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THE STRUCTURE OF TAXES AND ENVIRONMENTAL QUALITY

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Abstract. In this paper we analyze the implications of a number of shocks for optimal policy and various macroeconomic variables in the context of small open economy with environmental externalities in production. The result show that increased concern for the environment reduces employment despite the factor substitution induced by a lower tax on labour and a higher tax on natural resources.

Keywords: Natural resources, small open economy, environmental externalities, optimal taxation.

1. Introduction

The deterioration of the natural environment constitutes one of the major challenges facing public policy today. Indeed, environmental policy has raised many important economic issues. In particular, business groups are concerned that environmental protection induces both capital flight and major losses in private income. Environmental groups, in contrast, maintain that a more ambitious environmental policy may not impose large costs. In particular, environmental taxation may be attractive. In this way, pollution taxation would yield not only a cleaner environment but also a less distortionary tax system.

In particular, changing the tax structure away from labour taxation toward environmental taxation would encourage employers to substitute labour for capital and other inputs, thereby making production more labour intensive. At the same time, a lower level of labour taxation would yield after-tax wages, thereby increasing the incentives to supply labor. The hypothesis that higher pollution taxes associated with more environmental concern would not only improve the environment but also boost employment.

2. Natural resources in A small open economy

We focus on a small open economy which can freely trade goods, capital and natural resources on competitive world markets. Labour is, however, immobile internationally. National income amounts to the income received by domestic residents and must equal domestic demand for goods by domestic households and the domestic government. This may be written as:

$$Q \equiv F(K,NL,R) + P_R*(R_E - R) + P_K*(K_E - K) = NC + G + A, \qquad (1)$$

where $Q, K, K_E, P_K*, L, R, R_E, P_R*, C, G, A$ and N denote, repectively, national income , capital used in domestic production, the domestic endowment of capital, the world rental price of capital, hours worked by each household, the use of natural resources in domestic production, the domestic endowment of natural resources, the world price of natural resources, consumption of goods by the representative household, public consumption, public abatement, and the number of households. *F(.)* is concave and stands for a neoclassical production function with constant return to scale. An alternative way of expressing equation (1) is that net exports of goods (i.e. the trade balance of goods) must equal net imports of natural resources and capital:

$$F(K,NL,R) - NC - G - A = P_R*(R - R_E) + P_K*(K - K_E) \qquad (1a)$$

Profits of firms (π) are defined as sales minus the costs of labour, natural resources and capital including taxes on labour and natural resources:

$$\pi \equiv F(K,NL,R) - (w + t_L)NL - (P_R* + t_R)R - P_K*K \qquad (2)$$

where w, t_L and t_R stand for the market wage, the (employers') tax rate on labour and the tax rate on the use of natural resources, respectively. The household budget that can be used for consumption of goods consists of wage and profit income, lump-sum subsidies received from the government and the return on the endowments of capital and natural resources:

$$C = wL + (1/N)[\pi + P_K * K_E + (1-\xi)P_R * P_E] + T \tag{3}$$

where $(1-\xi)$ represents the share of the national endowment of natural resources that is owned by private agents and T stands for the (per-capita) lump-sum transfers received by each household from the government. Note that ξ may, alternatively, be interpreted as a tax rate on the return on the ownership of natural resources. Equation (3) assumes that each household owns an equal share of private assets. Spending of the government on public consumption, public abatement and lump-sum transfers must be financed by taxes on labour and the use of natural resources and by income from the sale of natural resources owned by the government:

$$G + A + NT = t_L NL + t_R R + \xi P_R * R_E \tag{4}$$

where ξ denotes the share of the endowment of natural resources that is owned (or taxed) by the government. According to Walras' law, (4) follows from (1), (2) and (3).

Firm maximise profits under perfect competition and thus equalise the marginal product of each factor to its user cost:

$$\begin{aligned} &F_K(K/NL,1,R/NL) = P_K*, \\ &F_R(K/NL,1,R/NL) = P_R * + t_R, \\ &F_{NL}(K/NL,1,R/NL) = w + t_L \end{aligned} \tag{5}$$

where subscripts denote partial derivatives. The first two first-order conditions yield the demands for capital and natural resources conditional on the level of employment:

$$\begin{aligned} &K/NL = k(P_K*, P_R * + t_R), \\ &R/NL = r(P_K*, P_R * + t_R). \end{aligned} \tag{6}$$

Note that $k_K = F_{RR}/\Delta < 0, k_R = r_K = -F_{RK}/\Delta$ and $r_R = F_{KK}/\Delta < 0$, where partial derivatives of *k(.)* and *r(.)* with respect to P_K* and $P_R * + t_R$ are denoted by the subscripts K and R, respectively. Concavity of the production function implies that $\Delta \equiv F_{RR}F_{KK} - F_{RK}{}^2 > 0$. Factor substitution away from capital (natural resources) towards labour takes place if the user cost of capital (natural resources) rises. If capital and natural resources are cooperant factors $(F_{RK} > 0)$, an increase in the cost of natural resources (capital) induces substitution away from capital (natural resources) towards labour. Substitution of the relative factor demand functions (6) into the third first-order condition given in (5) yields the factor price frontier:

$$w + t_L = \phi(P_K*, P_R * + t_R) \tag{7}$$

Constant returns to scale implies that $\phi_K = (F_{NL,K}F_{RR} - F_{RK}F_{NL,R})/\Delta = -k$ and $\phi_R = (F_{KK}F_{NL,R} - F_{NL,K}F_{KR})/\Delta = -r$ where the partial derivatives of $\phi(.)$ are denoted by the subscripts K and R. The producer wage is a negative function of both the producer cost of natural resources and the user cost of capital. Since the user cost of capital and the price of natural resources are determined on global competitive markets, a given tax on natural resources (t_R) uniquely determines the producer wage $(w + t_L)$. Constant returns to scale implies that profits (π) are zero in equilibrium.

Preferences are weakly separable in private utility (the bundle of private consumption and leisure), public consumption and environmental quality. The utility function of the representative household can thus be written as *U[M(C,V),G,E]*, where *U(.)* stands for total utility, *M(.)* represents private utility, V is leisure (i.e. *1-L* as the endowment of time is normalised at unity), and E denotes environmental quality. Households are atomistic and take the level of public consumption and environmental quality as given. They choose leisure and private consumption to maximise (private) utility subject to the budget constraint (3). Household thus equate the marginal rate of substitution between private consumption and leisure to the market (consumption) wage, i.e. $M_V / M_C = w$. This yields the demand for goods, the demand for leisure, indirect private utility and indirect social utility:

$$C = c(w,Y), V = v(w,Y), M = m(w,Y), U[m(w,Y), G.E] \equiv u(w,Y,G,E) \quad (8)$$

where private non-labour income (Y) is given by,

$$Y \equiv N^{-1}[P_K * K_E + (1-\xi)P_R * R_E] + T \quad (9)$$

The (uncompensated) wage elasticity of labour supply is defined as $\epsilon \equiv -wv_W / L$. Roy's identity gives employment as $L = u_w / \lambda$ where $\lambda \equiv U_C = U_M M_C = u_Y$ denotes the marginal utility of private income.

There is no international migration. Hence, equilibrium on the labour market requires that the demand for labour from (6) must equal household supply of labour from (8):

$$NL = K / k[P_K*, P_R * + t_R] = N[1 - v(w,Y)] \quad (10)$$

Substitution of the factor price frontier (7) into (10) yields an expression for the equilibrium level of domestically employed capital as a function of the producer costs of natural resources and capital, the tax on labour, and the level of non-labour income:

$$K = N[1 - v(\phi(P_K*, P_R * + t_R) - t_L, Y)]k(P_K*, P_R * + t_R) \quad (11)$$

A higher tax on labour reduces the consumption wage. If labour supply slopes upwards, a lower wage rate decreases both employment and domestically employed capital. A higher level of non-labour income raises the demand for leisure $(v_Y > 0)$, thereby reducing employment and capital. A higher user cost of natural resources depresses the market wage. If capital and natural resources are cooperant, the resulting change in relative input prices causes the demand for capital to decline relative to labour demand. If the labour supply curve slopes upwards, the lower wage reduces labour supply. As both employment and the capital-labour ratio decline, capital employed in domestic production falls. A higher cost of capital lowers the wage and, if labour supply slopes upwards, lowers labour supply. It also induces substitution away from capital towards labour. Accordingly, domestically employed capital falls.

3. Environmental quality and optimal government policy

Environmental quality declines with the use of natural resources and rises with public abatement:

$$E \equiv e(A) - R, e' > 0, \quad e'' < 0, \quad (12)$$

where $e(.)$ denotes the effectiveness of public abatement. The government selects the level of public consumption (G) and public abatement (A), the tax on labour (t_L), the tax on the use of natural resources (t_R), and the level of transfers (T) to maximise social welfare, i.e. $Nu[w,Y,G,E]$, subject to the factor price frontier (7), the definition of non-labour income (9), the ecological relationship (12), the demand for natural resources (6) (in which $L = 1 - v[\phi(.) - t_L, Y]$ has been substituted), employed capital (11), and the government budget constraint (4). The government is thus able to replicate the first-best outcome in a competitive, market economy. This may be seen from the first-order condition for the optimal level of lump-sum transfers:

$$Nu_Y - N\mu = 0 \quad (13)$$

where μ stands for the marginal reduction in social welfare arising from raising one more unit of public funds. The marginal cost of public funds (MCPF), $\eta \equiv \mu / \lambda$ expresses this fall in welfare in money units. Expression (13) reveals that if lump-sum subsidies and taxes are available, the shadow price of public funds (μ) equals marginal private utility of income $(u_Y = \lambda)$. Hence, the MCPF (i.e. η) is unity. In addition, the sum of the marginal rates of substitution between public and private consumption goods reduces to the marginal rate of transformation.

The remainder of the paper, however, assumes that lump-sum subsidies and taxes are not available (i.e. $T=0$). Accordingly, the government has to use distortionary taxes (or subsidies) to finance public spending.

Maximisation of social welfare with respect to the level of public consumption requires that the sum of the marginal rates of substitution between public consumption and private consumption must equal the MCPF:

$$NU_G / U_M M_C = \eta \equiv \mu / \lambda \quad (14)$$

This is the Samuelson rule for the optimal provision of public goods modified for the absence of lump-sum taxation. If the MCPF exceeds unity $(\eta > 1)$, an increase in public consumption exacerbates the deadweight loss of distortionary taxation. Accordingly, the sum of the marginal rates of substitution between public and private consumption needs to exceed the marginal rate of transformation (i.e. unity).

The optimal level of public abatement follows from setting the marginal rate of substitution between public consumption and environmental quality equal to the marginal rate of transformation between public abatement and environmental quality (e'):

$$U_G / U_E = e'(A) \tag{15}$$

where $e'(A)$ stands for the improvement in environmental quality that can be obtained by one additional unit of public abatement. Unlike (14), (15) does not feature the MCPF. The reason is that both public consumption and public abatement are financed by distortionary taxation. Hence, the MCPF affects the optimal demands for both these types of public spending in similar ways.

The first order condition for the optimal tax on the use of natural resources is:

$$[Nu_w + NU_E(R/L)v_w - \mu\{Nt_L + t_R(R/L)\}v_w]\phi_R + \mu R + (\mu t_R - NU_E)r_R NL = 0 \tag{16}$$

The first-order condition for the optimal tax on labour is:

$$-Nu_w - NU_E(R/L)v_w + \mu[N(L + t_L v_w) + t_R(R/L)v_w] = 0 \tag{17}$$

Upon substitution of (17) into (16), we obtain

$$\mu NL\phi_R + \mu R + (\mu t_R - NU_E)r_R NL = 0 \tag{16a}$$

If we make use of $\phi_R = -r$, the expression for the optimal tax on natural resources becomes:

$$t_R \equiv (NU_E / U_M M_C)(1/\eta) \tag{18}$$

Substitution of (14) into (18) yields:

$$t_R = U_E / U_G > 0 \tag{18a}$$

Substituting (18a) into (15), we find for the marginal productivity of abatement:

$$e'(A) = 1/t_R \tag{15a}$$

Public abatement thus increases with the tax on natural resources.

The optimal tax on the use of natural resources is zero if environmental externalities are absent (i.e $U_E = 0$). The reason is that a small open economy cannot affect the world market price of natural resources. Hence, the resource tax is fully born by the internationally immobile factor of production, i.e. labour, and thus amounts to an implicit labour tax. From a revenue-raising point of view, the explicit labour tax is a more efficient levy on labour income; while both taxes distort labour supply by reducing the consumption wage, only the input tax on resources (t_R) distorts production decisions.

Applying Roy's identity $(u_w = \lambda L)$ to (17), substituting (18) and dividing by $N\lambda L$ yields the following expression for the MCPF:

$$\eta = \frac{\mu}{\lambda} = \left[\frac{1}{1 - \left(\frac{t_L}{w}\right)\in_L}\right] \tag{19}$$

If labour supply is inelastic $(\in_L = 0)$, additional labour taxes do not affect the base of the labour tax and thus the MCPF is unity. If labour supply slopes upwards $(\in_L > 0)$, equation (19) reveals that a positive tax on labour raises the MCPF above unity. The reason is that a higher labour tax depresses labour supply, thereby eroding the base of the distortionary labour tax. If, however, labour supply bends backwards $(\in_L < 0)$, the negative income effect associated with a higher tax on labour boosts labour supply, thereby broadening the labour tax base. This causes the MCPF to fall below unity. Intuitively, the government uses the tax system to simultaneously accomplish two objectives, namely, first, raising public revenues, and second, internalising externalities. If public revenues become scarcer, as indicated by a higher MCPF, the tax system needs to focus more on raising revenue and less on environmental objectives. In this way, a high MCPF cuts the demand not only for public consumption but also for the public good of the environment.

The change in the demand for natural resources can (by using (6)) be written as:

$$\widetilde{R} = \widetilde{L} - \in_R [(1-\theta_R)\widetilde{P}_R * + \widetilde{t}_R],$$
$$\in_R \equiv -F_{KK}(r\Delta)^{-1}(P_R * + t_R) > 0 \tag{6b}$$

where $\widetilde{t}_R \equiv dt_R /(P_R * + t_R)$ and $\theta_R \equiv t_R /(P_R * + t_R)$. The factor price frontier (7) yields:

$$\widetilde{w} = -\delta_R[(1-\theta_R)\widetilde{P}_R * + \widetilde{t}_R] - \widetilde{t}_L,$$
$$\delta_R \equiv (P_R * + t_R)r / w > 0 \tag{7b}$$

where $\widetilde{t}_L \equiv dt_L / w$. The consumption wage ($w$) thus declines if firms face a higher cost of natural resources or a higher tax on labour.

Loglinearisation of (18a) yields the change in the tax on the use of natural resources:

$$\widetilde{t}_R = \theta_R(\widetilde{U}_E - \widetilde{U}_G) \tag{18b}$$

Loglinearising (15a) and then substituting (18b), we find for the change in public abatement:

$$\widetilde{A} = (\widetilde{t}_R / \theta_R)/\sigma_A = (\widetilde{U}_E - \widetilde{U}_G)/\sigma_A,$$
$$\sigma_A \equiv -Ae''/e' > 0 \tag{15b}$$

A higher utility weight for environmental quality or a lower priority for public consumption encourages the government to undertake more abatement, particularly if the elasticity of the productivity of public abatement (σ_A) is low. Intuitively, a higher priority for the environment makes the output of public abatement (i.e. a cleaner environment) more valuable while a lower priority for public consumption crowds in other types of public spending.

4. Environmental quality and production

We assumed that the use of natural resources in the production process harms the quality of the natural environment. An alternative specification is to allow capital and labour to produce either more output of goods (Q) or less pollution (P), say

$$G(Q,P) = \overline{F}(K,NL), G_Q, \overline{F}_K, \overline{F}_{NL} > 0, \quad G_P < 0, \tag{20}$$

where $\overline{F}(.)$ is a concave neoclassical production function and $G(.)$ allows for substitution between output of goods and pollution. Using the implicit function theorem, we can rewrite (20) as a reduced form production function:

$$Q = F(K,NL,P),$$
$$F_K \equiv \overline{F}_K / G_Q, \qquad F_{NL} \equiv \overline{F}_{NL} / G_Q, \quad F_P \equiv -G_P / G_Q > 0. \tag{20a}$$

this specification of production and pollution (P) is closely related to the one of production and use of natural resources (R); i.e. pollution can also be seen as a factor of production. Pollution as specified in (20) seems a special case of production with natural resources as a factor of production, i.e. production is separable between on the one hand capital and labour and on the other hand pollution (or equivalently the use of natural resources). However, there is an important difference in that, in contrast to the use of natural resources, there is generally no world market price for pollution other than a government tax.

Greener policies reduce labour supply and output. This result may disappear once one allows for the role of the environment as a public good in production. If environmental quality benefits productivity, we have:

$$Q_P = a(E)F(K,NL,R), a' > 0, \quad a'' < 0, \tag{21}$$

where Q_P stands for domestic output of goods. A good example of environmental quality improving productivity may be found in agriculture, where production typically benefits from a better quality of the soil and air. A better environmental quality may also reduce congestion and smog while improving health and morale , thereby boosting productivity. According to (21), environmental quality enhances the productivity of all inputs. An alternative specification is that environmental quality affects labour rather than general productivity.

The demands by firms for capital and natural resources relative to employment, (6), are unaffected. However, the factor price frontier becomes

$$w + t_L = \phi(P_K *, P_R * + t_R, E) \tag{7c}$$

with $\phi_K = -k$, $\phi_R = -r$ and $\phi_E = [a'(E)F(K,NL,R)/NL) > 0$. A better environmental quality boosts the marginal productivity of labour and thus the wage. Total differentiation of (7c) yields (using (6) and (12)):

$$dw = \Delta[(\phi_R - \phi_E r_R NL)dt_R - dt_L + \phi_E e'(A)dA], \quad \Delta \equiv (1 + \phi_E \in_L R/w)^{-1} \qquad (7d)$$

The first-order conditions for the tax on resources and the tax on labour can with the aid of (7d) be written as:

$$\Delta H_w(\phi_R - \phi_E r_R NL) + \mu R + (\mu t_R - NU_E)NLr_R = 0 \qquad (16b)$$

$$H_w = Nu_w + N^2 U_E v_w r - \mu(t_L + rt_R)Nv_w = \mu NL/\Delta \qquad (17a)$$

where H denotes the Lagrangian function for the government. Substituting (17a) into (16b), making use of $\phi_R = -r$ and rearranging, we obtain,

$$t_R = (NU_E/U_C)\eta^{-1} + a'(E)F(K,NL,R) \qquad (18c)$$

The expressions for the optimal provision of public goods, (14), the optimal level of public abatement, (15), and the MCPF, (19), are unaffected.

The main difference with the case in which environmental quality benefits only utility is that, in addition to a term to correct for the consumption externality, the tax on renewable resources incorporates a term to take into account the adverse impact of resource use on productivity. In contrast to the first term for the consumption externality, the second term corresponding to the production effect does not involve the MCPF. This may have important implications. In particular, if public funds become scarcer, the government's ability to differentiate tax rates for environmental purposes is not necessarily affected and thus the tax on resources does not need to fall. Moreover, the double dividend hypothesis may hold as a cleaner environment associated with greener preferences boosts labour productivity, thereby raising wages.

5. Conclusion

A shift toward a higher priority for public consumption makes optimal environmental policy less ambitious. In particular, the composition of the tax system becomes less friendly to the environment as taxes focus more on revenue raising rather than environmental protection. As a result of a lower pollution tax, production becomes more resource intensive. Moreover, as far as the composition of public spending is concerned, public consumption crowds out public abatement. These changes in the tax structure and the composition of public spending make economic activity dirtier. Hence, through these channels, a higher priority for one public good, namely public consumption, directly competes with the public good of a cleaner environment. However, if the input mix into production is not sensitive to the lower pollution tax, public abatement does not rise much, and, at the same time, the uncompensated wage elasticity of labour supply is positive and large, the environment may benefit from a higher social priority for public consumption. The reason is that a higher overall tax level causes private agents to substitute away from produced goods toward leisure, which is clean.

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