CentER for Economic Research

Discussion paper

[redacted]

TILBURG UNIVERSITY

CentER
for
Economic Research

No. 9345

Environmental Policy, Public Goods and the Marginal Cost of Public Funds

by Frederick van der Ploeg
and A. Lans Bovenberg

July 1993

ISSN 0924-7815

ENVIRONMENTAL POLICY, PUBLIC GOODS AND THE MARGINAL COST OF PUBLIC FUNDS*

Frederick van der Ploeg
University of Amsterdam, TI and CEPR

A. Lans Bovenberg
CentER, Tilburg University
OCFEB, Erasmus University Rotterdam and CEPR

ABSTRACT

The provision of public consumption goods and public abatement are analysed within a second-best framework of optimal taxation with environmental externalities. Households choose between consumption of produced goods and leisure. Pollution is a by-product of production and can be off-set by public abatement. If private goods are perfect substitutes for public goods and environmental quality, greener preferences reduce employment, raise abatement and improve environmental quality. One version of the "double dividend" hypothesis, i.e. greener preferences both enhance the environment and boost employment, thus fails. If the elasticity of substitution between private goods and leisure exceeds one, the tax rate increases, thereby reducing private consumption. However, if the labour supply curve bends backwards, private utility rises while the tax rate and public consumption fall. With imperfect substitution between private and public consumption, greener policies boost labour supply in the special case that the substitution elasticity between private and public consumption and the elasticity of the effectiveness of public abatement are small and the labour supply curve bends backwards.

JEL code: E60, H21, H41, Q28

Keywords: Environmental externalities; emissions; public abatement; excess burden of taxation; public goods; optimal taxation; "double dividend"; second-best.

December 1992

Revised April 1993

Mailing addresses:

A.Lans Bovenberg
CentER, Tilburg University
Postbox 90153
5000 LE Tilburg, The Netherlands
tel: (+31)-13-662770

Frederick van der Ploeg
FEE, University of Amsterdam
Roetersstraat 11
1018 WB Amsterdam, The Netherlands
tel: (+31)-20-5254201

---

* This paper has benefited from comments of Harry Huizinga and participants in the 1993 AUTE/RES Conference at the University of York.

Protecting the environment constitutes one of the major challenges facing politicians today. In the political debate, it is often forgotten that important trade-offs have to be faced and that environmental policy is part of the overall package of government policy instruments. Many politicians argue, for example, that the revenues from taxes on polluting activities should be used to reduce distortionary taxes elsewhere in the economy. This may yield a "double dividend" in the sense that both environmental quality and employment will rise (cf. Pearce, 1991). Environmental policy raises also important other issues. Under what conditions is a cleaner environment compatible with a higher rather than a lower level of public consumption? Does a cleaner environment require a fall in private utility? How does environmental policy affect the tax level and the level and composition of public spending? The objective of this paper is to provide answers to some of these major policy questions.

Taxes serve the dual purpose of, on the one hand, generating revenues to finance a sizeable public sector and, on the other hand, internalizing environmental externalities. Atkinson and Stern (1974) analyze the optimal provision of public goods, paying attention to deadweight losses of taxation and the marginal cost of public funds, but ignore environmental externalities. Sandmo (1975) considers the optimal determination of distortionary taxes in the presence of externalities in private consumption but assumes an exogenous public revenue target. Sandmo's analysis thus combines Ramsey and Pigovian objectives of public finance. Bovenberg and van der Ploeg (1992) extend Sandmo's results to the optimal provision of public goods while allowing for a rich mix of policy instruments, viz. public consumption of both dirty and clean goods, public abatement, a tax on private consumption of dirty goods and a labour tax. Their main result is that the "double dividend" hypothesis fails, i.e. greener preferences lead in general to a cut in the labour tax, a rise in the dirt tax, and a fall in employment. Bovenberg and van der Ploeg (1992) focus on external effects in consumption. This paper, in contrast, explores the effects of environmental production externalities. Morevover, we allow for imperfect substitution between private and public components of social welfare. Furthermore, we not only study the impact of changes in social preferences but also the consequences of changes in the emission-output ratio and productivity shocks.

Section I characterizes the second-best outcome for a competitive economy in which households obtain utility from consumption of private goods, leisure, public consumption and environmental quality. Section II assumes perfect substitution between private utility, public consumption and environmental quality and performs comparative statics with respect to changes in environmental or public concern, the emission-output ratio and labour productivity. Section III allows for imperfect substitution between private utility and public consumption. Section IV concludes the paper.

I. TAXATION, PUBLIC GOODS, AND ENVIRONMENTAL EXTERNALITIES

I.1. Private behaviour, market equilibrium and the government budget

The representative household receives income from employment (bL where b denotes the production wage and L stands for hours worked). After paying taxes (tbL where t denotes the tax rate), the household spends the after-tax labour income together with any (lump-sum) transfers received from the government (S) on consumption goods (C). The budget constraint of the representative household thus amounts to $(1-t)bL+S=C$. The household derives private utility (M) from the consumption of goods

(C) and leisure ($V=1-L$, where the total number of hours available to the household is normalized at unity). The household also obtains utility from public goods (G) and environmental quality. Pollution occurs as a by-product of production. Hence, environmental quality declines with production (Y). It can, however, be enhanced through public abatement (A). For example, the government may step in to clean up polluted soil arising from dumping of hazardous materials in the past. If utility is separable in private utility, public goods and environmental quality (i.e. $E^* \equiv e(A)-aY$), we have:

$$U \equiv M(C,V) + R(G) + E[e(A) - aY], \quad R' > 0, R'' \leq 0, E' > 0, e' > 0, e'' < 0 \tag{1}$$

where a denotes the emission-output ratio and e(.) represents the effectiveness of public abatement. The private utility function M(.) is concave and weakly homothetic so Engel curves are linear. Households are atomistic, so take wages, prices, the tax rate, public goods and environmental quality as given. Households equate the marginal rate of substitution between consumption goods and leisure to the after-tax wage (w), i.e. $M_V/M_C=(1-t)b\equiv w$ where subscripts denote partial derivatives. Using the household budget constraint, we obtain:

$$C = c[w,S], \quad V = 1 - l[w,S], \quad M = m[w,S]. \tag{2}$$

where m[.] denotes the indirect private utility function. Roy's identity gives labour supply, i.e. $L=m_w/\lambda$ where $\lambda \equiv m_S = M_C$ denotes the marginal private utility of private income. The (uncompensated) elasticity of labour supply (evaluated at $S=0$) is given by $\epsilon_L \equiv wl_w/L=(\sigma_M-1)V$ where σ_M stands for the elasticity of substitution between C and V in M(.). Clearly, the (uncompensated) labour supply curve slopes upwards (bends backwards) if the substitution effect dominates (is outweighed by) the income effect, i.e. if σ_M exceeds (is less than) unity.

Labour market equilibrium implies that all unemployment is voluntary, i.e. $L+V=1$. Equilibrium on the goods market requires that total demand for goods, consisting of private consumption (NC where N denotes the number of households), public consumption (G) and public abatement (A), is constrained by total output (Y):

$$Y \equiv b\,NL = NC + G + A. \tag{3}$$

We assume that output is proportional to employment and producer prices are fixed (without loss of generality at unity). Relaxing this assumption does not affect the results, so long as producer prices result from competitive behaviour and pure profits arising from decreasing returns to scale are taxed away (Auerbach, 1985). In accordance with the law of Walras, the government budget constraint follows from the household buget constraint and (3), i.e. $tbNL=G+A+NS$. Labour tax revenues thus finance public spending, which consists of public consumption, abatement and lump-sum subsidies.

I.2. The marginal cost of public funds and the second-best outcome

The government can freely choose the level of public goods (G), public abatement (A) and the tax rate (t), but is unable to employ lump-sum taxes or subsidies (S=0).[1] Thus, the tax rate serves the dual purpose of, on the one hand, internalizing environmental externalities and, on the other hand, financing public spending. This gives rise to second-best problems. The government thus selects G, A and t to maximize social welfare (W), i.e.

$$W \equiv N\,U = N\,m[(1\text{-}t)b,0] + N\,R(G) + N\,E[e(A) - aNb\ell[(1\text{-}t)b,0]], \tag{4}$$

subject to $tbN\ell[(1\text{-}t)b,0] = G + A$. This yields for public consumption and abatement:

$$N\,R'(G) = N\,E'\,[e(A) - aY]\,e'(A) = \mu \tag{5}$$

where μ is the marginal disutility of raising a unit of government revenues. Clearly, each pound of public spending must yield the same marginal utility, irrespective of whether it is used for public consumption or abatement. Rewriting the first part of (5) gives:

$$NR'(G)/M_C = \eta \equiv \mu/\lambda. \tag{6}$$

Hence, the sum of the marginal rates of substitution between public and private consumption should equal the marginal cost of public funds (η) which can diverge from the marginal rate of transformation between public and private goods (i.e. unity). Scarcer public funds (and thus a higher η) causes substitution away from public towards private consumption. The second part of (5) can be written as

$$e'(A) = a/t_N, \quad t_N \equiv (NaE'/M_C\eta) = aE'/R' \tag{7}$$

where t_N is the non-distortionary level of the tax rate. Because $e''<0$, the optimal level of public abatement increases with the implicit price of the environment (i.e. t_N/a which is the non-distortionary level of the tax rate scaled by the emission-output ratio). Equation (7) also reveals that the marginal rate of substitution between environmental quality and public goods (E'/R') must equal the implicit price of the environment. If the marginal cost of public funds is unity (i.e. if lump-sum taxes and subsidies are available), the non-distortionary level of the tax rate corresponds exactly to the textbook Pigovian tax rate, i.e. the sum of the marginal environmental damages (NaE' scaled by M_C to convert from utility

---

[1] If the government can adopt lump-sum subsidies and taxes, there is no excess burden of distortionary taxation and the marginal cost of public funds equals the marginal rate of transformation between public and private goods (unity). The resulting outcome is first best in the sense that the command outcome can be replicated by appropriate government policy in a competitive market economy.

units into pounds). The non-distortionary level of the tax rate (t_N) decreases with the marginal cost of public funds (η). The reason is the following. The optimal environmental tax equates the social costs of pollution to the social benefits associated with the additional tax revenue collected on pollution. If a high marginal cost of public funds indicates that tax revenue is scarce, pollution does not have to yield as much tax revenue to offset the environmental damage. Accordingly, the pollution tax rate falls with the marginal cost of public funds. Alternatively, a high marginal cost of public funds indicates that public goods, including the natural environment, are expensive so that the government can afford less to internalize environmental externalities.

The government also sets the tax rate to maximize social welfare (4) which yields:

$$- Nbm_w + NE' abNbV_w + \mu \, bN (L-tbV_w) = 0. \qquad (8)$$

Use of Roy's identity, substitution of (7) for t_N, and then division by $-bNL\lambda$ yields:

$$\eta \equiv \mu/\lambda = (1-t)/[1-t-(t-t_N)\epsilon_L] = (1-t)/[1-t-(\sigma_M-1)V(t-t_N)]. \qquad (8')$$

If the labour supply curve slopes upwards ($\epsilon_L>0$, $\sigma_M>1$) and the tax rate exceeds its non-distortionary level ($t>t_N$), the marginal cost of public funds (η) exceeds the marginal rate of transformation between public and private goods (i.e. unity). An increase in public revenues then exacerbates the deadweight loss of distortionary taxation and raises the marginal cost of public funds above unity. However, if $t>t_N$ and the labour supply curve bends backwards ($\epsilon_L<0$, $\sigma_M<1$), the marginal cost of public funds is less than unity. If labour supply is inelastic ($\epsilon_L=0$, $\sigma_M=1$), the marginal cost of public funds corresponds to the marginal rate of transformation between public and private consumption (i.e. unity). In that case, a labour tax acts like a lump-sum tax and the second-best outcome coincides with the first-best outcome.

II. Comparative statics of the second-best outcome

II.1. Private behaviour and market equilibrium

We loglinearize the equations for private behaviour, market equilibrium and optimal government policy around a benchmark with $S=0$. Logarithmic deviations from the benchmark are denoted by a tilde (e.g. $\tilde{b}\equiv db/b$), unless indicated otherwise. Equation (2) yields:

$$\tilde{L} = \epsilon_L (\tilde{b}-\tilde{t}), \;\; \tilde{V} = -\epsilon_L (L/V) (\tilde{b}-\tilde{t}), \;\; \tilde{C} = (1+\epsilon_L) (\tilde{b}-\tilde{t}), \;\; \tilde{M} = L (\tilde{b}-\tilde{t}) \qquad (2')$$

where $\epsilon_L=(\sigma_M-1)V$ and $\tilde{t}\equiv dt/(1-t)$. A higher tax rate reduces private utility (M). We use (2') to loglinearize (3), or equivalently the government budget constraint:

$$\omega_G \tilde{G} + \omega_A \tilde{A} = \tilde{b} + \tilde{L} - \omega_C \tilde{C} = \tilde{b} + [\omega_C-\epsilon_L(1-\omega_C)] (\tilde{t}-\tilde{b}) = \tilde{b} + (1-t-\epsilon_L t) (\tilde{t}-\tilde{b}) \qquad (3')$$

where $\omega_C \equiv NC/Y = 1\text{-}t$, $\omega_G \equiv G/Y$ and $\omega_A \equiv A/Y$ denote the national income shares of private consumption, public consumption and abatement, respectively. The left-hand side of (3′) stands for total public spending, which must equal public revenues. The first term in the bracket of the last right-hand side ($1\text{-}t = \omega_C$) corresponds to the "tax rate" effect. The second term in this bracket ($-\epsilon_L t$) stands for the "tax base" effect. If the labour supply curve slopes upwards (bends backwards), i.e. σ_M is greater (less) than unity, a higher tax rate narrows (broadens) the tax base and tax revenues thus rise less (more) than proportionally with the tax rate. We rule out a downward-sloping Laffer-curve (i.e. $\Delta \equiv 1\text{-}t\text{-}(\sigma_M\text{-}1)Vt > 0$ or $\epsilon_L < (1\text{-}t)/t$).

Substituting (3′) into (2′) to eliminate $\tilde{t}$, we obtain for the change in private utility:

$$\tilde{M} = L\,\Delta^{-1}\,(\tilde{b} - \omega_G\,\tilde{G} - \omega_A\,\tilde{A}), \text{ where } \Delta \equiv (1\text{-}t) - \epsilon_L t > 0. \tag{9}$$

Hence, private utility suffers from higher public consumption or abatement (on account of the higher tax rate required to finance these activities) but benefits from higher productivity.

II.2. Government policy and the marginal cost of public funds

We assume that private utility, public consumption and environmental quality are perfect substitutes, i.e. $R(G) = \gamma_G G$ and $E[e(A)\text{-}aY] = \gamma_E[e(A)\text{-}aY]$. The changes in public abatement and the non-distortionary level of the tax rate then follow from (7):

$$\tilde{A} = (\tilde{t}_N - \tilde{a})/\sigma_A = (\tilde{\gamma}_E - \tilde{\gamma}_G)/\sigma_A \quad \text{and} \quad \tilde{t}_N = \tilde{a} + \tilde{\gamma}_E - \tilde{\gamma}_G \tag{7′}$$

where $\sigma_A \equiv -Ae''/e' > 0$ is the elasticity of the effectiveness of public abatement. More environmental concern ($\tilde{\gamma}_E > 0$) or less priority for public consumption ($\tilde{\gamma}_G < 0$) raises the non-distortionary level of the tax rate. This pushes up the shadow price of the environment (t_N/a) which in turn induces the government to undertake more abatement. A higher emission-output ratio (a) raises the non-distortionary level of the tax rate, but does not affect public abatement.

Loglinearizing the condition for optimal public consumption (6) while using $\tilde{M}_C = (\tilde{V} - \tilde{C})V/\sigma_M$ and (2′), we obtain the modified Samuelson rule:

$$\tilde{\gamma}_G - V\,(\tilde{t} - \tilde{b}) = \tilde{\gamma}_G + (V/L)\,\tilde{M} = \tilde{\eta}. \tag{6′}$$

The change in the marginal cost of public funds follows from (8′):

$$\tilde{\eta} = \epsilon_L \eta (1\text{-}t)^{-1}\,[(\kappa + t - t_N)\,\tilde{t} - t_N\,\tilde{t}_N - (t - t_N)\epsilon_L (L/V)\,\tilde{b}]$$

$$= \epsilon_L \eta (1\text{-}t)^{-1}\,[(1 - t_N)\,\tilde{b} - t_N\,\tilde{t}_N - (\kappa + t - t_N)L^{-1}\,\tilde{M}] \tag{8″}$$

where $\kappa \equiv 1-t+(t-t_N)(\sigma_M-1)L$. We assume that $\kappa>0$.[2] If the labour supply curve slopes upwards ($\sigma_M>1$), a higher tax rate raises the marginal cost of public funds and thus makes public consumption and abatement more expensive (as we assume that $\kappa+t-t_N>0$). Increases in environmental concern ($\tilde{\gamma}_E>0$) or the emission-output ratio ($\tilde{a}>0$) boost the non-distortionary level of the tax rate (see (7′)). The higher non-distortionary tax rate reduces the marginal cost of public funds if the labour supply curve slopes upwards. This induces substitution away from private utility towards public goods, including abatement (see (6′)). If, in contrast, the labour supply curve bends backwards ($\sigma_M<1$), greener preferences or a higher emission-output ratio raise the marginal cost of public funds as distortionary taxes are replaced by non-distortionary pollution taxes (see (8′)).

Substituting (8″) and (7′) into (6′) and solving for $\tilde{\eta}$ and $\tilde{t}$ yields:

$$\tilde{\eta} = \left(\frac{\sigma_M-1}{\kappa\sigma_M}\right)\left[(1-t_N)V\,\tilde{b} - t_N V\,(\tilde{a}+\tilde{\gamma}_B) + (1-Lt+L\sigma_M(t-t_N))\,\tilde{\gamma}_G\right] \tag{10}$$

$$\tilde{t} = \frac{t_N}{\kappa}\left(\frac{\sigma_M-1}{\sigma_M}\right)(\tilde{a}+\tilde{\gamma}_B) + \left(\frac{\Delta}{\kappa V\sigma_M}\right)\tilde{\gamma}_G + \left[1-\left(\frac{1-t_N}{\kappa}\right)\left(\frac{\sigma_M-1}{\sigma_M}\right)\right]\tilde{b} \tag{11}$$

where the coefficient of $\tilde{b}$ in (11) can be shown to be positive if $t>t_N$.[3]

II.3. Private utility, public consumption and environmental quality

When we use (10) in (6′), we obtain for private utility:

$$\tilde{M} = \left[\frac{(\sigma_M-1)L}{\kappa\sigma_M}\right]\left[(1-t_N)\,\tilde{b} - t_N\,(\tilde{a}+\tilde{\gamma}_B)\right] - \left(\frac{\Delta L}{\kappa\sigma_M V}\right)\tilde{\gamma}_G. \tag{12}$$

Clearly, $\tilde{L}=(\epsilon_L/L)\tilde{M}$ and $\tilde{C}=(1+\epsilon_L)L^{-1}\tilde{M}$ follow directly from (12). As long as the labour supply curve is not completely inelastic, $\tilde{L}$ is a negative function of $\tilde{a}+\tilde{\gamma}_E$ and a positive function of $\tilde{b}$, irrespective of whether σ_M exceeds or is less than one. The change in public consumption ($\tilde{G}$) follows residually by substituting (7′) and (12) into (9):

$$\omega_G\tilde{G} = \left[\frac{\Delta t_N(\sigma_M-1)}{\kappa\sigma_M}\right](\tilde{a}+\tilde{\gamma}_B) - \left(\frac{\omega_A}{\sigma_A}\right)\tilde{\gamma}_E + \left[\frac{\Delta^2}{\kappa\sigma_M V}+\frac{\omega_A}{\sigma_A}\right]\tilde{\gamma}_G + \left[1-\frac{\Delta(1-t_N)(\sigma_M-1)}{\kappa\sigma_M}\right]\tilde{b}. \tag{13}$$

With the aid of (2′), (3) and (7) we obtain for environmental quality ($E^* \equiv e(A)-aY$):

$$\tilde{E}^* = -(t_N/\alpha_E)\left[\tilde{a} + \tilde{b} + \epsilon_L(\tilde{b}-\tilde{t})\right] + (\omega_A/\alpha_E)\,\tilde{A} \tag{14}$$

---

[2] If $t>t_N$, then $t<½$ is sufficient for $\kappa>0$. If $t<t_N$, then $t_N(\sigma_M-1)<1$ is sufficient for $\kappa>0$.

[3] This coefficient is equal to $[\Delta+t_N V(\sigma_M-1)+(t-t_N)L(\sigma_M-1)^2]/\kappa\sigma_M$.

where $\alpha_E \equiv (t_N/a)E^*/Y$ denotes the social value of environmental quality relative to national income. Environmental quality improves if public abatement rises or the emission-output ratio (a) falls. A higher tax rate improves (worsens) environmental quality if the labour supply curve slopes upwards (backwards). A higher productivity of labour (b) worsens the quality of the environment (as $1+\epsilon_L = L + V\sigma_M > 0$). Substituting (7′) and (11) into (14), we obtain:

$$\alpha_E \tilde{E}^* = -t_N\left[1-\left(\frac{t_N V(\sigma_M-1)^2}{\kappa\sigma_M}\right)\right]\tilde{a} - t_N\left[1+\left(\frac{(1-t_N)V(\sigma_M-1)^2}{\kappa\sigma_M}\right)\right]\tilde{b} + \left[\frac{\omega_A}{\sigma_A}+\left(\frac{t_N^2 V(\sigma_M-1)^2}{\kappa\sigma_M}\right)\right]\tilde{\gamma}_E + \left[\frac{\omega_A}{\sigma_A}-\left(\frac{t_N\Delta(\sigma_M-1)}{\kappa\sigma_M}\right)\right]\tilde{\gamma}_G. \quad (14')$$

II.4. More concern about the environment

Greener preferences ($\tilde{\gamma}_E > 0$) raises both the non-distortionary level of the tax rate and public abatement (see (7′)). If the labour supply curve slopes upwards ($\sigma_M > 1$), the larger non-distortionary level of the tax rate depresses the marginal cost of public funds and makes public spending cheaper. The associated higher tax rate decreases private utility but increases aggregate public spending (i.e. public consumption plus abatement). If the elasticity of effectiveness of public abatement (σ_A) is small, public abatement rises substantially. Hence, despite the rise in the tax rate and overall public spending, public consumption (being residually determined) may fall. The higher tax burden changes the composition of private demand away from private consumption goods towards leisure ($\tilde{V} > \tilde{C}$). As $\sigma_M > 1$, this substitution effect outweighs the decline in demand for leisure on account of the negative income effect associated with the higher tax level. Hence, greener preferences reduce employment so that environmental quality is improved through a lower level of economic activity and emissions as well as through more public abatement (i.e. a cleaner composition of activity).

However, if the labour supply curve bends backwards ($\sigma_M < 1$), more concern for the environment raises the marginal cost of public funds. In this case, the higher non-distortionary level of the tax rate raises the marginal cost of public funds (see (8′)) and makes public spending more expensive. Hence, the tax rate and the level of public spending fall while private consumption rises. The lower tax burden induces households to shift away from leisure towards consumption goods ($\tilde{C} > \tilde{V}$). In this case, the increase in leisure demand due to the positive income effect associated with a lower tax level offsets the substitution effect away from leisure (as $\sigma_M < 1$). Employment, activity and emissions thus fall. The lower overall level of public spending together with the rise in public abatement (see (7′)) imply that public consumption must fall. Public consumption is thus crowded out by both more abatement (i.e. cleaner composition of public spending) and by a lower tax rate and level of public spending.

Proposition 1: *Greener preferences reduce employment, output and emissions, unless labour supply is completely inelastic. Environmental quality improves also due to more public abatement. If the labour supply curve slopes upwards (downwards), the marginal cost of public funds and the private component of* *utility fall (rise) while the tax rate and public spending rise (fall). Public consumption rises only if a large elasticity of the effectiveness of public abatement contains the rise in public abatement and at the same time an upward-sloping labour supply curve raises the aggregate level of public spending.*

Green and red preferences are thus incompatible, in the sense that environmental quality and public consumption do not move together, if there is a lot of scope for public abatement or if labour supply bends backwards. However, if the elasticity of the effectiveness of public abatement and the (uncompensated) labour supply elasticity are large and positive, public consumption increases so that green and red preferences are compatible. In that case, public abatement does not rise much while employment falls substantially. Hence, most of the improvement in environmental quality is achieved through a lower level rather than a cleaner composition of economic activity.

A higher emission-output ratio (a) induces the same effects on the marginal cost of public funds, the tax rate, private utility and employment as does an increase in environmental concern (γ_E), but does not affect public abatement. If labour supply slopes upwards (downwards), the marginal cost of public funds falls (rises) so public consumption rises (falls) while private utility decreases (increases). The deterioration of the environment induced by the higher emission-output ratio is reduced by the fall in output. In fact, a rise in the emission-output ratio may improve environmental quality if σ_M is very small (see (14′)).

II.5. More priority for public consumption

A greater desire for public consumption ($\tilde{\gamma}_G > 0$) lowers both the non-distortionary level of the tax rate and public abatement (see (7′)) as the government can afford less to use taxes to internalize environmental externalities. The tax rate rises and the private component of utility falls in order to make room for public consumption. If the labour supply slopes upwards (bends backwards), the marginal cost of public funds rises (falls) and employment falls (rises). Overall public spending expands while the composition changes away from abatement towards public consumption. Environmental quality worsens due to fall in public abatement and, if labour supply bends backwards, the increase in output and thus emissions. However, if the elasticity of labour supply is large and positive and the elasticity of the effectiveness of public abatement (σ_A) is large, the environment improves because the beneficial effect of the fall in output and emissions outweighs the adverse effect of less abatement. While economic activity contracts a lot due to the disincentive effects of a higher tax burden (as σ_M is large), the composition of activity does not become much dirtier (as σ_A is large). Environmental quality and public consumption thus move together (i.e. green and red preferences are compatible) if the level of activity is reduced while the composition of activity is not affected much.

Proposition 2: *More concern about public consumption increases the tax rate and decreases private utility and public abatement. If the labour supply curve slopes upwards (downwards), employment and emissions* *fall (rise). Unless substitution effects in labour supply are strong and the elasticity of the effectiveness of public abatement is large (i.e., both σ_M and σ_A are large), environmental damages increase so that red and green preferences are incompatible.*

II.6. Increase in labour productivity

A higher labour productivity (b) boosts employment (unless, of course, labour supply is completely inelastic). Since public abatement is unaffected, environmental quality suffers. If the labour supply curve slopes upwards (downwards), the marginal cost of public funds and private utility rise (fall). Public consumption rises due to the higher tax rate.

III. IMPERFECT SUBSTITUTION BETWEEN PRIVATE UTILITY AND PUBLIC GOODS

To allow for imperfect substitution between the private component of utility and public consumption, consider the following social welfare function:

$$W \equiv N\,Q[M(C,V),G] + N\,\gamma_E[e(A) - aY] \tag{4'}$$

where Q[.] is concave and weakly homothetic. We use the specification $Q[M,G]=[M^{\zeta}+\gamma_G G^{\zeta}]^{1/\zeta}$ with $\zeta<1$ and $\sigma_Q \equiv (1-\zeta)^{-1}>0$ is the elasticity of substitution between M and G in Q[.]. This CES-specification reduces to the case studied in section II if σ_Q tends to infinity. The separability of private consumption and leisure on the one hand and public consumption on the other hand, implies that private behaviour (2) and hence (2′) are unaffected.

The optimality condition for the provision of public consumption becomes:

$$NQ_G/Q_M M_C = \eta \equiv \mu/\lambda. \tag{6''}$$

For public abatement and the non-distortionary level of the tax rate, we obtain:

$$e'(A)=a/t_N, \quad t_N \equiv (Na\gamma_E/Q_M M_C)/\eta = a\gamma_E/Q_G. \tag{7''}$$

Expression (8′) for the marginal cost of public funds is unaffected.

III.1. The MCPF-schedule and the GBC-schedule

Loglinearizing the modified Samuelson rule (6″), we obtain:

$$\tilde{G} - \tilde{M} = \sigma_Q\,[\tilde{\gamma}_G + (V/L)\,\tilde{M} - \tilde{\eta}] \tag{15}$$

where σ_Q stands for the elasticity of substitution between G and M. A higher priority for public consumption (γ_G), a higher real consumption wage (or higher M), and a lower marginal cost of public funds (η) induce a shift away from the private component of utility to public consumption, particularly if public consumption and private utility are good substitutes.

Loglinearizing (7″), we obtain:

$$\tilde{A} = (\tilde{t}_N - \tilde{a})/\sigma_A, \quad \tilde{t}_N = \tilde{a} + \tilde{\gamma}_E - [1+\alpha_G(\sigma_Q-1)^{-1}]\,\tilde{\gamma}_G - (1-\alpha_G)\sigma_Q^{-1}\,(\tilde{M}-\tilde{G}) \tag{16}$$

where $\alpha_G \equiv GQ_G/Q = \gamma_G[\gamma_G + (M/Q)^{\zeta}]^{-1}$. Substitution from public consumption towards private utility (i.e., $\tilde{M} > \tilde{G}$) raises the marginal utility of public consumption. This reduces the non-distortionary level of the tax rate as this part of the tax is defined in terms of public revenue. Public abatement falls in response to the lower non-distortionary level of the tax rate.

Substituting (16) into (8″) and then into (15), we obtain:

$$\tilde{G} = \tilde{M} + \sigma_Q \left[\frac{\left(1-t-\epsilon_L\left[t+\frac{t_N\alpha_G}{\sigma_Q-1}\right]\right)\tilde{\gamma}_G + t_N\epsilon_L\,(\tilde{a}+\tilde{\gamma}_E) - (1-t_N)\epsilon_L\,\tilde{b} + \frac{V}{L}\kappa\sigma_M\,\tilde{M}}{1-t-\epsilon_L(t-t_N\alpha_G)} \right]. \tag{12'}$$

A higher level of private utility (M) raises public consumption through two channels. The first channel, represented by the last term in square brackets in (12′), is a reduction in the marginal cost of public funds. This is due to the substitution away from leisure as a result of higher private utility (i.e., $\tilde{V} < \tilde{C}$ if $\tilde{M} > 0$, see (2′)). The second channel involves imperfect substitution between private utility and public consumption. If private utility and public consumption are poor substitutes, the two components of social utility move together.

The MCPF-schedule (12′) shifts upwards when the weight given to public consumption (γ_G) increases (see Figure 1). If the labour supply curve slopes upwards (downwards), the MCPF-schedule shifts upwards (downwards) in response to an increase in environmental concern (γ_E), an increase in the emission-output ratio (a) or a fall in labour productivity (b). If private utility and public consumption are perfect substitutes, the MCPF-locus is vertical (cf. (12)). If private utility and public consumption are perfect complements ($\sigma_Q = 0$), in contrast, the MCPF-schedule corresponds to the 45°-line going through the origin and is unaffected by changes in environmental concern, the emission-output ratio or labour productivity.

The government budget constraint may with the aid of (9) and (16) be loglinearized as:

$$\tilde{G} = \left[\tilde{b} - \frac{\omega_A}{\sigma_A}\left[\tilde{\gamma}_E - \left(1+\alpha_G(\sigma_Q-1)^{-1}\right)\tilde{\gamma}_G\right] - \left(\frac{\Delta}{L} - \left[\frac{\omega_A(1-\alpha_G)}{\sigma_A\sigma_Q}\right]\right)\tilde{M}\right]\left(\omega_G + \left[\frac{\omega_A(1-\alpha_G)}{\sigma_A\sigma_Q}\right]\right)^{-1}. \tag{17}$$

If public consumption and private utility are fairly close substitutes (large σ_Q), there is a negative relationship between the changes in public consumption and private utility which arises from the positive relationship between $\tilde{G}$ and the change in the tax rate. If the priority attached to environmental quality rises relative to public consumption, public abatement increases. Hence, given private utility, less finance is available for public consumption and the GBC-schedule (17) thus shifts downwards (see Figures 1(a) and 1(b)).

If public consumption and private utility are not close substitutes (small σ_Q) and the elasticity of the effectiveness of public abatement (σ_A) is small, the GBC-locus may actually slope upwards (as in Figures 1(c) and 1(d)). Intuitively, an increase in private utility requires a similar increase in public consumption if it is difficult to substitute between the two components of social utility. A higher level of private utility then crowds out public abatement rather than public consumption. In particular, if private utility and public consumption are imperfect substitutes, higher private utility raises the marginal social utility of public consumption (Q_G). This reduces the Pigovian tax component (see (7″)) and, if the elasticity σ_A is small, substantially decreases public abatement. If the fall in public abatement is large enough, public consumption can rise despite the decline in overall public spending.

III.2. Comparative statics of the second-best outcome

Figures 1(a) and 1(b) present the case of easy substitution between private utility and public consumption (large σ_Q) or a large elasticity of the effectiveness of abatement (σ_A), i.e. a downward-sloping GBC-schedule. Figure 1(a) assumes an upward-sloping and Figure 1(b) a downward-sloping labour supply curve. The benchmark is **E** while **E′** and **E″** are the equilibria after an increase in the emission-output ratio (a) and in environmental concern (γ_E), respectively. Figure 1(a) confirms propositions 1 and 2. An increase in the emission-output ratio decreases the private component of utility and employment and increases public consumption. Greener preferences yield similar effects, except that public consumption may fall if a small σ_A causes public abatement to rise a lot (shifting the GBC-schedule substantially downward)[4].

Figure 1(b) (with large σ_Q and σ_A but with $\sigma_M < 1$) reveals that a higher emission-output ratio raises private utility but reduces public consumption and employment, thus confirming propositions 1 and 2. However, Figure 1(b) also illustrates the possibility of a counter-example to propositions 1 and 2 in case of a green shock. If the labour supply curve bends backwards ($\sigma_M < 1$) and the elasticity of the effectiveness of public abatement (σ_A) is small, the GBC-schedule shifts downward quite a lot. An increase in environmental concern (γ_E) may then reduce private utility[5] (as well as public consumption). The associated adverse income effect reduces the demand for leisure, thereby raising employment. Accordingly, for this special case we confirm the "double dividend" hypothesis, i.e. greener preferences not only enhance environmental quality but also boost employment.

Figures 1(c) and 1(d) present the case where substitution between public consumption and private utility is difficult (low σ_Q) and the elasticity of the effectiveness of public abatement (σ_A) is small

[4] σ_Q needs to be large.

[5] This can only happen if the MCPF-schedule is not vertical, i.e. σ_Q cannot be infinite.

so that the GBC-schedule slopes upwards. If also the labour supply curve slopes upwards, then Figure 1(c) reveals that private utility, public consumption and employment fall. Intuitively, a green shock must reduce at least one of the other two parts of social utility (i.e., private utility M or public consumption G). If substitution between M and G is difficult, M and G move in the same direction and thus both decline. The lower level of private utility associated with the higher tax rate reduces the demand for leisure as the substitution effect exceeds the income effect (as $\sigma_M > 1$).

If the labour supply curve bends backwards ($\epsilon_L < 0$), Figure 1(d) reveals that a higher emission-output ratio raises public consumption and private utility but reduces employment. However, an increase in environmental concern may reduce private utility, especially if a small elasticity of the effectiveness of public abatement causes a substantial downward shift of the GBC-schedule. The fall in private utility raises employment, since the adverse income effect more than offsets the substitution effect ($\sigma_M < 1$), thereby reducing the demand for leisure. This provides another counter-example to propositions 1 and 2.

These diagrammatic results are confirmed by analytically solving (12′) and (17). For example, the impact on private utility of more environmental concern may be written as:

$$\tilde{M} = -L\left[\frac{\left(\dfrac{\omega_A(1-t)}{\sigma_A \eta}\right) + \sigma_Q \omega_G t_N \epsilon_L}{(L\omega_G + \Delta)[1 - t - \epsilon_L(t - \alpha_G t_N)] + \dfrac{\omega_A}{\sigma_A}(1-\alpha_G)V\sigma_M \kappa + \sigma_Q V \sigma_M \kappa \omega_G}\right]\tilde{\gamma}_E. \qquad (18)$$

The effects on the tax rate, the marginal cost of public funds and employment follow from $\tilde{t} = -\tilde{M}/L$, $\tilde{\eta} = V\tilde{M}/L$ and $\tilde{L} = \epsilon_L \tilde{M}/L$, respectively. If σ_Q approaches infinity, (18) boils down to (12). If $\sigma_Q = 0$ and σ_A is finite, an increase in environmental concern (γ_E) reduces the marginal cost of public funds, thereby raising the tax rate and thus reducing private utility (see (18)). Government consumption declines (as $\tilde{G} = \tilde{M}$ if $\sigma_Q = 0$). Employment falls (rises) if labour supply slopes upwards (downwards). Overall public spending and thus abatement increase.

IV. CONCLUDING REMARKS

A more ambitious environmental policy raises the non-distortionary level of the tax rate and boosts public abatement. In general, this depresses labour supply and economic activity. If substitution effects dominate income effects in labour supply, a greener policy raises the tax rate and reduces the marginal cost of public funds which makes more room for public spending. In this case, public consumption may rise if most of the improvement in environmental quality is achieved through lower production rather than more abatement. However, if the environment improves mainly due to public abatement and employment does not fall too much, public consumption falls.

In general, a higher priority to environmental policy reduces employment because consumption of leisure is clean[6] while production pollutes the environment. However, if private utility and public consumption are poor substitutes, the elasticity of the effectiveness of public abatement is small and the labour supply curve bends backwards, an increase in environmental concern may actually raise employment. The improvement in the quality of the environment is then achieved through an expansion of public abatement rather than through an increase in the consumption of leisure and a reduction in emissions. The increase in public abatement is financed by an increase in the tax rate, a broadening of the tax base, and a cut in public consumption. While the *level* of economic activity increases, the *composition* of that activity becomes more friendly to the environment. This is a channel through which the "double dividend" hypothesis can be given some support.

References

Atkinson, A.B. and N.H. Stern (1974). 'Pigou, taxation and public goods.' *Review of Economic Studies*, vol. XLI, no. 1, pp. 119-128.

Auerbach, A.J. (1985). 'The theory of excess burden and optimal taxation.' in Alan J. Auerbach and Martin Feldstein (eds.), *Handbook of Public Economics, Volume I*, pp. 61-127. Amsterdam: North-Holland.

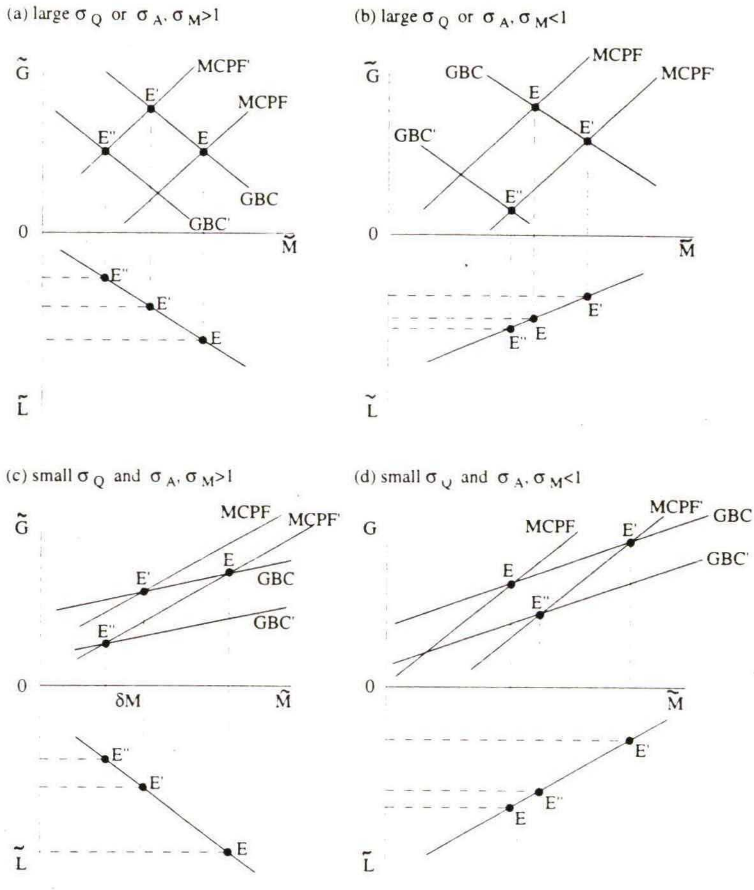
Bovenberg, A.L. and F. van der Ploeg (1992). 'Environmental policy, public finance and the labour market in a second-best world.' Discussion Paper No. 745. London: CEPR.

Pearce, D.W. (1991). 'The role of carbon taxes in adjusting to global warning.' *Economic Journal*, vol. 101, pp. 938-948.

Sandmo, Agner (1975). 'Optimal taxation in the presence of externalities.' *Swedish Journal of Economics*, vol. 77, pp. 86-98.

[6] Of course, one may consume polluting activities during leisure (e.g., travel). However, these consumption goods can be acquired only after having earned sufficient income out of employment. Indeed, travel is included in C rather than than L.

Figure 1: Effects of an increase in environmental concern on public consumption and private utility



Discussion Paper Series, CentER, Tilburg University, The Netherlands:

(For previous papers please consult previous discussion papers.)

No.	Author(s)	Title
9211	S. Albæk	Endogenous Timing in a Game with Incomplete Information
9212	T.J.A. Storcken and P.H.M. Ruys	Extensions of Choice Behaviour
9213	R.M.W.J. Beetsma and F. van der Ploeg	Exchange Rate Bands and Optimal Monetary Accommodation under a Dirty Float
9214	A. van Soest	Discrete Choice Models of Family Labour Supply
9215	W. Güth and K. Ritzberger	On Durable Goods Monopolies and the (Anti-) Coase-Conjecture
9216	A. Simonovits	Indexation of Pensions in Hungary: A Simple Cohort Model
9217	J.-L. Ferreira, I. Gilboa and M. Maschler	Credible Equilibria in Games with Utilities Changing During the Play
9218	P. Borm, H. Keiding, R. Mclean, S. Oortwijn and S. Tijs	The Compromise Value for NTU-Games
9219	J.L. Horowitz and W. Härdle	Testing a Parametric Model against a Semiparametric Alternative
9220	A.L. Bovenberg	Investment-Promoting Policies in Open Economies: The Importance of Intergenerational and International Distributional Effects
9221	S. Smulders and Th. van de Klundert	Monopolistic Competition, Product Variety and Growth: Chamberlin vs. Schumpeter
9222	H. Bester and E. Petrakis	Price Competition and Advertising in Oligopoly
9223	A. van den Nouweland, M. Maschler and S. Tijs	Monotonic Games are Spanning Network Games
9224	H. Suehiro	A "Mistaken Theories" Refinement
9225	H. Suehiro	Robust Selection of Equilibria
9226	D. Friedman	Economically Applicable Evolutionary Games
9227	E. Bomhoff	Four Econometric Fashions and the Kalman Filter Alternative - A Simulation Study

No.	Author(s)	Title
9228	P. Borm, G.-J. Otten and H. Peters	Core Implementation in Modified Strong and Coalition Proof Nash Equilibria
9229	H.G. Bloemen and A. Kapteyn	The Joint Estimation of a Non-Linear Labour Supply Function and a Wage Equation Using Simulated Response Probabilities
9230	R. Beetsma and F. van der Ploeg	Does Inequality Cause Inflation? - The Political Economy of Inflation, Taxation and Government Debt
9231	G. Almekinders and S. Eijffinger	Daily Bundesbank and Federal Reserve Interventions - Do they Affect the Level and Unexpected Volatility of the DM/$-Rate?
9232	F. Vella and M. Verbeek	Estimating the Impact of Endogenous Union Choice on Wages Using Panel Data
9233	P. de Bijl and S. Goyal	Technological Change in Markets with Network Externalities
9234	J. Angrist and G. Imbens	Average Causal Response with Variable Treatment Intensity
9235	L. Meijdam, M. van de Ven and H. Verbon	Strategic Decision Making and the Dynamics of Government Debt
9236	H. Houba and A. de Zeeuw	Strategic Bargaining for the Control of a Dynamic System in State-Space Form
9237	A. Cameron and P. Trivedi	Tests of Independence in Parametric Models: With Applications and Illustrations
9238	J.-S. Pischke	Individual Income, Incomplete Information, and Aggregate Consumption
9239	H. Bloemen	A Model of Labour Supply with Job Offer Restrictions
9240	F. Drost and Th. Nijman	Temporal Aggregation of GARCH Processes
9241	R. Gilles, P. Ruys and J. Shou	Coalition Formation in Large Network Economies
9242	P. Kort	The Effects of Marketable Pollution Permits on the Firm's Optimal Investment Policies
9243	A.L. Bovenberg and F. van der Ploeg	Environmental Policy, Public Finance and the Labour Market in a Second-Best World
9244	W.G. Gale and J.K. Scholz	IRAs and Household Saving
9245	A. Bera and P. Ng	Robust Tests for Heteroskedasticity and Autocorrelation Using Score Function

No.	Author(s)	Title
9246	R.T. Baillie, C.F. Chung and M.A. Tieslau	The Long Memory and Variability of Inflation: A Reappraisal of the Friedman Hypothesis
9247	M.A. Tieslau, P. Schmidt and R.T. Baillie	A Generalized Method of Moments Estimator for Long-Memory Processes
9248	K. Wärneryd	Partisanship as Information
9249	H. Huizinga	The Welfare Effects of Individual Retirement Accounts
9250	H.G. Bloemen	Job Search Theory, Labour Supply and Unemployment Duration
9251	S. Eijffinger and E. Schaling	Central Bank Independence: Searching for the Philosophers' Stone
9252	A.L. Bovenberg and R.A. de Mooij	Environmental Taxation and Labor-Market Distortions
9253	A. Lusardi	Permanent Income, Current Income and Consumption: Evidence from Panel Data
9254	R. Beetsma	Imperfect Credibility of the Band and Risk Premia in the European Monetary System
9301	N. Kahana and S. Nitzan	Credibility and Duration of Political Contests and the Extent of Rent Dissipation
9302	W. Güth and S. Nitzan	Are Moral Objections to Free Riding Evolutionarily Stable?
9303	D. Karotkin and S. Nitzan	Some Peculiarities of Group Decision Making in Teams
9304	A. Lusardi	Euler Equations in Micro Data: Merging Data from Two Samples
9305	W. Güth	A Simple Justification of Quantity Competition and the Cournot-Oligopoly Solution
9306	B. Peleg and S. Tijs	The Consistency Principle For Games in Strategic Form
9307	G. Imbens and A. Lancaster	Case Control Studies with Contaminated Controls
9308	T. Ellingsen and K. Wärneryd	Foreign Direct Investment and the Political Economy of Protection
9309	H. Bester	Price Commitment in Search Markets

No.	Author(s)	Title
9310	T. Callan and A. van Soest	Female Labour Supply in Farm Households: Farm and Off-Farm Participation
9311	M. Pradhan and A. van Soest	Formal and Informal Sector Employment in Urban Areas of Bolivia
9312	Th. Nijman and E. Sentana	Marginalization and Contemporaneous Aggregation in Multivariate GARCH Processes
9313	K. Wärneryd	Communication, Complexity, and Evolutionary Stability
9314	O.P.Attanasio and M. Browning	Consumption over the Life Cycle and over the Business Cycle
9315	F. C. Drost and B. J. M. Werker	A Note on Robinson's Test of Independence
9316	H. Hamers, P. Borm and S. Tijs	On Games Corresponding to Sequencing Situations with Ready Times
9317	W. Güth	On Ultimatum Bargaining Experiments - A Personal Review
9318	M.J.G. van Eijs	On the Determination of the Control Parameters of the Optimal Can-order Policy
9319	S. Hurkens	Multi-sided Pre-play Communication by Burning Money
9320	J.J.G. Lemmen and S.C.W. Eijffinger	The Quantity Approach to Financial Integration: The Feldstein-Horioka Criterion Revisited
9321	A.L. Bovenberg and S. Smulders	Environmental Quality and Pollution-saving Technological Change in a Two-sector Endogenous Growth Model
9322	K.-E. Wärneryd	The Will to Save Money: an Essay on Economic Psychology
9323	D. Talman, Y. Yamamoto and Z. Yang	The $(2^{n+m+1} - 2)$-Ray Algorithm: A New Variable Dimension Simplicial Algorithm For Computing Economic Equilibria on $S^n \times R^m_+$
9324	H. Huizinga	The Financing and Taxation of U.S. Direct Investment Abroad
9325	S.C.W. Eijffinger and E. Schaling	Central Bank Independence: Theory and Evidence
9326	T.C. To	Infant Industry Protection with Learning-by-Doing
9327	J.P.J.F. Scheepens	Bankruptcy Litigation and Optimal Debt Contracts
9328	T.C. To	Tariffs, Rent Extraction and Manipulation of Competition
9329	F. de Jong, T. Nijman and A. Röell	A Comparison of the Cost of Trading French Shares on the Paris Bourse and on SEAQ International

No.	Author(s)	Title
9330	H. Huizinga	The Welfare Effects of Individual Retirement Accounts
9331	H. Huizinga	Time Preference and International Tax Competition
9332	V. Feltkamp, A. Koster, A. van den Nouweland, P. Borm and S. Tijs	Linear Production with Transport of Products, Resources and Technology
9333	B. Lauterbach and U. Ben-Zion	Panic Behavior and the Performance of Circuit Breakers: Empirical Evidence
9334	B. Melenberg and A. van Soest	Semi-parametric Estimation of the Sample Selection Model
9335	A.L. Bovenberg and F. van der Ploeg	Green Policies and Public Finance in a Small Open Economy
9336	E. Schaling	On the Economic Independence of the Central Bank and the Persistence of Inflation
9337	G.-J. Otten	Characterizations of a Game Theoretical Cost Allocation Method
9338	M. Gradstein	Provision of Public Goods With Incomplete Information: Decentralization vs. Central Planning
9339	W. Güth and H. Kliemt	Competition or Co-operation
9340	T.C. To	Export Subsidies and Oligopoly with Switching Costs
9341	A. Demirgüç-Kunt and H. Huizinga	Barriers to Portfolio Investments in Emerging Stock Markets
9342	G.J. Almekinders	Theories on the Scope for Foreign Exchange Market Intervention
9343	E.R. van Dam and W.H. Haemers	Eigenvalues and the Diameter of Graphs
9344	H. Carlsson and S. Dasgupta	Noise-Proof Equilibria in Signaling Games
9345	F. van der Ploeg and A.L. Bovenberg	Environmental Policy, Public Goods and the Marginal Cost of Public Funds

P.O. BOX 90153, 5000 LE TILBURG, THE NETHERLAND