

Effects on Growth of Environmental Policy in Open Economy

By

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Introduction

- A large number of observers and policy makers have expressed different degrees of concern about the existence of serious environmental dangers associated with economic growth.
- Environmentalists have argued that economic growth requires the use of the environment both as a source of raw materials and energy and as a sink for the waste generated through production.
- None of these is good for the environment and poses a serious threat on life on earth.
- Thus, continued economic growth is deemed incompatible with non-deteriorating environmental quality (Daly, 1987).
- Nevertheless, the literature has to a large extent agreed that environmental policy will be inimical to economic growth because it raises the cost of capital and slows down capital accumulation.
- However, these costs do not come without benefit which could be growth enhancing through the accumulation of human capital (Smulders, 1995).

Introduction continued

- Most of the earlier works investigating the interactions between economic growth and environmental policy do not make extensions to the open economy
- There is thus a gap in the literature that theoretically examines the effect on growth of environmental policy.
- The objective of this paper is to examine the effect of environmental policy on growth in a small open economy within the framework of the one sector neoclassical growth model in which pollution serves as an input in the production function.
- The idea of modelling pollution as serving as an input in the production function is not novel (see for instance Copeland and Taylor, 2003; Xepapadeas, 2003; van Ewijk and van Wijnbergen, 1995; Brock, 1977).
- The novelty of this paper is its extension of the basic model to a small open economy in which the government redistributes pollution tax proceeds in lump sum form over all households.

Introduction continued

- The paper attempts to seek answers to the following vital questions:
 - Does strict environmental policy lead to “capital flight”? Can it lead a “flip” from stability to instability?
 - What happens to the wage rate as an economy is opened to international capital movements? How is it influenced by environmental policy?

The basic model

- Our setup begins with a closed economy neoclassical-type model with environmental policy.
- The role of government is limited to taxing polluting firms and redistributing the proceeds to households as a way of internalizing externalities generated through production.
- We thus abstract from government purchases; only households and firms interact at the market place.
- The government's budget constraint satisfies $\tau Z = \varphi$
- Where τZ is the total tax revenue and φ is the lump sum pollution subsidy to a representative household.

The firms

- Firms produce goods with effective labour (LT), capital (K) and pollution (Z), according to a Cobb-Douglas production function, which exhibits constant returns to scale in all its three arguments.

$$Y = K^\alpha Z^\beta (LT)^{1-\alpha-\beta} \quad (1)$$

Where (Y) is aggregate output

- The index of technological progress, T , is assumed to grow exogenously at the rate x .
- Raw labour, L , grows at the exogenous rate, n .
- In addition to the CRS property, the production function in (1) satisfies the neoclassical assumption of diminishing marginal returns, essentiality and the Inada conditions.
- Firms are atomistic and pay each input its marginal contribution to output

Firms continued

- The problem facing a representative firm then is to maximize profits given by equation (2).

- $$\pi = K^\alpha Z^\beta (LT)^{1-\alpha-\beta} - RK - wL - \tau Z \quad (2)$$

- The appropriate FOCs are as in equations (3)-(5)

- $$\alpha \frac{Y}{K} = R \Leftrightarrow \alpha \frac{1}{v} = R \quad \text{and} \quad R = r + \delta \Rightarrow \frac{1}{v} = \frac{r + \delta}{\alpha} \quad (3)$$

- Where we have used $v = \frac{K}{Y} \Leftrightarrow \frac{Y}{K} = \frac{1}{v}$

- $$\beta \frac{Y}{Z} = \tau \Leftrightarrow Z = \beta \frac{Y}{\tau} \quad (4)$$

- $$(1 - \alpha - \beta) \frac{Y}{L} = w \quad (5)$$

The households

- Households are atomistic and take prices in both the output and factor markets as given.
- Each individual owns one unit of labour which he supplies inelastically at any wage rate.
- The household receives a lump-sum subsidy φ of from the government as a compensation for the deterioration in environmental quality due to activities of firms in period t .
- There are negative externalities in the form of environmental pollution but the single household cannot influence that.
- Households use income that they do not consume to accumulate more assets according to the following dynamic equation:

- $$\dot{A} = rA + wL + \varphi - C \tag{6}$$

- Note: equation (6) corresponds to equation (9) in the main text.

Households continued

- To develop (6) further, we use the firms optimality conditions in (3-5), the governments budget constraint and the fact that in a closed economy $A=K$.

note that;

$$r = R - \delta$$

$$A = K$$

$$RK = \alpha Y$$

$$\tau Z = \beta Y$$

$$wL = (1 - \alpha - \beta)Y$$

$$(6) \Leftrightarrow$$

$$\dot{K} = (R - \delta)K + wL + \tau Z - C$$

$$\dot{K} = \underbrace{RK + wL + \tau Z}_{=Y} - C - \delta K$$

$$\dot{K} = Y - C - \delta K$$

$$\dot{K} = Y - C - \delta K$$

Households

- Equation (7) (equation 10 in the main text) is the aggregate resource constraint for the closed economy model.
- According to (7) the change in the aggregate capital stock over time is given by the difference between aggregate production and the sum of two terms, consumption and the amount of depreciation or replenishment of the aggregate capital stock.
- Equations (1, 3-7) play a key role in the rest of the paper and we shall make many references back to them in the rest of the discussions.

Open Ramsey model

Intertemporal Utility Function

Consider an infinite-horizon economy and suppose that the economy admits a representative household with instantaneous utility function

$$u(C/L, Z) = \frac{(C/L)^{1-\theta}}{1-\theta} - \phi \frac{Z^{1+\eta}}{1+\eta} \quad \theta \geq 0, \eta \geq 0, \phi > 0$$

The parameter, ϕ is the weight of disutility of pollution.

The household is assumed to be altruistic towards all of its future member and always makes the allocation of consumption among current and futures members cooperatively.

OpenRamsey model

- Under optimal policy the fully internalize the pollution externality, the social optimum coincides with the decentralized equilibrium. I exploit this equivalence by assuming optimal policy right away.
- I therefore focus on the problem facing a benevolent social planner in what remains.
- The objective of the social planner is to maximize

$$u = \int_0^{\infty} u(C/L, Z) e^{-(\rho-n)t} dt = \int_0^{\infty} \left[\frac{(C/L)^{1-\theta} - 1}{1-\theta} - \phi \frac{Z^{1+\eta}}{1+\eta} \right] e^{-(\rho-n)t} dt \quad (14)$$

With respect to C , I and Z subject to

$$\dot{D} = C + I + rD - Y \quad \text{and} \quad \dot{K} = I - \delta K$$

Open economy Ramsey model

The current value Hamiltonian for the planner's problem is

$$H(C/L, Z, K, D, \mu, q) = \frac{(C/L)^{1-\theta}}{1-\theta} - \phi \frac{Z^{1+\eta}}{1+\eta} + \mu(Y - C - rD) + q(I - \delta K)$$

where :

μ is the shadow cost of the debt

and

q is the shadow price of capital

Open economy Ramsey model

- The optimality conditions are:

$$\frac{\partial H}{\partial C} = 0 \Leftrightarrow C^{-\theta} = -\mu L^{1-\theta}$$

$$\frac{\partial H}{\partial C} = 0 \Leftrightarrow -\mu = q$$

$$\frac{\partial H}{\partial Z} = 0 \Leftrightarrow \phi Z^\eta = -\mu\beta \frac{Y}{Z}$$

$$\frac{\dot{\mu}}{\mu} = \rho - n - r$$

$$\frac{\dot{q}}{q} = \rho + \delta - n - \alpha / v$$

$$\lim_{t \rightarrow \infty} \mu(t) D(t) e^{-(\rho-n)t} = 0$$

$$\lim_{t \rightarrow \infty} q(t) K(t) e^{-(\rho-n)t} = 0$$

- By the usual procedure, we obtain the following consumption Euler's equation for the open economy Ramsey as:

$$\frac{\dot{C}}{C} = \frac{1}{\theta} \left[\frac{\alpha}{v} + \theta n - (\rho + \delta) \right]$$

Open economy Ramsey

- Recall that in the open economy the COR jumps to the steady state value of
- $V^* = \alpha/(r+\delta)$
- Using the steady state condition for the COR, the consumption Euler's equation simplifies to:

- $$\frac{\dot{C}}{C} = \frac{1}{\theta}(r - \rho) + n \quad (A)$$

- The growth rate of pollution is

$$\frac{\dot{Z}}{Z} = \frac{1}{1+\eta} \left(\frac{\dot{\mu}}{\mu} + \frac{\dot{Y}}{Y} \right)$$

Open economy Ramsey model

- Transversality conditions reduces to

- $\frac{\dot{D}}{D} < r$ and $\frac{\dot{K}}{K} < r$

- **Steady state growth rates**

The capital stock (and GDP) grow at the rate of:

$$g_K = \frac{\dot{K}}{K} = n + x - \beta \frac{\eta(n+x) - (n+r-\rho)}{(1-\alpha)(1+\eta) - \beta} \quad (\text{B})$$

The socially optimal growth rate of pollution at the steady state is:

$$\frac{\dot{Z}}{Z} = \frac{(1-\alpha)(\rho-r) + (1-\alpha-\beta)x - \beta n}{((1+\eta)(1-\alpha) - \beta)}$$

Open economy Ramsey

- Consumption-capital ratio:

$$\frac{\dot{\chi}}{\chi} = \frac{\dot{C}}{C} - \frac{\dot{K}}{K} \Rightarrow$$

$$g_{\chi} \equiv \frac{\dot{\chi}}{\chi} = \frac{(1-\alpha)(1+\eta) + (\theta-1)\beta}{((1-\alpha)(1+\eta) - \beta)\theta} (r - \rho) + \frac{(1+\eta)\beta n - (1-\alpha - \beta)(1+\eta)x}{(1-\alpha)(1+\eta) - \beta}$$

- This expression can be integrated to obtain:

$$\chi(t) = \chi(0)e^{g_{\chi}t}$$

- The growth rate of the consumption-capital ratio can be positive, negative or zero.

Open economy Ramsey model

- Debt-Capital ratio;

Combine the two constraints to obtain

$$\dot{K} - \dot{D} = Y - C - rD - \delta K$$

Divide through by K

$$\frac{\dot{K}}{K} - \frac{\dot{D}}{K} = \frac{Y}{K} - \frac{C}{K} - r \frac{D}{K} - \delta$$

Define $d = D/K$. This then implies

$$\dot{d}/d = \dot{D}/D - \dot{K}/K \Leftrightarrow \dot{D}/K = \dot{d} + d(\dot{K}/K)$$

After some simplifications we obtain the following differential equation

$$\dot{d} = g_K - (r + (1 - \alpha)\delta) / \alpha + \chi(0)e^{g_K t} - (g_K - r)d$$

Open economy Ramsey model

- The solution to the above differential equation is:

$$d = \left(\left[g_K - r \frac{(1-\alpha)(r-\delta)}{\alpha} \right] \frac{1}{r-g_K} \right) + \chi(0) \frac{1}{r-g_K-g_\chi} e^{g_\chi t} + \Gamma e^{[r-g_K]t}$$

- Where

$$\Gamma = d(0) - \left(\left[\frac{(1-\alpha)(r+\delta)}{\alpha} + r - g_K \right] \frac{1}{r-g_K} \right) - \frac{\chi(0)}{r-g_K-g_\chi}$$

- which may very well be negative.

Open economy

- Recall that $d=D/K$. This implies that $D=dK$. But $K = K(0)e^{g_K t}$
- We therefore can rewrite the solution to our differential equation for the debt capital ratio as
- $$D(t) = \frac{K(0)}{r - g_K} \left[\frac{(1-\alpha)(r + \delta)}{\alpha} + r - g_K \right] e^{g_K t} - \frac{K(0)\chi(0)}{r - g_K - g_\chi} e^{g_\chi t} + \Gamma K(0)e^{rt}$$
- Since the growth rate of the final term is r the TVC cannot be satisfied unless we choose the initial value of C/K , $\chi(0)$ such that $\Gamma=0$
- This gives the final solution of
- $$D(t) = K(0)B e^{g_K t} - (B - d(0)) K(0) e^{g_\chi t} \quad (C)$$
- where $B \equiv \left[\frac{(1-\alpha)(r + \delta)}{\alpha} + r - g_K \right] \frac{1}{r - g_K}$

Open economy

- The dynamics of the model is now given by the growth rate of consumption, growth rate of capital stock and the debt. (i.e. Equations (A), (B) and (C))
There are now three possible qualitative different scenarios, depending on the relationship between the growth rate of consumption and the capital stock
- **CASE 1** $g_K < g_C$
- Under this scenario, the final term grows faster than the first term in the D equation
- Hence D turn to negative and continue to decline.
- The country accumulates assets abroad due to a high aversion to pollution
- **CASE 2** $g_K > g_C$
- This may be so if there is low aversion to pollution
- **CASE 3** $g_K = g_C$
- Under this scenario, C , K , Y and D all grow at the same rate

Conclusion

- The economy can make use of the international capital market and reduce its emissions
- Thus, due to polluting effect of production, a large and increasing share of consumption will be financed by international capital management. This is the idea of *pollution haven* presented in a new way
- This finding equally reechoes the environmental Kuznets curve (EKC) hypothesis
- *At the initial levels of development country depends much on domestic production to finance its consumption and investments. Over time however, it can afford to investment in the international capital markets and thus cut down on the accumulation of domestic capital and hence production. Other things equal, this will imply an inverted-U time path for emissions.*

END

- THANK YOU FOR YOUR ATTENTION