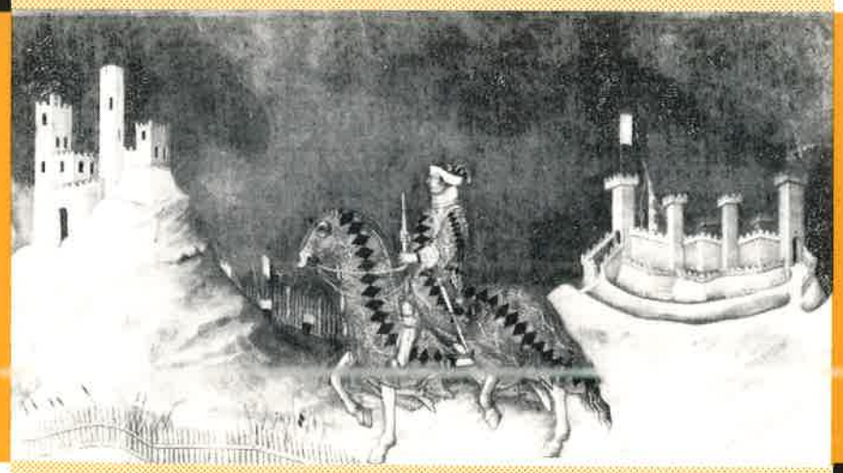
UNIVERSITÀ DEGLI STUDI DI SIENA

QUADERNI DEL DIPARTIMENTO
DI ECONOMIA POLITICA

Giancarlo Marini

Pasquale Scaramozzino

ENVIRONMENTAL EXTERNALITIES, DISCONNECTED GENERATIONS AND POLICY



QUADERNI DEL DIPARTIMENTO DI ECONOMIA POLITICA

Redazione: **Dipartimento di Economia Politica**, Piazza S. Francesco, 17 - 53100 Siena - tel.0577/298620

La Redazione ottempera agli obblighi previsti dall'Art.1 del D.L.L. 31.8.45 n.660

Le richieste di copie della presente pubblicazione dovranno essere indirizzate alla Redazione

I Quaderni del Dipartimento di Economia Politica dell'Università di Siena vengono pubblicati come servizio atto a favorire la tempestiva divulgazione di ricerche scientifiche originali, siano esse in forma provvisoria o definitiva. **I Quaderni** vengono regolarmente inviati a tutti gli istituti e dipartimenti italiani, a carattere economico, nonché a numerosi docenti e ricercatori universitari. Vengono altresì inviati ad enti e personalità italiane ed estere. L'accesso ai **Quaderni** è approvato dal Comitato scientifico, sentito il parere di un referee.

(Dal 1979 a tutto il 1987 la denominazione della presente Collana è stata: **"Quaderni dell'Istituto di Economia"**. La numerazione progressiva rimane tuttavia la stessa).

Giancarlo Marini
Pasquale Scaramozzino

ENVIRONMENTAL EXTERNALITIES, DISCONNECTED GENERATIONS AND POLICY

Siena, ottobre 1993

Environmental Externalities, Disconnected Generations and Policy

by

GIANCARLO MARINÍ and PASQUALE SCARAMOZZINO

April 1993

Revised, October 1993

Giancarlo Marini, Dipartimento di Economia Politica, Università di Siena.
Pasquale Scaramozzino, University College, Londra.

ABSTRACT

This paper presents a general equilibrium dynamic model with disconnected generations and externalities, where pollution is an input of production. It is demonstrated that the social planner can achieve the desired allocation of physical assets and environment by optimal choice of the available policy instruments. We characterise both the necessary transfers across generations alive at a given time and the optimal intertemporal distribution of resources.

We are grateful to Fondazione ENI Enrico Mattei, Milan for financial support.

1. Introduction

Environmental resources can be depleted at a socially sub-optimal rate in a decentralised economy with incomplete markets. Pollution is an inevitable consequence of the production process: hence, when markets for tradable pollution rights are missing, there is in principle a clear rôle for government intervention. In particular, the welfare of unborn generations can be seriously impaired by the production decisions of optimising egoistic agents.

The central policy issue is to investigate what governments should do and which instruments they should use in order to achieve a socially equitable intertemporal distribution of natural resources and consumption (see Dasgupta and Heal (1979), Pearce and Turner (1992)). A popular criterion is the so-called Solow-Hartwick rule, designed to preserve equal consumption opportunities over time. However, the representative agent models typically employed do not appear, as argued by Solow (1986), adequate to investigate intergenerational equity issues. Overlapping generations models, by contrast, naturally lend themselves to analyse intertemporal externalities among heterogeneous agents.

Another important line of research has focussed on the choice of the discount rate that the planner should optimally set to achieve her social objectives (see, among others, Musu (1991), van der Ploeg and Withagen (1991), Markandya and Pearce (1988)). No clear-cut answer has been provided, since the long-run built-in trade-off between environment and consumption of physical assets cannot be eased by manipulation of the social discount rate alone. Intergenerational equity is not, in fact, a cost-benefit problem but

depends on the intertemporal distribution of assets across disconnected generations, as clearly pointed out by Howarth and Norgaard (1992). The representative agent model is thus unsuitable, since it implicitly assumes away any form of heterogeneity across generations.

In the present paper we set out an overlapping generations (OLG) model in order to characterise the fiscal policy required to achieve an equitable use of environmental resources. The demand side of the model we develop is a variant of the Blanchard-Yaari-Weil-Buiter set-up[1], where disconnected generations of individuals derive utility from consumption and from environmental quality. The supply sector is modelled as an aggregate constant returns to scale technology with labour, capital, and pollution as inputs. Pollution is in part endogenously assimilated by the environment. The absence of markets for pollution rights, which implies that the environmental resource has the nature of a public good, requires an active rôle for the government in enacting pollution abatement policies.

The structure of the paper is as follows. Section 2 outlines the model and discusses the steady state effects of government spending on pollution abatement. Section 3 addresses the social welfare issues and derives the optimal environmental tax. Section 4 concludes.

2. Overlapping generations and externalities

We consider a continuous-time overlapping generations framework in which individuals face a constant instantaneous death rate and a constant rate of (parthenogenetic) reproduction. There is a large number of agents who derive

utility from consumption of a physical commodity and from the enjoyment of an environment resource. The latter can however also be used directly as an input to production. This has a destructive impact on the remaining amount of the environmental resource. Since the environment available to each individual can be regarded as a public good, these externalities give rise to a socially suboptimal use of production inputs. Appropriate environmental taxes are required in order to correct such inefficiencies.

In addition to the above externalities, however, there are further market failures in the economy due to population heterogeneity and the disconnectedness across generations. Since no fully operative bequest motive is present, each generation will neglect the impact on the future generations of its own use of the environment. Hence, a fiscal policy directed at protecting the environment should be designed in such a way as to enact both the cross-sectional and the across-generations taxes and transfers which are required for achieving inter-generational equity and an optimal use of resources over time.

The objective function at time t of agents born at time s≤t is defined as

$$(1)\qquad \max_{\{\bar{c}(s,v)\}} \int_t^{\infty} [\gamma \ln \bar{c}(s,v) + (1-\gamma) \ln \bar{\eta}(s,v)]\, e^{-(\rho+\lambda)(v-t)} dv$$

where $\bar{c}(s,v)$ and $\bar{\eta}(s,v)$ denote consumption of the physical commodity and of the environment respectively, ρ is the pure subjective rate of time preference, and λ is the instantaneous death rate. The probability of death is constant over time and independent of age[2]. For simplicity, the instantaneous felicity function is assumed to be additively separable in its

arguments.

The individual budget constraint on non-human wealth follows the differential equation

$$(2) \qquad \frac{d}{dt}\,\bar{a}(s,t) = [r(t)+\lambda]\,\bar{a}(s,t) + \bar{w}(s,t) - \bar{c}(s,t)$$

where r(t) is the rate of interest and $\bar{w}(s,t)$ is labour income. In equation (2), the term $\lambda\bar{a}(s,t)$ reflects the existence of a perfectly competitive market for annuities. Since generations are not interconnected by an operative bequest motive, the optimal insurance contract prescribes that each consumer's estate be appropriated by the insurance company upon the agent's death. Each individual thus receives the actuarially fair insurance premium, $\lambda\bar{a}(s,t)$, whilst alive. Human capital is defined as the present discounted value of expected future labour earnings:

$$(3) \qquad \bar{h}(s,t) = \int_t^{\infty} \bar{w}(s,v)\; e^{-\int_t^v [r(\mu)+\lambda]d\mu}\, dv$$

The appropriate discount rate must incorporate the instantaneous rate of death. The first-order conditions for an interior solution for consumption yield the usual Ramsey-type equation:

$$(4) \qquad \frac{d\bar{c}(s,t)}{dt} = [r(t)-\rho]\,\bar{c}(s,t)$$

It is important to note that in the objective function of the consumer,

equation (1), the path describing the use of the environmental resource, $\langle\bar{\eta}(s,v)|v\geq s\rangle$, is *not* a control variable. Since at each moment in time there is a large number of individuals, and since the individual enjoyment of the environmental resource is given by total environment per head, each consumer's decision about the use of the natural resource is bound to have a negligible impact upon the amount of resources available for personal use. Thus, the path $\langle\bar{\eta}(s,v)|v\geq s\rangle$ will be taken as exogenously given by each individual consumer.

Subject to the usual condition that households are solvent, the consumption function takes the form

$$(5) \qquad \bar{c}(s,t) = (\lambda+\rho)\,[\bar{a}(s,t) + \bar{h}(s,t)]$$

For simplicity, wages are constant for all agents alive at time t, irrespective of their age: thus,

$$(6) \qquad \bar{w}(s,t) = \bar{w}(t)$$

It follows that human capital is independent of age.

If we normalise population size by setting L(0)=1, we obtain

$$(7) \qquad L(t) = e^{nt} = \beta e^{-\lambda t}\int_{-\infty}^{t} e^{\beta s}\,ds$$

where β is the instantaneous birth rate and $n\equiv\beta-\lambda$ is the population growth rate. The value of the other aggregate variables can be obtained in an analogous fashion (see for instance Buiter (1988)). Total human capital and

assets are respectively given by

$$(8) \qquad H(t) = \beta e^{-\lambda t} \int_{-\infty}^{t} \bar{h}(t) e^{\beta s} ds$$

$$= \bar{h}(t) e^{nt}$$

$$(9) \qquad A(t) = \beta e^{-\lambda t} \int_{-\infty}^{t} \bar{a}(s,t) e^{\beta s} ds$$

Upon aggregation of (5) and using (8) and (9), aggregate consumption is seen to be proportional to total wealth:

$$(10) \qquad C(t) = (\lambda+\rho)\,[A(t) + H(t)]$$

On the production side, output can be obtained by combining capital input, K(t), a flow of environmental resources, Z(t), and labour, L(t).

$$(11) \qquad Y(t) = F[K(t),Z(t),L(t)] = L(t)\, f[k(t),z(t)]$$

The production function exhibits constants returns to scale and can therefore be written in the usual labour intensive form. We assume that $F_K, F_Z, F_L > 0$, $F_{KK}, F_{ZZ}, F_{LL} < 0$, $F_{KZ} > 0$, and $F_{ZZ}F_{LL} - F_{KZ}^2 > 0$. In particular, an increased use of the environmental resource raises the marginal product of capital. The use of natural resources in the production process directly adds to the cumulative stock of pollution, P(t):

$$(12) \qquad \frac{dP(t)}{dt} = - mP(t) + Z(t) - \psi[G(t)]$$

where m is the assimilation rate at which the environment endogenously absorbs the stock of pollution, G(t) is government spending on pollution abatement activities, and $\psi(\cdot)$ represents the impact of such expenditures. It is assumed that pollution abatement by the government exhibits decreasing returns: $\psi'(\cdot)>0$, $\psi''(\cdot)<0$. The formulation in (12) is consistent with the absolute effect model of pollution stock accumulation (see Ulph, Ulph and Pezzey (1991) for a motivation and a discussion). The stock of environment is given by

$$(13) \qquad E(t) = \hat{E} - P(t)$$

where $\hat{E}$ is a constant. By combining (12) and (13) one obtains the evolution over time of the environmental resource:

$$(14) \qquad \frac{dE(t)}{dt} = - mE(t) + m\hat{E} - Z(t) + \psi[G(t)]$$

The government levies taxes on the use of the environment as a production input:

$$(15) \qquad T(t) = \tau(t)Z(t)$$

where $\tau(t)$ is the (time-varying) tax rate. This form of taxation would be close in spirit to a *carbon tax*, discussed amongst others by Pearce (1991)

and Bovenberg and van der Ploeg (1992). The budget deficit is financed by issuing loans. The government instantaneous budget constraint is therefore

$$(16) \qquad \frac{dB(t)}{dt} = r(t)B(t) + G(t) - T(t)$$

Public sector solvency requires that the current stock of debt, plus the present value of the future exhaustive spending programmes, does not exceed the present value of future taxation:

$$(17) \qquad B(t) + \int_t^{\infty} G(v)\, e^{-\int_t^v r(\mu)d\mu}\, dv = \int_t^{\infty} T(v)\, e^{-\int_t^v r(\mu)d\mu}\, dv$$

The dynamics of the system can be expressed in *pro capite* form as

$$(18) \qquad \frac{dk(t)}{dt} = f[k(t),z(t)] - nk(t) - g(t) - c(t)$$

$$(19) \qquad \frac{db(t)}{dt} = \{f_k[k(t),z(t)]-n\}\, b(t) + g(t) - \tau(t)z(t)$$

$$(20) \qquad \frac{dc(t)}{dt} = \{f_k[k(t),z(t)]-\rho\}c(t) - (\lambda+\rho)\beta k(t) - (\lambda+\rho)\beta b(t)$$

$$(21) \qquad \frac{d\eta(t)}{dt} = -(m+n)\eta(t) + m\hat{\eta} + \psi[g(t)] - z(t)$$

where small letters denote variables per head (we use the notation $\eta(t)=$

$E(t)/L(t)$). Equation (18) requires that net investment in the economy be equal to total saving. Equation (19) gives the evolution of public debt per head. Use has been made of the first-order condition on capital, which prescribes that, in the absence of adjustment costs, its marginal product be equal to its rental cost. The interest rate must be corrected for the demographic growth rate, because of the dilution in debt per head as population grows. Equation (20) is the usual Ramsey-Blanchard condition, and equation (21) gives the dynamics of environment per head.

The conditions for the steady state of the economy are given by the following equations (22)-(26):

$$(22) \qquad f(k,z) = nk + g + c$$

$$(23) \qquad [f_k(k,z) - n]b + g = \tau z$$

$$(24) \qquad [f_k(k,z) - \rho]c = (\rho+\lambda)\beta k + (\rho+\lambda)\beta b$$

$$(25) \qquad (m+n)\eta = m\hat{\eta} - z + \psi g$$

$$(26) \qquad f_z(k,z) = \alpha + \tau$$

Equations (22)-(25) are obtained by setting $\dot{k}=\dot{b}=\dot{c}=\dot{\eta}=0$ respectively, whereas (26) is the first-order condition on the use of the environmental resource. The marginal product of the latter must be equal to its marginal cost, which is here assumed to be given by the technological constant α plus the environmental tax, τ. The system of steady state conditions is block

recursive: equations (22)-(24) and (26) determine k, b, z, and c, whilst equation (25) determines η.

A useful policy exercise is to consider the steady-state implications of a balanced budget increase in government spending on pollution abatement. Formally, we set $dg = \tau dz + z d\tau$ and log-linearise the sub-system formed of (22)-(24) and (26) in a neighbourhood of the steady-state equilibrium to obtain, in compact notation:

$$(27) \qquad \begin{bmatrix} r-n & -1 & f_z-\tau & 0 \\ f_{kk}c-\nu & r-\rho & f_{kz}c & -\nu \\ f_{kz} & 0 & f_{zz} & 0 \\ f_{kk}b & 0 & f_{kz}b & r-n \end{bmatrix} \begin{bmatrix} dk \\ dc \\ dz \\ db \end{bmatrix} = \begin{bmatrix} z \\ 0 \\ 1 \\ 0 \end{bmatrix} d\tau$$

where we have set $r=f_k$ and $\nu \equiv (\rho+\lambda)\mu$. There is one predetermined variable, k, and three jump variables: c, z, and b. The determinant of the system (27) is given by

$$\Delta = f_{kz}\Delta_1 + f_{zz}\Delta_2 < 0$$

where

$$\Delta_1 \equiv -(f_{kz}[\nu b+(r-n)c] + \alpha(r-n)(r-\rho)) < 0$$
$$\Delta_2 \equiv f_{kk}[\nu b+(r-n)c] + (r-n)[(r-n)(r-\rho)-\nu] \gtreqless 0$$

and where the sign on Δ follows from assuming that the system is locally stable around its steady state equilibrium[3]. The main comparative statics

results of interest are:

$$(28) \qquad \frac{dk}{d\tau} = \frac{1}{\Delta}\{\Delta_1 + zf_{zz}(r-\rho)(r-n)\} > 0$$

$$(29) \qquad \frac{dc}{d\tau} = -\frac{1}{\Delta}\{[\nu b+(r-n)c]\{z(f_{kk}f_{zz}-f_{kz}^2)+[(r-n)f_{kz}-\alpha f_{kk}]\}+\nu(r-n)(\alpha-zf_{zz})\}>0$$

$$(30) \qquad \frac{dz}{d\tau} = \frac{1}{\Delta}\{\Delta_2 - f_{kz}(r-\rho)(r-n)\} \gtreqless 0 \qquad \Longleftrightarrow \qquad f_{kz}(r-\rho)(r-n) \gtreqless \Delta_2$$

A increase in public spending financed by the environmental tax leads to an increased use of capital input in production and to higher consumption per head. There is therefore a *trade-in* between pollution abatement and individual consumption. On the other hand, the impact of the environmental tax τ on the use of the environmental resource as a production input, z, is in principle ambiguous. If f_{kz} is large, i.e. if an increase in k is able to raise substantially the marginal product of the environmental resource, then a higher τ could be associated to a higher steady state value of z: the relevant condition at the margin, equation (26), would still be met if *both* k *and* z increase as τ is raised. However, provided that $f_{kz}<\Delta_2/[(r-\rho)(r-n)]$ the environmental tax unambiguously brings about a reduction in the input of z in production.

The impact on the steady state stock of environment can be inferred by totally differentiating equation (25): under balanced budget,

$$(31) \qquad \frac{d\eta}{d\tau} = -\frac{1-\psi\tau}{m+n}\frac{dz}{d\tau} + \psi z$$

which is positive for $\tau<1/\psi$ and $dz/d\tau<0$. Thus, for plausible values of the

underlying "technological" parameters ψ and f_{kz}, a tax on the use of pollutants in production would indeed lead to an improvement in the quality of the environment per head.

3. Fiscal transfers across generations and the optimal environmental tax

Optimal setting of taxes and government expenditures requires that the welfare of both current and future generations be adequately taken into account. Since consumers alive at a given time are heterogeneous, equity considerations require that their individual utilities are appropriately weighted in the social welfare function. Calvo and Obstfeld (1988) have shown that, in the Blanchard-Yaari overlapping generations framework in which agents differ in their date of birth, the requirement that fiscal policy be time consistent prescribes that each consumer's welfare be discounted back to her birth date, rather than to the present. In accordance to this rule, the different generations are treated in a prefecly simmetric fashion and the government would have no incentive to renege *ex post* on its previous transfer and spending committments.

The appropriate objective functional for the social planner is given by[4]

$$(32) \qquad \Omega(t) = \int_t^{\infty} \left\{ \int_0^{\infty} u[\bar{c}(v-h,v),\bar{\eta}(v)] e^{[(\delta-n)-(\rho+\lambda)]h} \, dh \right\} e^{-(\delta-n)v} dv$$

where δ is the social rate of pure time preference and where the index h denotes age. Time consistency of the fiscal policy programme requires that

the utility of each generation is discounted back to its birth date. The functional (32) must be maximised subject to the dynamic constraints on capital accumulation, the stock of debt, consumption, and to the first-order condition on environmental use:

$$(33) \qquad \frac{dK}{dt} = F[K(t),Z(t),L(t)] - G(t) - C(t)$$

$$(34) \qquad \frac{dB}{dt} = F_K[K(t),Z(t),L(t)]B(t) + G(t) - T(t)$$

$$(35) \qquad \frac{dC}{dt} = (F_K+n-\rho)\, C(t) - (\rho+\lambda)\beta\, K(t) - (\rho+\lambda)\beta\, B(t)$$

$$(36) \qquad F_Z[K(t),Z(t),L(t)] \geq \alpha + \tau(t)$$

In addition, the differential equation on the evolution of the environmental resource, equation (14), must be met. The social planner can be thought of as seeking to achieve an optimal allocation of resources across all agents alive at a given time, and then maximising over time for the given cross-sectional allocations[5]. The problem therefore consists of maximising the following objective functional

$$(37) \qquad \max \Omega(t) = \int_t^{\infty} U^{\bullet}[C(\mu),E(\mu)]\, e^{-(\delta-n)\mu}\, d\mu$$

where

(38) $$U^{\bullet}[C(\mu),E(\mu)] = U[C(\mu)] + V[E(\mu)]$$

The functions $U[C(\cdot)]$ and $V[C(\cdot)]$ are respectively defined as

(39) $$U[C(\mu)] = \max_{\{\bar{c}(\mu-h,\mu)\}_{h=0}^{\infty}} \int_0^{\infty} u[\bar{c}(\mu-h,\mu),\bar{\eta}(\mu)]\, e^{[(\delta-n)-(\rho+\lambda)]h}\, dh$$

subject to

(40) $$\beta e^{-\lambda\mu} \int_0^{\infty} \bar{c}(\mu-h,\mu)\, e^{\beta(\mu-h)}\, dh \leq C(\mu)$$

and

(41) $$V[E(\mu)] = \int_0^{\infty} (1-\gamma)\, \ln\, \bar{\eta}(\mu)\, e^{[(\delta-n)-(\rho+\lambda)]h}\, dh$$

The first-order conditions for the optimal cross-sectional allocations yield

(42) $$u_c[\bar{c}(t-h),\bar{\eta}(t)]e^{(\delta-n-\rho)h} = U'[C(t)]$$

that is, the age-weighted marginal utility of consumption must be equalised across all generations alive at a given time. For our choice of functional forms, equation (42) can be expressed as

(43) $$\frac{\gamma}{\bar{c}(t-h,t)}\, e^{(\delta-n-\rho)h} = U'[(C(t)]$$

When $\delta=\rho+n$, i.e. when the social intertemporal discount rate is equal to the growth-augmented private discount rate, consumption must be the same for all generations irrespective of their age. When $\delta=\rho$, by contrast, consumption must be a decreasing function of age: if the social planner discounts the future at exactly the same rate as private individuals, then time consistency requires that the younger generations be allocated a greater amount of consumption *pro capite* that the older ones.

The generalised Hamiltonian function for the dynamic programme[6], which has an immediate interpretation as the net national product of the economy, can be written as

(44) $$\begin{aligned} H = {} & U[C(t)] + V[E(t)] \\ & + \mu_K(t)\, \{F[K(t),Z(t),L(t)] - G(t) - C(t)\} \\ & + \mu_B(t)\, \{F_K[K(t),Z(t),L(t)]B(t) + G(t) - \tau(t)Z(t)\} \\ & + \mu_C(t)\, \{(F_K[K(t),Z(t),L(t)]+n-\rho)C(t)-(\rho+\lambda)\beta K(t)-(\rho+\lambda)\beta B(t)\} \\ & + \mu_E(t)\, \{-mE(t) + m\bar{E}(t) - Z(t) + \psi[G(t)]\} \\ & + \lambda_Z(t)\, \{F_Z[K(t),Z(t),L(t)] - \alpha - \tau(t)\} \end{aligned}$$

where $\mu_K(t)$, $\mu_B(t)$, $\mu_C(t)$, and $\mu_E(t)$ are the dynamic co-state variables pertaining to K(t), B(t), C(t), and E(t) respectively, and where $\lambda_Z(t)$ is the Kuhn-Tucker multiplier associated to the constraint (36) on the use of the environmental resource in production. In our formulation of the planner's programme G(t), Z(t), and $\tau(t)$ are the control variables whereas K(t), B(t), C(t), and E(t) are the state variables.

The necessary Hamilton-Jacobi-Bellman conditions for an interior solution are:

(45) $\lambda_Z = - Z\mu_B$

(46) $\psi'(G)\mu_E + \mu_B = \mu_K$

(47) $F_Z\mu_K - F_{ZZ}\lambda_Z + F_{KZ}(B\mu_B+C\mu_C) - \tau\mu_B = \mu_E$

The complementary slackness conditions pertaining to the inequality constraint (36) are:

(48) $\lambda_Z(F_Z[K,Z,L] - \alpha - \tau) = 0$

(49) $\lambda_Z \geq 0, \qquad F_Z[K,Z,L] - \alpha - \tau \geq 0$

Equation (45) requires that the marginal social benefit of using the environment as a production input be equal to the marginal social benefit of a decrease in public debt. Since $\lambda_Z \geq 0$ from (49), it follows that $\mu_B \leq 0$: the use of a distorsionary tax instruments implies that the marginal social benefit of issuing public debt must be non-positive. Equation (46) prescribes that, at the margin, the benefit from an increase in abatement spending, net of the effect on public debt, exactly balances the loss from the displacement of private investment. Equation (47) says that the marginal benefit on the environment from a reduced use of pollutant Z must be balanced by the effects of a higher Z on capital accumulation, on consumption and debt service (*via* a

higher interest rate), and on tax revenue.

The co-state equation associated to the stock of the environmental resource can be expressed as:

(50) $\dot{\mu}_E = (\delta-n+m)\mu_E - V'[E(t)]$

If one integrates the differential equation (50) forward, one obtains the following expression for the dynamic multiplier pertaining to the environmental resource:

(51) $\mu_E(t) = \int_t^{\infty} e^{-(\delta+m-n)(s-t)}V'[E(s)]\, ds$

Along the optimal path, the marginal social benefit of the environment must be equal to the present discounted value of marginal private utility. The growth-corrected discount rate must be augmented by the assimilation rate, m, which measures the capacity of the environment to endogenously absorbe the stock of pollution.

In the above framework, the optimal Pigovian tax must equalise the marginal social benefit of the environment to the marginal private cost of pollution emissions. Thus, the government must set

(52) $\mu_E(t) = \alpha + \tau(t) = F_Z[K(t),Z(t),L(t)]$

By making use of (51) and (52) one obtains the optimal environmental tax as

$$(53) \qquad \tau(t) = \int_t^{\infty} e^{-(\delta+m-n)(s-t)} V'[E(s)]\, ds - \alpha$$

Finally, by rearranging equation (46), the optimal level of public spending on pollution abatement is

$$(54) \qquad G(t) = \Phi\left[\frac{\mu_K(t)-\mu_B(t)}{\mu_E(t)}\right]$$

where $\Phi(\cdot) \equiv (\psi')^{-1}(\cdot)$, with $\Phi'(\cdot)<0$ since $\psi''<0$. The optimal government expenditure on abatement is therefore an increasing function of the marginal social benefit of the environment net of public debt, and a decreasing function of the marginal social benefit of physical capital accumulation.

It is important to note that, if heterogeneity is assumed away - i.e. $\beta=\lambda=n=0$ - then the problem of the social planner coincides with the maximisation of the individual objective function, equation (1), where the discount factor is given by δ instead of ρ. It thus appears that the exclusive focus on the choice of the discount rate as the key policy decision is only justified in the restrictive case of perfect homogeneity across economic agents, that is in the representative consumer paradigm.

4. Conclusions

The present paper examines the issue of intergenerational redistribution in a general equilibrium model with disconnected generations and environmental externalities, where pollution directly enters a constant returns to scale production function. Extending the utilitarian criterion proposed by Calvo and Obstfeld (1988), a social planner can achieve the optimal allocation of physical assets and environmental resources across generations. Social optimality requires, in particular, that the marginal social benefit of a positive public debt be equal to the marginal social benefit of the environmental resource, weighted by the total amount employed in the production process. Also, the optimal government spending on pollution abatement should be an increasing function of the ratio between the marginal social benefit of the environment and of physical capital accumulation.

References

Blanchard, Olivier J. (1985), "Debt, Deficits and Finite Horizons", *Journal of Political Economy*, Vol. 93, April, pp. 223-247.

Blanchard, Olivier J., and Stanley Fischer (1989), *Lectures on Macroeconomics*, MIT Press, Cambridge (Mass.).

Bovenberg, A.L. and F. van der Ploeg (1992), "Environmental Policy, Public Finance and the Labour Market in a Second-Best World", University of Amsterdam, mimeo.

Buiter, Willem H. (1988), "Death, Birth, Productivity Growth and Debt Neutrality", *Economic Journal*, Vol. 98, June, pp. 279-293.

Calvo, Guillermo A., and Maurice Obstfeld (1988), "Optimal Time-Consistent Fiscal Policy with Finite Lifetimes", *Econometrica*, Vol. 56, No. 2, March, pp. 411-432.

Dasgupta, P.S., and G.M. Heal (1979), *Economic Theory and Exhaustible Resources*, Cambridge University Press, Cambridge.

Howarth, R.B., and R.B. Norgaard (1992), "Environmental Valuation under Sustainable Development", *American Economic Review*, Papers and Proceedings, Vol. 80, pp. 473-477.

Markandya, Anil, and David W. Pearce (1988), "Environmental Considerations and the Choice of the Discount Rate in Developing Countries", Washington, World Bank.

Marini, Giancarlo, and Pasquale Scaramozzino (1991), "Overlapping Generations, Time Consistency and Environmental Control", Department of Economics, University College London, Discussion Paper No. 91-20.

Musu, Ignazio (1991), "Sustainable Growth and Time Preference", Università di

Venezia, D.P. No. 91.08.

Pearce, David W. (1991), "The Role of Carbon Taxes in Adjusting to Global Warming", *Economic Journal*, Vol. 101, No. 407, July, pp. 938-948.

Pearce, David W., and R. Kerry Turner (1990), *Economics of Natural Resources and the Environment*, Harvester Wheatsheaf, Hertfordshire.

van der Ploeg, Frederick, and Cees Withagen (1991), "Pollution Control and the Ramsey Problem", *Environmental and Resource Economics*, Vol. 1, No. 2, pp. 215-236.

Smith, Stephen (1992), "Taxation and the Environment: A Survey", *Fiscal Studies*, Vol. 13, No. 4, November, pp. 21-57.

Solow, Robert M. (1986), "On the Intergenerational Allocation of Natural Resources", *Scandinavian Journal of Economics*, pp. 141-149.

Takayama, Akira (1985), *Mathematical Economics*, 2nd ed., Cambridge University Press, Cambridge.

Ulph, Alistair, David Ulph and John Pezzey (1991), "Should a Carbon Tax Rise or Fall over Time?", Department of Economics, University of Bristol, Discussion Paper No. 91/309.

Weil, P. (1989), "Overlapping Families of Infinitely-Lived Agents", *Journal of Public Economics*, Vol. 38, pp. 183-198.

Yaari, M. (1965), "Uncertain Lifetime, Life Insurance and the Theory of the Consumer", *Review of Economic Studies*, Vol. 32, April, pp. 137-150.

Notes

[1]The original references are Yaari (1965), Blanchard (1985), Weil (1989), and Buiter (1988).

[2]Blanchard and Fischer (1989, chapter 3) describe this set-up as the "perpetual youth" model.

[3]Note that, if $f_{kz}=0$, stability requires that $\Delta_2>0$ since $f_{zz}<0$.

[4]See Marini and Scaramozzino (1991) for a more extensive motivation and discussion of the planner's programme.

[5]The two-stage optimisation procedure in a similar framework is described in detail in Marini and Scaramozzino (1991).

[6]See for instance Takayama (1985), chapter 8, section C.

Elenco dei Quaderni pubblicati

n.1 (febbraio 1979) **MASSIMO DI MATTEO,** Alcune considerazioni sui concetti di lavoro produttivo e improduttivo in Marx
n.2 (marzo 1979) **MARIA L.RUIZ,** Mercati oligopolistici e scambi internazionali di manufatti. Alcune ipotesi e un'applicazione all'Italia
n.3 (maggio 1979) **DOMENICO MARIO NUTI,** Le contraddizioni delle economie socialiste: una interpretazione marxista
n.4 (giugno 1979) **ALESSANDRO VERCELLI,** Equilibrio e dinamica del sistema economico-semantica del linguaggi formalizzati e modello keynesiano
n.5 (settembre 1979) **A. RONCAGLIA - M. TONVERONACHI,** Monetaristi e neokeynesiani: due scuole o una?
n.6 (dicembre 1979) **NERI SALVADORI,** Mutamento dei metodi di produzione e produzione congiunta
n.7 (gennaio 1980) **GIUSEPPE DELLA TORRE,** La struttura del sistema finanziario italiano: considerazioni in margine ad un'indagine sull'evoluzione quantitativa nel dopoguerra (1948-1978).
n.8 (gennaio 1980) **AGOSTINO D'ERCOLE,** Ruolo della moneta ed impostazione antiquantitativa in Marx: una nota
n.9 (novembre 1980) **GIULIO CIFARELLI,** The natural rate of unemployment with rational expectations hypothesis. Some problems of estimation
n.10 (dicembre 1980) **SILVANO VICARELLI,** Note su ammortamenti, rimplazzi e tasso di crescita
n.10 bis (aprile 1981) **LIONELLO F. PUNZO,** Does the standard system exist?
n.11 (marzo 1982) **SANDRO GRONCHI,** A meaningful sufficient condition for the uniqueness of the internal rate of return
n.12 (giugno 1982) **FABIO PETRI,** Some implications of money creation in a growing economy
n.13 (settembre 1982) **RUGGERO PALADINI,** Da Cournot all'oligopolio: aspetti dei processi concorrenziali
n.14 (ottobre 1982) **SANDRO GRONCHI,** A Generalized internal rate of return depending on the cost of capital
n.15 (novembre 1982) **FABIO PETRI,** The Patinkin controversy revisited
n.16 (dicembre 1982) **MARINELLA TERRASI BALESTRIERI,** La dinamica della localizzazione industriale: aspetti teorici e analisi empirica
n.17 (gennaio 1983) **FABIO PETRI,** The connection between Say's law and the theory of the rate of interest in Ricardo
n.18 (gennaio 1983) **GIULIO CIFARELLI,** Inflation and output in Italy: a rational expectations interpretation
n.19 (gennaio 1983) **MASSIMO DI MATTEO,** Monetary conditions in a classical growth cycle
n.20 (marzo 1983) **M. DI MATTEO - M.L. RUIZ,** Effetti dell'interdipendenza tra paesi produttori di petrolio e paesi industrializzati: un'analisi macrodinamica
n.21 (marzo 1983) **ANTONIO CRISTOFARO,** La base imponibile dell'IRPEF: un'analisi empirica
n.22 (gennaio 1984) **FLAVIO CASPRINI,** L'efficienza del mercato dei cambi. Analisi teorica e verifica empirica
n.23 (febbraio 1984) **PIETRO PUCCINELLI,** Imprese e mercato nelle economie socialiste: due approcci alternativi
n.24 (febbraio 1984) **BRUNO MICONI,** Potere prezzi e distribuzione in economie mercantili caratterizzate da diverse relazioni sociali
n.25 (aprile 1984) **SANDRO GRONCHI,** On investment criteria based on the internal rate of return
n.26 (maggio 1984) **SANDRO GRONCHI,** On Karmel's criterion for optimal truncation
n.27 (giugno 1984) **SANDRO GRONCHI,** On truncation "theorems"
n.28 (ottobre 1984) **LIONELLO F. PUNZO,** La matematica di Sraffa
n.29 (dicembre 1984) **ANTONELLA STIRATI,** Women's work in economic development process
n.30 (gennaio 1985) **GIULIO CIFARELLI,** The natural rate of unemployment and rational expectation hypotheses: some empirical tests
n.31 (gennaio 1985) **SIMONETTA BOTARELLI,** Alcuni aspetti della concentrazione dei redditi nel Comune di Siena
n.32 (febbraio 1985) **FOSCO GIOVANNONI,** Alcune considerazioni metodologiche sulla riforma di un sistema tributario
n.33 (febbraio 1985) **SIMONETTA BOTARELLI,** Ineguaglianza dei redditi personali a livello comunale
n.34 (marzo 1985) **IAN STEEDMAN,** Produced inputs and tax incidence theory
n.35 (aprile 1985) **RICHARD GOODWIN,** Prelude to a reconstruction of economic theory. A critique of Sraffa
n.36 (aprile 1985) **MICHIO MORISHIMA,** Classical, neoclassical and Keynesian in the Leontief world
n.37 (aprile 1985) **SECONDO TARDITI,** Analisi delle politiche settoriali: prezzi e redditi nel settore agroalimentare
n.38 (maggio 1985) **PIETRO BOD,** Sui punti fissi di applicazioni isotoniche
n.39 (giugno 1985) **STEFANO VANNUCCI,** Schemi di gioco simmetrici e stabili e teoremi di possibilità per scelte collettive
n.40 (luglio 1985) **RICHARD GOODWIN,** The use of gradient dynamics in linear general disequilibrium theory
n.41 (agosto 1985) **M. MORISHIMA** and **T. SAWA,** Expectations and the life span of the regime.
n.42 (settembre 1985) **ALESSANDRO VERCELLI,** Keynes, Schumpeter, Marx and the structural instability of capitalism
n.43 (ottobre 1985) **ALESSANDRO VERCELLI,** Money and production in Schumpeter and Keynes: two dichotomies
n.44 (novembre 1985) **MARCO LONZI,** Aspetti matematici nella ricerca di condizioni di unicità per il Tasso Interno di Rendimento
n.45 (dicembre 1985) **NIKOLAUS K.A. LAUFER,** Theoretical foundations of a new money supply hypothesis for the FRG.
n.46 (gennaio 1986) **ENRICO ZAGHINI,** Una dimostrazione alternativa dell'esistenza di equilibri in un modello di accumulazione pura
n.47 (febbraio 1986) **ALESSANDRO VERCELLI,** Structural stability and the epistemology of change: a critical appraisal
n.48 (marzo 1986) **JOHN HICKS,** Rational behaviour: observation or assumption?
n.49 (aprile 1986) **DOMENICO MARIO NUTI,** Merger conditions and the measurement of disequilibrium in labour-managed economies
n.50 (maggio 1986) **SUSAN SENIOR NELLO,** Un'applicazione della Public Choise Theory alla questione della riforma della Politica Agricola Comune della CEE
n.51 (maggio 1986) **SERENA SORDI,** Some notes on the second version of Kalecki's Business Cycle Theory
n.52 (giugno 1986) **PIERANGELO GAREGNANI,** The classical theory of wage and the role of demand schedules in the determination of relative prices
n.53 (luglio 1986) **FRANCO BIRARDI,** Crescita, sviluppo ed evoluzione: l'affermazione dei nessi strutturali sistematici e la combinazione di scienza, tecnologia ed economica nelle prime industrializzazioni
n.54 (agosto 1986) **M. AMENDOLA - J.L. GAFFARD,** Innovation as creation of technology: a sequential model
n.55 (settembre 1986) **GIULIO CIFARELLI,** Exchange rates, market efficiency and "news". Model specification and econometric identification
n.56 (settembre 1986) **ALESSANDRO VERCELLI,** Technological flexibility, financial fragility and the recent revival of Schumpeterian entrepreneurship
n.57 (ottobre 1986) **FABIO PETRI,** The meaning of the Cambridge controversies on capital theory: an attempt at communication
n.58 (ottobre 1986) **DANIELE CHECCHI,** The international coordination of counter-cyclical policies
n.59 (novembre 1986) **ALESSANDRO VERCELLI,** Probabilistic causality and economic models: Suppes, Keynes, Granger
n.60 (dicembre 1986) **LIONELLO F. PUNZO,** J. Von Neumann and K. Menger's mathematical colloquium
n.61 (dicembre 1986) **MICHAEL BACHARACH,** Three scenarios for fulfilled expectations
n.62 (gennaio 1987) **J. ESTEBAN** and **T. MILLAN,** Competitive equilibria and the core of overlapping generations economies
n.63 (gennaio 1987) **ROBERT W. CLOWER,** New directions for keynesian economics
n.64 (febbraio 1987) **MARCO P. TUCCI,** A simple introduction to flexible functional forms and consumer behaviour theory
n.65 (marzo 1987) **NICOLA DIMITRI,** Generalizations of some continuos time epidemic models

n.66 (aprile 1987) **MASSIMO DI MATTEO**, Goodwin and the Evolution of a Capitalistic Economy: An Afterthought
n.67 (maggio 1987) **MASSIMO DI MATTEO**, Early Discussions on Long Waves
n.68 (giugno 1987) **MASSIMO DI MATTEO**, Warranted, Natural, and Actual Rates of Growth: Reflections of a Perplex
n.69 (settembre 1987) **LUISA MONTUSCHI**, Inward-Looking development and import substitution in the Argentine Economy 1950-1980
n.70 (dicembre 1987) **GIANCARLO GANDOLFO** and **PIETRO CARLO PADOAN**, The Mark V version of the Italian continuos time model
n.71 (dicembre 1987) **SILVANO VICARELLI**, Impatience to consume, the utility of wealth and the rate of interest
n.72 (gennaio 1988) **OMAR CHISARI**, Worker's assets, foreign debt and the dynamics of an economy
n.73 (febbraio 1988) **STEFANO VANNUCCI**, On exactly strong-Nash-implementable power allocations
n.74 (marzo 1988) **PIER LUIGI LANDI**, Aspetti economici della società anonima della strada ferrata Empoli-Siena o Centrale Toscana fino al 1859
n.75 (aprile 1988) **FRANCO BIRARDI**, Generating the space of physical characteristics by means of elements which are discrete and limited over time (A note on innovation in chemical technologies)
n.76 (maggio 1988) **LILIA COSTABILE**, Politica monetaria, debito pubblico e tasso di interesse
n.77 (giugno 1988) **GIUSEPPE DELLA TORRE**, L'evoluzione dei sistemi finanziari nell'approccio contabile di Raymond Goldsmith.
Alcune considerazioni analitiche
n.78 (luglio 1988) **FRANCESCO FARINA**, Fattori tecnologici e transazionali nella divisione interindustriale del lavoro
n.79 (ottobre 1988) **FRANCESCO FARINA**, Gli obiettivi della Banca d'Italia e i tassi d'interesse sul debito pubblico
n.80 (novembre 1988) **GIULIO CIFARELLI**, La razionalità del tasso di cambio a termine e le "notizie": una analisi empirica
n.81 (dicembre 1988) **MAURO CAMINATI**, Cyclical growth in a long-period perspective
n.82 (gennaio 1989) **LUIGI LUINI**, Crescita esterna dell'impresa e teorie economiche
n.83 (marzo 1989) **LUIGI M. TOMASINI**, A Scheme to Allocate Wastewater Rights
n.84 (aprile 1989) **STEFANO VANNUCCI**, On Consistency Properties of some Strongly Implementable Social Choice Rules with Endogenous Agenda Formation
n.85 (maggio 1989) **AGOSTINO D'ERCOLE**, Economia e Moneta in Schumpeter
n.86 (maggio 1989) **CHARLES GOODHART**, What do Central Banks Do?
n.87 (giugno 1989) **PAOLO DEL GIOVANE**, Foreign Firms' Behavior in the United States Market during the Dollar Cycle
n.88 (giugno 1989) **GÉRARD DUMÉNIL** and **DOMINIQUE LÉVY**, The classical legacy and beyond
n.89 (luglio 1989) **RICCARDO FIORITO**, Inventory accounting and profit evaluation
n.90 (settembre 1989) **NICOLA DIMITRI**, On the robustness of the rational expectations hypothesis
n.91 (settembre 1989) **PIERMARIO PACINI**, Expectations, learning and equilibrium in a non-walrasian model: a constructive approach
n.92 (ottobre 1989) **AGOSTINO D'ERCOLE**, Sulla teoria monetaria del tasso di interesse di Schumpeter
n.93 (ottobre 1989) **UGO PAGANO**, Firms, co-ordination and disequilibrium
n.94 (novembre 1989) **UGO PAGANO**, Determinazione endogena dei diritti di proprietà in una economia di mercato
n.95 (dicembre 1989) **UGO PAGANO**, Property rights, asset specificity, and the division of labour under alternative capitalist relations
n.96 (dicembre 1989) **MICHIO MORISHIMA**, Wage differentials in Japan: 1958-1985
n.97 (gennaio 1990) **PIERPAOLO PIERANI - PIER LUIGI RIZZI**, An econometric analysis of the olive oil market in Italy
n.98 (febbraio 1990) **ENRICO GIOVANNINI**, Squilibri settoriali e dinamica macroeconomica di breve periodo: il caso dell'industria italiana
n.99 (maggio 1990) **GIULIO CIFARELLI** Sui determinanti degli errori di previsione a termine nel mercato dei cambi
n.100 (maggio 1990) **EDITED BY MASSIMO DI MATTEO** Celebrating R.M. Goodwin's 75 birthday
n.101 (maggio 1990) **OMAR O. CHISARI - JOSE' M. FANELLI** Three-gap models, optimal growth and the economic dynamics of highly indebted countries
n.102 (giugno 1990) **FRANCESCO FARINA** Italy's monetary policy inside the european monetary system
n.103 (giugno 1990) **STEFANO VANNUCCI** On the closure operators of an effectivity function
n.104 (giugno 1990) **STEFANO VANNUCCI** Struttura del mercato, giochi semplici e potenziali monopolistici
n.105 (luglio 1990) **STEFANO VANNUCCI** A note on ergodic and vnm-stable sets of abstract games
n.106 (luglio 1990) **SIMONETTA BOTARELLI** I nuovi estimi catastali: motivazioni ed effetti distributivi
n.107 (luglio 1990) **PIETRO PUCCINELLI** Impresa e mercato un approccio dinamico
n.108 (agosto 1990) **UGO PAGANO** Braverman, Harry (1920-1976)
n.109 (agosto 1990) **UGO PAGANO** Property rights equilibria and institutional stability
n.110 (settembre 1990) **STEPHAN R. EPSTEIN** Cities, regions and the late medieval crisis: Sicily and Tuscany compared
n.111 (ottobre 1990) **MAURO CAMINATI** On the stability of long-period positions: an introductory note
n.112 (ottobre 1990) **MAURO CAMINATI** Cicli endogeni in disequilibrio e congetture
n.113 (ottobre 1990) **AGOSTINO D'ERCOLE** Il concetto di integrazione finanziaria internazione, Problemi e prospettive
n.114 (ottobre 1990) **LIONELLO F. PUNZO** Hilbert's mathematical formalism and the neoclassical revolution
n.115 (ottobre 1990) **BRUNO MICONI - PIER MARIO PACINI** Price systems, bargaining theory and social relations
n.116 (ottobre 1990) **LIONELLO F. PUNZO** J.-M. Grandmont on "temporary equilibrium: money, expectations and dynamics". Some Comments.
n.117 (novembre 1990) **GIULIO CIFARELLI** Cointegration and the unbiased efficiency of the forward exchange rate
n.118 (novembre 1990) **SIMONETTA BOTARELLI** L'imposizione delle imprese minori: problemi di determinazione della base imponibile nei sistemi forfettari. Una nota
n.119 (dicembre 1990) **GIUSEPPE DELLA TORRE** Teoria economica e contabilità sociale. Il «national bureau of economic research» (1920-1945)
n.120 (dicembre 1990) **ELISABETTA CROCI ANGELINI - SECONDO TARDITI** Ec Enlargement and trade liberalization in the vegetable oils market
n.121 (dicembre 1990) **ELISABETTA CROCI ANGELINI** Costs and benefits of the common agricultural policy to the member countries
n.122 (dicembre 1990) **GIANCARLO MARINI - PASQUALE SCARAMOZZINO** Inflation expectations, price flexibility, and output variability in macro models
n.123 (dicembre 1990) **RAUL de LUZENBERGER - GIANCARLO MARINI** The sustainability of public debt: tests and indicators
n.124 (dicembre 1990) **MARCO P. TUCCI** Time-varying parameters: a critical introduction
n.125 (dicembre 1990) **GIOVANNI FERRI** Preferences and technology in the real business cycle
n.126 (dicembre 1990) **SILVANO VICARELLI** Preferenza per la liquidità e valore dell'informazione
n.127 (gennaio 1990) **FABIO CESARE BAGLIANO - GIANCARLO MARINI** On the role of monetary factors in business cycle models
n.128 (febbraio 1991) **LUIGI TOMASINI** Due modelli di controllo dell'evasione fiscale
n.129 (giugno 1991) **MASANAO AOKI - RICCARDO FIORITO** Analysis of us real GNP and unemployment interactions: state space approach
n.130 (luglio 1991) **PIERPAOLO PIERANI - PIER LUIGI RIZZI** Produttività totale dei fattori e progresso tecnico nell'agricoltura italiana: un confronto Nord-Sud
n.131 (settembre 1991) **AGOSTINO D'ERCOLE** L'integrazione finanziaria internazionale e la relazione risparmi-investimenti
n.132 (settembre 1991) **GIULIO CIFARELLI** Le fluttuazioni del dollaro negli anni ottanta. Una analisi econometrica
n.133 (novembre 1991) **STEFANO VANNUCCI** On Stable standards of behaviour
n.134 (novembre 1991) **LUIGI M. TOMASINI** Politica dei redditi e compartecipazione
n.135 (dicembre 1991) **NICOLA DIMITRI** Asymptotic consensus with partitions
n.136 (gennaio 1992) **MAURIZIO BAUSSOLA - RICCARDO FIORITO** Regional Unemployment in Italy: sources and cures

n.137 (febbraio 1992) **STEFANO VANNUCCI** Implementation Theory and Ethics
n.138 (febbraio 1992) **MASSIMO DI MATTEO** Forms of trade control in an equilibrium north-south model : a comparative evaluation
n.139 (febbraio 1992) **MASSIMO DI MATTEO** E' veramente da criticare una politica export-led? Alcuni risultati usando un modello di equilibrio nord-sud
n.140 (maggio 1992) **BERNHARD BÖHM** An Introduction into environmental econimics (lecture notes)
n.141 (settembre 1992) **RICCARDO FIORITO - FLAVIO PADRINI** Unemployment components in the G7 countries
n.142 (ottobre 1992) **GIULIO CIFARELLI** Fundamentals, regime shifts and dollar behaviour in the 19805. An empirical analysis
n.143 (ottobre 1992) **FRANK HAHN** A Remark on incomplete market equilibrium
n.144 (ottobre 1992) **NICOLA DIMITRI** Generalized Information structures: some theoretical and methodological issues
n.145 (ottobre 1992) **FRANCESCO FARINA** Distributive justice as a coordination problem
n.146 (ottobre 1992) **MAURIZIO FRANZINI** The role of the market in a complex institutional order
n.147 (novembre 1992) **FRANCESCO PULITINI** Le vestali del mercato. Qualche appunto sull'antitrust italiano
n.148 (novembre 1992) **VALERIA DE BONIS** On stabilisation Policy in a single currency area. An IS-LM-AS Model
n.149 (dicembre 1992) **FRANK HAHN** An Economist's view of higher education
n.150 (gennaio 1993) **GIANROCCO TUCCI** Integrazione tra efficienza ed equità-come-assenza-di invidia in un'analisi costi-benefici non tradizionale
n.151 (gennaio 1993) **BERNHARD BÖHM** An Introduction into environmental economics - Reprint-
n.152 (febbraio 1993) **NICOLA DIMITRI** Learning partitions
n.153 (marzo 1993) **SERENA SORDI** Nonlinear models of the business cycle and chaos theory: a critical analysis
n.154 (maggio 1993) **UGO MARANI-RICCARDO AZZOLINI** Svalutazione e politica economica . Osservazioni sulla crisi valutaria del 1992
n.155 (giugno 1993) **CARLO ZAPPIA** The notion of private information in a modern perspective: a re-appraisal of hayek's contribution
n.156 (settembre 1993) **FABIO PETRI** The impermanence problem in general equilibrium analyses
n.157 (ottobre 1993) **GIULIO CIFARELLI** Sistematic forward forecast errors, ex ante real interest rate differentials and ex ante real exchange rate changes. An empirical analisis

Alla presente Collana "gialla" di quaderni il Dipartimento di Economia Politica affianca una Collana "celeste" di monografie. I numeri pubblicati a tutt'oggi sono i seguenti:

1) **GIUSEPPE DELLA TORRE,** Istituzioni creditizie ed Accumulazione del Capitale in Italia (1948-81), 1984.

2) **SANDRO GRONCHI,** Tasso Interno di Rendimento e Valutazione dei Progetti: una Analisi Teorica, 1984.

3) **ALDINO MONTI,** La Proprietà Immobiliare a Bologna in Età Napoleonica (1797-1810), 1984.

4) **GIULIO CIFARELLI,** Equilibrium and Disequilibrium Interpretations of Inflation, 1985.

5) **STEPHAN E. EPSTEIN,** Sicily and its markets: 1300-1500 economic growth and social transformation

6) **ROBERT SOLOW,** Siena Lectures on Endogenous Growth Theory, edited by Serena Sordi

7) Guida alle attività del Dipartimento di Economia Politica

Stampato nel 1993 dalla
COPISTERIA EMMECI, Via Pantaneto 132 - Siena -