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Neutrality of an increase in the price of natural resources to the level of technology

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Abstract

This paper constructs an endogenous variety expansion model of a small open economy based on Grossman and Helpman (1991) to investigate how an increase in the price of natural resources affects the level of technology. This paper concludes that an increase in the price of natural resources does not affect the level of technology.

Keywords: Natural Resources, R&D, Economic Growth
JEL classification: F43, O31

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1 Introduction

Starting in the 1970s, the price of oil has fluctuated dramatically. Before the 1970s, the price of oil had been stable at between \$10 and \$20 per barrel in 2007 US dollars. Following the oil shock, the price of oil again became stable at around \$30 during the period 2000-2004. However, the price of oil rose sharply in July 2008 to \$145 per barrel. Therefore, fluctuations in the price of oil profoundly influence countries importing crude oil.

This paper investigates how an increase in the price of natural resources affects the level of technology. We construct an endogenous variety expansion model in a small open economy based on Grossman and Helpman (1991). In this model, firms produce final goods using intermediate goods and a natural resource. Therefore, when the price of the natural resource increases, firms will substitute the natural resource for the intermediate goods and the demand for the intermediate goods increases. This increases R&D investment and the level of technology. However, the cost of the natural resource also increases, the expenditure of the country decreases, and the R&D investment then decreases. This paper shows that these two effects cancel out each other. Therefore, when the price of the natural resource increases, the firms substitute natural resources for the intermediate goods. However, the level of technology does not change. In the steady state, when the price of a natural resource increases, the consumption level decreases.[1]

2 The Model

We develop a dynamic general equilibrium model based on Grossman and Helpman (1991). In this model, there are final goods, intermediate goods, and a natural resource. Individuals consume only the final goods. Each individual lives forever and is endowed with one unit of labor services, which is inelastically supplied at each point of time. The population size in this economy is constant over time and normalized to unity. To produce the final goods, firms use the intermediate goods and the natural resource. This economy is a small open country that trades final goods and the natural resource at an exogenously given world price. We suppose that the final goods and the natural resource are tradable. In contrast, we assume that the intermediate goods are not tradable.

[1] Many researchers investigate the relationship between the price of natural resources and economic growth. For instance, Peretto (2009) finds that an optimal tax rate on energy use exists that maximizes the welfare. In the short run, a tax on energy use then generates the temporary acceleration of total factor productivity growth.

2.1 Production

Production of the final goods requires variety-specific intermediate goods and the natural resource. The production function is given by:

$$Y = [\gamma D^{\sigma} + (1-\gamma)G^{\sigma}]^{\frac{1}{\sigma}}, \tag{1}$$

where Y denotes the output of final goods, G is the natural resource input, and D denotes the composite input of the intermediate goods. σ and γ are parameters. The composite of the intermediate goods is given by:

$$D \equiv \left(\int_0^{n_t} {x_i}^{\alpha} di \right)^{\frac{1}{\alpha}}, \tag{2}$$

where x_i denotes the intermediate goods produced by firm i and n_t denotes the level of technology at time t. α is the elasticity of substitution between any two varieties in a given sector. If α is close to one, the goods are nearly perfect substitutes. The final goods firms sell their output to their own country and abroad. The final goods is chosen to be the numeraire and the price index of the composite intermediate goods is as follows:

$$P_D \equiv \left(\int_0^{n} {p_i}^{\frac{\alpha}{\alpha-1}} dj \right)^{\frac{\alpha-1}{\alpha}}, \tag{3}$$

where p_i denotes the price of the intermediate goods produced by firm i. We then obtain the profit-maximization conditions as follows:

$$P_D = \gamma^{\frac{1}{\sigma}} \left[1 - (1-\gamma)^{-\frac{1}{\sigma-1}} P_g^{\frac{\sigma}{\sigma-1}} \right]^{\frac{\sigma-1}{\sigma}}, \tag{4}$$

$$D = \left(\frac{P_D}{\gamma} \right)^{\frac{1}{\sigma-1}} Y, \tag{5}$$

$$G = \left(\frac{P_g}{1-\gamma} \right)^{\frac{1}{\sigma-1}} Y, \tag{6}$$

$$x_i = \left(\frac{P_D}{p_i} \right)^{\frac{1}{1-\alpha}} D, \tag{7}$$

where P_g denotes the world price of the natural resource.

The intermediate goods firms buy a patent from the R&D sector and sell the intermediate goods exclusively to the final goods firm. The production of one unit of each intermediate good requires one unit of labor. Therefore, we can write the profit of the intermediate goods firm i as follows:

$$\pi_i = p_i x_i - w x_i, \tag{8}$$

where π_i denotes the profit of the intermediate goods firm i and w denotes the wage rate of labor. The monopoly price and the profit level are then:

$$p_i = \frac{w}{\alpha}, \tag{9}$$

$$\pi_i = (1-\alpha)\alpha^{\frac{-\sigma}{\sigma-1}}\gamma^{\frac{-1}{\sigma-1}}w^{\frac{\sigma}{\sigma-1}}n^{\frac{\alpha-\sigma}{\alpha(\sigma-1)}}Y. \tag{10}$$

Consequently, we obtain the total output of intermediate goods and the price index of intermediate goods P_D as follows:

$$\chi \equiv n x_i = \left(\frac{w}{\alpha\gamma}\right)^{\frac{1}{\sigma-1}} n^{\frac{\sigma(\alpha-1)}{\alpha(\sigma-1)}}Y, \tag{11}$$

$$P_D = \frac{w}{\alpha} n^{\frac{\alpha-1}{\alpha}}, \tag{12}$$

where χ denotes the total output of intermediate goods.

2.2 R&D sector

The R&D activities of the present model follow Grossman and Helpman (1991). The intermediate goods producers enter into the R&D race and finance the cost of R&D by issuing equity in the stock market. The equity is bought by individuals. The stock value of the intermediate goods producers at time t is equal to the present discounted sum of its profit stream subsequent to t. Then, the stock value of the intermediate goods producers at time t is given by:

$$v = \int_t^{\infty} e^{-\int_t^s r_v dv}\pi_i ds, \tag{13}$$

where r_s denotes the interest rate on a riskless loan at time s. Differentiating (13) with respect to time t yields the following no-arbitrage condition:

$$\dot{v} = -\pi + r_t. \tag{14}$$

The intermediate goods producers hire labor to develop blueprints. In this model, an increase in the number of intermediate goods implies an increase in the efficiency of the natural resource. We assume that L_a units of labor for R&D activity over a time interval

dt produce a new variety of intermediate goods according to:

$$dn = \frac{L_a}{a} dt, \tag{15}$$

where a^{-1} denotes the productivity of R&D. The cost of R&D activities is $wL_a dt$. The blueprints create value for the intermediate goods producers of vdn as each blueprint has a market value of v. We assume there is free entry into the R&D race. Therefore, the following free-entry condition must hold:

$$v \leq aw \quad \text{with equality whenever } \dot{n} \equiv \frac{dn}{dt} > 0. \tag{16}$$

2.3 Consumers

A representative agent has the following preference:

$$U_0 = \int_0^{\infty} e^{-\rho t} \log c_t dt, \tag{17}$$

where c_t stands for the consumption of the final goods at time t and $\rho > 0$ is the constant subjective discount rate. The budget constraint is represented by

$$\int_0^{\infty} E_t e^{-\int_0^t r_s ds} dt = a_0 + \int_0^{\infty} w_t e^{-\int_0^t r_s ds} dt, \tag{18}$$

where E_t denotes expenditure at time t, and $a_0 \equiv n_0 v_0$ denotes the economy's aggregate equity value at time 0. Then, from the first-order conditions of the maximization problem, we obtain the following Euler equation:

$$\frac{\dot{E}_t}{E_t} = r_t - \rho. \tag{19}$$

2.4 Labor market equilibrium and trade balance conditions

Each individual supplies one unit of labor services over any time t. These labor services are supplied to the R&D sector and to the production of intermediate goods. Thus, the labor market equilibrium condition is given by:

$$1 = \chi + a\dot{n}. \tag{20}$$

In this small open economy, final goods are exported to foreign countries and the natural resource is imported from abroad. Therefore, the trade balance condition becomes as follows:

$$Y - E = P_g G. \tag{21}$$

The left-hand side of this equation represents the volume of exports and the right-hand side represents the volume of imports.

3 The Equilibrium Path

The equilibrium conditions are the no-arbitrage condition of (14), the free-entry condition of (16), the Euler equation of (19), the labor market equilibrium condition of (20), and the trade balance condition of (21). We can derive the two differential equations for the number of intermediate goods, n, and expenditure, E, as follows:

$$\dot{n}_t = \frac{1}{a}\left[1 - \frac{E}{P_D} n^{\frac{\alpha-1}{\alpha}}\right], \tag{22}$$

$$\frac{\dot{E}_t}{E_t} = \left(\frac{1-\alpha}{a\alpha}\right)\frac{E}{P_D} n^{-\frac{1}{\alpha}} - \rho. \tag{23}$$

These two equations constitute the dynamic system of this economy.

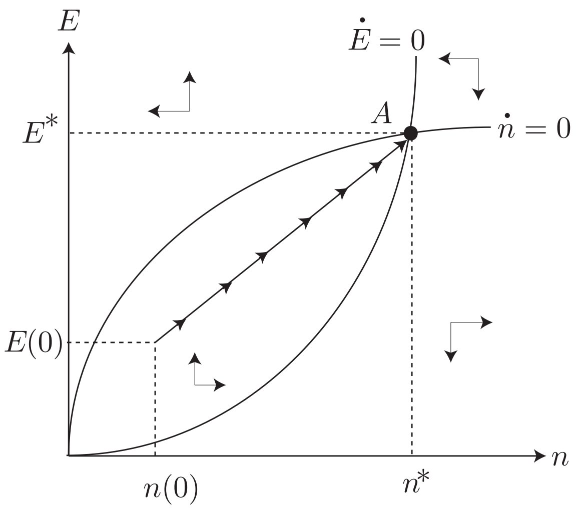

Figure 1: The phase diagram

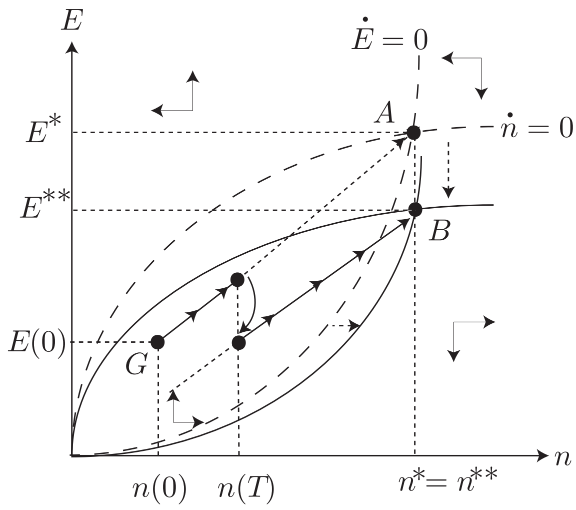

Figure 2: An increase in P_g at time T

Figure 1 depicts the phase diagram for the system in the (n, E) plane. The intersection point of the two curves $\dot{n} = 0$ line and $\dot{E} = 0$ corresponds to the steady state of this system. The $\dot{n} = 0$ line is given by:

$$E = P_D n^{\frac{1-\alpha}{\alpha}}. \tag{24}$$

When $\alpha < \frac{1}{2}$, the $\dot{n} = 0$ line is convex. On the other hand, when $\alpha > \frac{1}{2}$, the $\dot{n} = 0$ line is concave. Hereafter, we focus on the case of $\alpha > \frac{1}{2}$.[2] The $\dot{E} = 0$ locus is given by:

$$E = \frac{a\alpha\rho}{1-\alpha} P_D n^{\frac{1}{\alpha}}. \tag{25}$$

The $\dot{E} = 0$ locus is convex. Thus, there exists a unique steady state. The steady state value of n^* is given by:

$$n^* = \frac{1-\alpha}{a\alpha\rho}. \tag{26}$$

We can show the steady state A becomes saddle path stable (see Appendix for the proof).

Figure 2 depicts the phase diagram when the price of the natural resource increases suddenly at time T. We assume that the agent does not expect the sudden increase in the price of the natural resource and has rational expectations. Suppose that the initial number of intermediate goods is sufficiently small at G in Figure 2. The agent expects that the economy follows the stable path to A in Figure 2 in the future. Then, at time T, the price of the natural resource increases suddenly. The agent decreases his expenditure immediately in response and induces the economy to follow the stable path to B in Figure 2.

The effects of a sudden increase in the price of the natural resource on the steady state value of the number of intermediate goods and expenditure are summarized as follows:

$$\frac{\partial n^*}{\partial P_g} = 0, \tag{27}$$

$$\frac{\partial E^*}{\partial P_g} = -\gamma^{\frac{1}{\sigma}}(1-\gamma)^{\frac{-1}{\sigma-1}}(\frac{1-\alpha}{a\alpha\rho})^{\frac{1-\alpha}{\alpha}} P_g^{\frac{1}{\sigma-1}} \left[1-(1-\gamma)^{-\frac{1}{\sigma-1}} P_g^{\frac{\sigma}{\sigma-1}}\right]^{\frac{-1}{\sigma}} < 0. \tag{28}$$

Because $P_D > 0$, $1-(1-\gamma)^{-\frac{1}{\sigma-1}} P_g^{\frac{\sigma}{\sigma-1}} > 0$.

Accordingly, in the steady state, an increase in the price of the natural resource decreases expenditure and does not change the level of technology. Thus, we can summarize these results as the following proposition.

PROPOSITION 1. *In the long run, an increase in the price of the natural resource decreases expenditure without affecting the level of technology.*

4 Conclusion

This paper constructs an endogenous variety expansion model in a small open economy based on Grossman and Helpman (1991). We focus on the effect of a sudden increase in the price of natural resources. We conclude that an increase in the price of the natural resource decreases expenditure but does not affect the level of technology.

[2] When $\alpha < \frac{1}{2}$, the following discussion can be applied.

References

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A Appendix

A.1 Proof of the stable saddle path

We derive that the steady state of this economy is saddle point. The linearized system of (22) and (23) around the steady state is given by:

$$\begin{pmatrix} \dot{n}_t \\ \dot{E}_t \end{pmatrix} = \begin{pmatrix} \rho & -\frac{1}{aE^*} \\ -\frac{1-\alpha}{a\alpha} P_D {n^*}^{\frac{1-3\alpha}{\alpha}} & \rho \end{pmatrix} \begin{pmatrix} n_t - n^* \\ E_t - E^* \end{pmatrix}.$$

The determinant of the characteristic matrix is $-\frac{\alpha\rho^2}{1-\alpha} < 0$. Then, the determinant takes a negative value. Therefore, the two eigenvalues of the system have opposite signs and the steady state is saddle point.