depends on ϕ.

From the arbitrage condition of investment between physical capital and human capital stock, we obtain the dynamics for u:

$$\frac{\dot{u}}{u} = \frac{\alpha}{1-\beta}B(u-u^*) - \frac{\alpha-\beta}{1-\beta}(\chi-\chi^*) \tag{26}$$

The dynamics of u does not depend on ϕ or polluting input directly, however, this is affected by natural disasters through the dynamics of χ.

Next, let us examine the Jacobi matrix of (24), (25), and (26).

$$J = \begin{bmatrix} 1 & \frac{((\alpha-\beta)-\theta(1-\beta))\phi}{\theta\beta} & 0 \\ \frac{1-\alpha}{1-\beta} & -\frac{(1-\alpha)\phi}{\beta} & -\frac{1-\alpha-\beta}{1-\beta} \\ -\frac{\alpha-\beta}{1-\beta} & 0 & \frac{\alpha}{1-\beta} \end{bmatrix}.$$

Its characteristic equation is given by:

$$\left(\frac{\alpha}{1-\beta}-\lambda\right)\left[(1-\lambda)\left(-\frac{(1-\alpha)\phi}{\beta}-\lambda\right)-\frac{((\alpha\beta)-\theta(1-\beta))\phi(1-\alpha)}{\theta\beta(1-\beta)}\right]=0.$$

The eigenvalues of J are given by:

$$(\lambda_1,\lambda_2,\lambda_3) = \left(\frac{\alpha}{1-\beta},\quad \frac{1}{2}\left(\Omega+(\Omega^2-\Gamma)^{\frac{1}{2}}\right),\quad \frac{1}{2}\left(\Omega-(\Omega^2-\Gamma)^{\frac{1}{2}}\right)\right),$$

where

$$\Omega = -\frac{(1-\alpha)\phi-\beta}{\beta}, \qquad \Gamma = \frac{4(\alpha-\beta)\phi(1-\alpha)}{\theta\beta(1-\beta)}.$$

Hence, since $\alpha > \beta$, two engenvalues of J are positive, the other is negative, which implies that the stability of this system is saddle path stable.

4 Conclusion

This paper has examined the impact of natural disasters on economic growth in an endogenous growth model. The optimal growth rate chosen by the social planner is not affected by the parameter relating to the risk of natural disasters, while the transitional dynamics is affected. What affects the economic growth is the polluting input's share of output. The larger the share of polluting input, the lower the optimal growth. Therefore, cleaner technology is required for higher growth rate. Since the social planner makes savings decisions taking the risk of natural disasters into account, the negative externality of pollution is endogenized. Furtherwork is necessary to analyze a decentralized economy.

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Reference

Barro, R. J. and Sala-i-Martin, X. (1995), *Economic Growth*. New York: McGraw Hill.

Dayton-Johnson, J. (2004), "Natural Disasters and Adaptive Capacity," *Working Paper*, 237, OECD Development Center.

IPCC (2001), "Summary for Policymakers," A Report of Working Group I of the Intergovernmental Panel on Climate Change.

Lucas Jr., R. E.,(1988), "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 22, 1, 3-42.

National Climatic Data Center (2005), "Technical Report 2005-01". U.S. Department of commerce, National Oceanic and Atomospheric Administration

Skidmore, M. and Toya, H. (2002), "Do Natural Disasters Promote Long-Run Growth?" *Economic Inquiry*, 40, 664-687.

Uzawa, H. (1965), "Optimal Technical Change in an Aggregative Model of Economic Growth," *International Economic Review*, 6, 18-31.

World Meteorological Organization (2005), *World Climate News*, 27, Geneva, Switzerland, World Meteorological Organization