Sustainability Policy and Environmental Policy

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Abstract

A theoretical, representative-agent economy with a depletable resource stock, polluting emissions and productive capital is used to contrast environmental policy, which internalises externalised environmental values, with sustainability policy, which achieves some form of intergenerational equity. The obvious environmental policy comprises an emissions tax and a resource stock subsidy, each equal to the respective external cost or benefit. Sustainability policy comprises an incentive affecting the choice between consumption and investment, and can be a consumption tax, capital subsidy or investment subsidy, or a combination thereof. Environmental policy can reduce the strength of the sustainability policy needed. More specialised results are derived in a small open economy with no environmental effects on utility.

Keywords: Sustainability; optimality; externalities; tax; policy

JEL classification: H3; O23; Q1; Q28

I. Introduction

In the government literature on sustainable development that has poured forth since the Brundtland report (WCED, 1987) popularised the idea, it is often difficult to distinguish sustainability policy from environmental policy. A document on a country’s approach to sustainable development often starts with statements about sustainability as safeguarding the well-being of future generations, but then continues with little more than a list of environmental policies. Detailed policies are spelt out on air and water pollution, solid waste, habitat and biodiversity protection, etc., perhaps with emphasis on

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some forms of long-term environmental damage. Nothing is said, however, about other policies that may be needed to sustain well-being.

If governments believe that limits to the substitutability of human-made capital and knowledge for environmental resources are fairly imminent, then this implicitly “strong” approach to sustainability, which treats environmental protection as the essence of sustainability policy, would be logical. But by the very finite values that their policies place on environmental resources, most governments reveal that they do not much believe in such limits to substitutability. It thus seems relevant at least to explore the neoclassical or “weak” approach to sustainability, and assume capital-resource substitutability at the margin. In so doing however, we refrain from expressing views on the difficult, uncertain questions of where limits to substitutability do actually exist, or on what should be the appropriate policy response to such uncertainties.

Within the confines of our substitutability assumptions, this analysis confirms the intuition that if it is needed at all, sustainability policy should include non-environmental aspects of providing more for future generations, such as encouraging more saving and hence capital investment to substitute for some degree of future environmental resource depletion. Sustainability and environmental policies are thus at least partially distinct. The aim of this paper is to clarify these distinctions, using a standard, representative-agent, neoclassical model of economic development.

The two types of policy are defined as follows. Simply put, environmental policy here is the time path of all incentives, such as emission taxes and resource conservation subsidies, with which the government can intervene in decentralised markets to internalise the costs that a single agent treats as external to her private maximisation of intertemporal welfare. By contrast, sustainability policy is the time path of incentives which persuade agents to achieve a collectively desired “sustainability” goal. We thus do not consider government taxation of resource rents to fund public investment, for example in trust funds. The sustainability goal is viewed generally as any departure from maximising social welfare based on current agents’ individual time preferences, i.e., aimed at improving intergenerational equity. Below we briefly mention the question of how such a departure can be justified, and also say more about efficient versus inefficient sustainability policies. The lack of consensus on any precise sustainability goal, and the differences between efficient and inefficient policies to achieve it, imply that the treatment of sustainability policy is necessarily less uniform here than that of environmental policy. The usual outline of the contribution and organisation of the paper is at the end of the next section, after we first review the relevant literature.
Il. Literature Relevant to Environmental and Sustainability Policies

A distinction between environmental and sustainability policies broadly similar to that sketched above was envisioned long ago by Stiglitz (1979, p. 61). However, the formal economic literature on “sustainability” has mostly focused on defining and justifying it, as in Howarth (1992) and Asheim, Buchholz and Tungodden (2001), or on measuring it, as in Pearce and Atkinson (1993) and Hamilton and Clemens (1999), rather than on finding policies to achieve it. The wider literature about environmental and/or general intergenerational policies in a dynamic economy can be divided into four categories and, unless otherwise stated, uses an overlapping generations model.

First, papers such as Smulders (2000) adopt a representative-agent (RA) format and focus solely on a social planner’s viewpoint, without considering policy instruments. Second, there are papers which consider a dynamic instrument of environmental policy to internalise externalities, but offer either no explicit sustainability goal, as in Jouvet, Michel and Vidal (2000), or no policy to achieve this goal. Third, papers such as Howarth and Norgaard (1990) analyse some kind of sustainability goal, but contain no conventional externalities, and hence no environmental policy. Fourth, there are papers which consider both environmental policy and sustainability policy. Howarth and Norgaard (1992), for example, use intergenerational transfers as the sustainability policy instrument. Such transfers are unavailable here because of our RA format, and our equivalent instrument is comprised of incentives that directly affect the choice between consumption and investment. Becker’s (1982) instrument (also in RA format) was direct manipulation of the interest rate path, which we exclude as practically implausible. Pezzey (1992) foreshadowed the analysis in the present paper, but was much simpler and more restricted.

What is new here is that we combine and include pollution, resource depletion and physical capital accumulation. Compared to much of the literature, our functional forms are more general. The focus is mostly on transitional rather than steady-state paths. We study interactions of environmental policy and sustainability policy. Our focus on encouraging saving as a sustainability policy is supported by empirical measurement studies, as acknowledged in Hamilton and Clemens (1999, Sec. V), but has so far received little theoretical attention. Our approach also allows us to consider two more specialised topics of possible interest to policymakers. One is whether on their own, resource incentives such as depletion taxes can prevent unsustainability in an economy with non-renewable resources. The other is

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1 An earlier version of this paper gives a detailed review which is summarised here; see Pezzey (2002).
what effect sustainability policy has on resource management and domestic production in a small open economy.

The rest of the paper is organised as follows. In Section III we describe a simple economy with four environmental externalities, and a formalisation of (but not justification for) sustainability policy intervention. The environmental policies required to internalise all externalities, and the sustainability policies needed to reach an intergenerational equity objective, are then derived from a unified analysis. Section IV offers an example of an economy with specific functional forms to show a precise effect of environmental policy on sustainability policy. Using a modified simple economy, Section V considers the two more specialised topics mentioned above. Section VI concludes.

III. Environmental Policy and Sustainability Policy in a Simple Economy

The Economy

We model a simple dynamic, deterministic, optimising economy, with a representative agent who makes decisions in continuous time. (There is no foreign trade until the second part of Section V.) All variables are time dependent, but to reduce clutter we show this only where needed for clarity. The stock at time $t$ of a depletable, natural resource is $S$. The resource grows naturally at a stock-dependent rate $G(S)$ (though $G$ could be zero for the case of non-renewable resources) and is depleted at rate $R$, so:

$$\dot{S} := \frac{dS}{dt} = G(S) - R; \quad S(t) \geq 0; \quad S(0) = S_0 > 0, \text{ given};$$  \hspace{1cm} (1)

and

$$G_S := \frac{\partial G}{\partial S} > 0 \text{ is assumed.}$$   \hspace{1cm} (2)

The other stock of the economy is productive capital $K$, which grows at rate of investment $I$ (capital depreciation does not affect our results and is thus excluded):

$$\dot{K} = I; \quad K(t) \geq 0; \quad K(0) = K_0 > 0, \text{ given.}$$  \hspace{1cm} (3)

Transient, polluting emissions $E$ depend positively on resource depletion (and use in production) $R$, and negatively on abatement current expenditure $a$.\footnote{Contrast this with Jouvet et al. (2000), where the dirty variable is output, and a positive tax on capital is desirable for environmental reasons.} Production $F$ of a consumption–investment good depends positively on productive capital and resource depletion, and negatively on emissions.
There is no exogenous technical progress. Production is divided among consumption $C$, investment and abatement spending:

$$F[K, R, E(R, a)] = C + I + a$$

$$F_K, F_R > 0, F_{KK}, F_{RR} < 0, F_{KR} > 0, F_E < 0, F_{EE} < 0, E_R > 0, E_a < 0.$$ (4)

Instantaneous utility $U$ depends positively on consumption and resource stock, and negatively on emissions:

$$U = UC, US > 0, UCC, USS < 0, UCS, UE, UE < 0, \lim_{t \to \infty} UC = 0.$$ (5)

The economy follows an intertemporally efficient path in the interests of the current generation and, to do this, it chooses paths of consumption $C(t)$, abatement current expenditure $a(t)$, and resource depletion $R(t)$ so as to maximise present value $W^p(0)$. This is defined as the (social) present value of utility, using a (perhaps constant) discount rate $\rho(t)$:

$$W^p(0) := \int_0^\infty \exp \left[ - \int_0^t \rho(z)dz \right] U[C(t), S(t), E(t)]dt; \rho(t) > 0.$$ (6)

With $\Psi^K$ and $\Psi^S$ as co-state variables, the current-value Hamiltonian for maximising present value (6) subject to conditions (1)–(5) is then

$$H = U + \Psi^K \dot{K} + \Psi^S \dot{S}$$

$$= UC, US > 0, UCC, USS < 0, UCS, UE, UE < 0, \lim_{t \to \infty} UC = 0.$$ (7)

All functional forms in (1)–(5) are assumed to be as smooth and convex as is required for the existence of a unique, interior development path which maximises present value. We call this “optimal” or “socially optimal” whenever it needs to be distinguished from private optimality as defined below.

Principles of Environmental Policy

We have defined the economy’s environmental policy as the time path of price incentives which the government must create to induce an individual agent in a decentralised equilibrium to follow the socially optimal path based on her own time preferences. Policy intervention is needed because the agent is presumed to maximise present value $W^p(0)$ imperfectly, by ignoring (externalising) the public or “environmental” effects of her actions when making marginal choices of control variables. The result of these choices is called the “privately optimal” path. The four externalised effects selected
here are the partial derivatives of utility with respect to the environmental resource stock, $U_S$, and emissions, $U_E$; of production with respect to emissions, $F_E$; and of resource growth with respect to the stock, $G_S$. Many other selections could be made. Externalities from human-made resources such as knowledge could be treated using similar techniques, but following convention, are not included here in environmental policy.

An environmental policy incentive $\{\tau^i(t)\}$ is a tax when positive and a subsidy when negative, though either can occur at different times for the same incentive and, in general, the incentive is called a “tax”. Thus, we do not consider quantity restrictions (though tradable permits would be theoretically indistinguishable from taxes in our model), and ignore the bands of different rates found in many real-world tax schedules. Importantly, any net revenue from (or cost of) the incentive system is assumed to be immediately refunded to (or taxed from) the representative consumer as a lump sum. (To do otherwise, by including government spending and unbalanced budgets, and by excluding lump-sum transfers, would significantly alter our analysis.)

Seven instruments are available in our model: taxes on consumption ($\tau^C$), capital ($\tau^K$), investment ($\tau^I$), abatement current spending ($\tau^a$), resource extraction ($\tau^R$), resource stock ($\tau^S$) and emissions ($\tau^E$). We mainly consider the consumption tax but not the capital or investment taxes, though in Section III we note the substitutability among these three taxes. Both an abatement tax and a tax on resource depletion turn out to be theoretically redundant, but we include them here because they are realistic policy options.

The private individual thus has a utility function:

$$U = U(C, \bar{S}, \bar{E}(R, a)),$$

and accounting relationships are

$$\dot{K} = F(K, R, \bar{E}(R, a)) - C - \dot{K} - a - (\tau^C C + \tau^a a + \tau^R R + \tau^S S + \tau^E E - \Omega),$$
$$\dot{S} = G(\bar{S}) - R,$$

where overbars mark the environmental variables $\bar{S}$ and $\bar{E}$ that individuals take as given when making private, maximising choices, and $\Omega$ is the lump-sum refund of all net tax revenues that balances the government’s budget.

**Principles of Sustainability Policy**

It turns out that the same analysis gives results for both environmental and sustainability policies if these policies are applied together. We should thus begin by clarifying the goal of sustainability policy. Whatever it is, the policy must be ethically motivated by considerations of intergenerational

equity, and must aim at some departure from the social maximisation of present value $W^p$ in (6) using the representative agent’s discount rate $\rho(t)$; see Pezzey (2004) on justifying such a departure. Of many possible exact goals of sustainability policy, three which make sense in our context are:

(i) achieving constant utility, after Solow (1974) and Hartwick (1977);
(ii) avoiding any decline in utility, after Pearce, Markandya and Barbier (1989), Pezzey (1992), and Pezzey (1997) who labels this more precisely as “sustainedness”;
(iii) avoiding any decline in present value $W^p(t)$ from time $t$ onwards, defined as $\int_t^\infty \exp \left[-\int_t^s \rho(z)dz\right] U[C(s), S(s), E(s)]ds$, after Riley (1980).

Non-declining wealth or non-declining aggregate capital, two well-known alternatives suggested by Pearce et al. (1989), are best viewed here as (possibly flawed) means, rather than ends, of sustainability policy.

Choosing among goals (i)–(iii) is less important in this context than knowing how the goal relates to the socially and privately optimal paths of the economy; see Pezzey (1992, p. 26). We assume that an explicit sustainability policy is required, in the sense that the goal is met on neither the socially optimal nor the privately optimal path. In order to achieve sustainability, there must be a binding policy instrument, distinct from the instruments of environmental policy.

We also assume that, in general, sustainability policy is enacted at the same time as environmental policies, so that the overall result of intervention is an (intertemporally) efficient path of development. In fact, we then further assume that the sustainability goal is reached **optimally**, that is, with minimum loss of present value $W^p$, although this stronger assumption (which of course implies efficiency) is not needed for our analytical result.³

As in Takayama (1985, p. 188), to be on an efficient sustainable path, the economy must act as if it maximises some present value measure, say $W^\sigma(0)$, using a “sustainable discount rate” path $\sigma(\cdot)$ in place of $\rho(\cdot)$ in (6), even though the fundamental sustainability goal may have nothing to do with discount rates:

$$W^\sigma(0) := \int_0^\infty \exp \left[-\int_0^t \sigma(z)dz\right] U[C(t), S(t), E(t)]dt; \quad \sigma(t) > 0. \quad (10)$$

³ As an example of the difference, if the sustainability goal is non-declining utility, then achieving maximum constant utility will be efficient, but may not be optimal.
Combined Analysis of Environmental and Sustainability Policies: The Set of Optimal Sustainability Policies

Using Takayama’s result, the resulting optimal sustainable path satisfies first-order conditions identical to those for the socially optimal path, except that \( \sigma(t) \) replaces \( \rho(t) \). Hence, we can analyse both policies together by comparing the socially optimal \( W^\sigma \)-maximisation path, still derived from (7), with the privately optimal path with policy intervention. The Hamiltonian for the latter is denoted \( \tilde{H} \), and formed from the private utility function (8) and accounting relationships (9), with \( \tilde{\Psi}^K \) and \( \tilde{\Psi}^S \) as the new co-state variables, with the individual discount rate \( \rho(t) \) taken as understood:

\[
\tilde{H} = U(C, \tilde{S}, \tilde{E}(R,a)) + \tilde{\Psi}^K[F(K, R, \tilde{E}(R,a)) - C - a] \\
- \tilde{\Psi}^K[\tau^C C + \tau^a a + \tau^R R + \tau^S S + \tau^E E(R,a) - \Omega] + \tilde{\Psi}^S[G(\tilde{S}) - R]. \tag{11}
\]

Formulas for policy instruments \( \tau^C \), \( \tau^R \), \( \tau^S \) and \( \tau^E \) arise from comparing the first-order conditions of the two optimal paths. (To consider environmental policy alone, we simply set \( \sigma(t) \) equal to the individual discount rate \( \rho(t) \) when manipulating the Hamiltonian \( H \) for the socially optimal solution.) It can be shown (see the Appendix) that the obvious, sufficient (but not necessary) optimal sustainability policy at any time is then the combination, with all quantities measured on the optimal sustainable (\( W^\sigma \)-maximising) path, of:

Environmental policies

\[
\tau^E = -1/E_a = -(U_E/U_C + F_E) > 0 \tag{12}
\]

\[
\tau^a = 0 \tag{13}
\]

\[
-\tau^S = U_S/U_C + (F_R - \tau^E E_R)G_S \\
= U_S/U_C + [F_R + (U_E/U_C + F_E)E_R]G_S > 0 \tag{14}
\]

\[
\tau^R = 0 \tag{15}
\]

Sustainability policy

\[
-\tau^C/(1 + \tau^C) = \rho - \sigma. \tag{16}
\]

The intuition behind the environmental policies is simple. Tax \( \tau^E \) internalises the external costs of emissions, measured in consumption units:
\(-U_E/U_C\), the amenity cost, and \(-F_E\), the productivity cost. Subsidy \(-\tau^S\) internalises the consumption-valued, external benefits of the resource stock: \(U_S/U_C\), the amenity benefit, and \(G_S(F_R - \tau^E E_R)\), the benefit from faster resource growth, valued at price minus user cost. Neither an abatement subsidy \(\tau^a\) nor a resource tax \(\tau^R\) are required. On the basis of this example, “internalise all externalities at their source” is a useful general rule for dynamic environmental policy. On a more practical note, the \(U_E/U_C\) and \(U_S/U_C\) terms in (12) and (14) would typically be measured in dollars per tonne of emissions or resource stock. Data on them would have to come from the same, difficult, non-market valuation exercises needed for other methods of resource accounting and sustainability measurement. The non-measurability of the separate partial derivatives of utility here does not add extra difficulty to these exercises, contrary to a claim in Pearce et al. (1989, p. 49, n. 3).

The sustainability policy (16) would change an individual’s effective utility discount rate from \(\rho\) to \(\sigma\), and would “almost” be a way of achieving Becker’s direct manipulation of this rate. The intuition can readily be seen whenever discount rate \(\sigma\) is strictly less than \(\rho\), thereby expressing stronger concern for future generations. \(\tau^C(t)\) would then be a falling consumption tax or rising consumption subsidy, which provides an incentive to delay consumption and bring forward productive investment.

As noted earlier, sustainability policy instruments other than a consumption tax are available, though all instruments act to influence the consumption–investment decision towards less consumption and more investment in the early stages of development. In the Appendix we show that if a capital tax \(\tau^K\) as well as a consumption tax \(\tau^C\) were to be used, (16) would be replaced by

\[
-\tau^C/(1 + \tau^C) - \tau^K = \rho - \sigma. \tag{17}
\]

If an investment tax \(\tau^I\) were then used instead of the consumption tax, substituting \(C = F - (1 + \tau^I) I - \tau^K K - \tau^a a - \tau^R R - \tau^E E - \tau^S S + \Omega\) throughout and using investment \(I\) as a control variable can likewise be shown to give

\[
(\tau^I - \tau^I F_K - \tau^K)/(1 + \tau^I) = \rho - \sigma. \tag{18}
\]

The Interaction of Environmental and Sustainability Policies

The environmental policies and sustainability policy above belong to the same dynamic general equilibrium, and must therefore interact. The levels of emission tax (12) and resource subsidy (14), that maximise present value in the presence of the sustainability policy (16) required whenever \(\rho - \sigma > 0\), generally differ from the levels that are optimal when \(\rho - \sigma = 0\), and thus no

sustainability policy is required. This echoes Howarth and Norgaard’s (1992) result, found in an overlapping-generations context, that environmental valuations (here the sizes of $\tau^E$ and $-\tau^S$) depend on society’s view of intergenerational equity (here the size of $\rho - \sigma$).

There will also be an interaction in the other direction, in the sense that whether or not environmental policy is actually implemented will affect the strength of sustainability policy required to reach a goal defined in terms of utility change. However, we would then need to compare efficient sustainability policy with inefficient sustainability policy, and the above results do not apply to the latter. It is only in simple cases with specific functional forms (as illustrated next) that we can be clear about the sign and size of interactions.

IV. An Example of the Interaction of Sustainability and Environmental Policies

We now turn to an explicit example of an economy where (asymptotic) sustainability and environmental policies are not only distinct in both form and strength, but also interact. The economy is a variant of Stiglitz (1974); it is closed, with a known, non-renewable resource, it has no emissions, and just one externality, from the presence with power $\chi$ of the resource stock in a Cobb–Douglas production function, which also has exogenous technical progress at rate $v$ (the last two features were absent from the simple model in the first part of Section III). This may be written as:

$$F(K, R, S, t) = K^\alpha R^\gamma S^\chi e^{vt} = C + \dot{K}; \ 0 < \alpha, \gamma, \chi < 1; \ \alpha + \gamma + \chi \leq 1; \ v > 0. \quad (19)$$

Utility is isoelastic and purely materialistic:

$$U(C) = C^{1-\eta}, \ 0 < \eta < 1. \quad (20)$$

The utility discount rate $\rho$ is a positive constant. To ensure, respectively, that the present value integral converges and that socially optimal utility declines asymptotically (so that sustainability is not an automatic side-effect of implementing environmental policy), we assume

$$(1 - \alpha)\rho > (1 - \eta)v \quad \text{and} \quad \rho^\gamma > v. \quad (21)$$

Asymptotic growth rates are denoted as $g_X = \lim_{t \to \infty} \dot{X}/X$ for any variable $X$. Since the resource is non-renewable, $S = -R$, hence $g_S = g_R < 0$ and $R = g_RS$. Three asymptotic, balanced growth paths can be computed for this economy: the socially optimal path, the privately optimal path with sustain-
ability policy only, and the privately optimal path with both sustainability and environmental policies. In terms of this comparison, we cannot define sustainability as effectively moving to a “sustainability discount rate” $\sigma$ as in Section III, since this applies only if sustainability is achieved efficiently, which will not happen with the inefficient, sustainability-only policy. The sustainability goal is therefore defined as constant utility ($g_C = 0$). Consumption growth rates $g_C$ on the three paths are then (see the Appendix):

**Socially optimal path**

$$g_C = (v - \rho \gamma)/(1 - \alpha - (1 - \eta)\gamma) \quad (< 0 \text{ from } (21))$$

(22)

**Privately optimal path with sustainability policy ($\tau^C$) only**

$$g_C = [v - (\rho + \tau^C/(1 + \tau^C))(\gamma + \chi)]/[1 - \alpha - (1 - \eta)(\gamma + \chi)]$$

(23)

**Privately optimal path with sustainability policy ($\tau^C$) and environmental policy ($-\tau^S$)**

$$g_C = [v - (\rho + \tau^C/(1 + \tau^C))\gamma]/[1 - \alpha - (1 - \eta)\gamma].$$

(24)

The required strength of sustainability policy (i.e., to make $g_C = 0$) is less if environmental policy is already in place: $-\tau^C/(1 + \tau^C) = \rho - v/\gamma$ from (24), instead of the larger $-\tau^C/(1 + \tau^C) = \rho - v/(\gamma + \chi)$ from (23). Here, environmental policy makes sustainability policy easier. The amount of the difference made by environmental policy is related to $\chi$, the strength of the stock externality in the production function.

Unfortunately, it is difficult to assess analytically the consequences for environmental policy of aiming at a stronger sustainability goal. Intuitively, this might be expected to cause an increase in the required strength of environmental policy, as found numerically by Howarth and Norgaard (1992), but proving analytically when this happens remains for further work.

**V. Two More Specialised Economies**

*The Powerlessness of Resource Incentives Alone to Prevent Falling Utility*

In a special case of the basic economy in Section III, where the resource is non-renewable, production depends only on capital and resource flow, the

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4 In all three cases, it is not possible to tell whether utility rises or falls in the (potentially long) period before development approaches the asymptotic, balanced growth path.
discount rate $\rho$ is constant and emissions have no amenity effect, a fairly striking result can be shown. Resource depletion and stock incentives ($\tau^R(t)$ and $\tau^E(t)$) are then powerless on their own to prevent unsustainability in the form of asymptotically falling utility. The only way to prevent this would be to use an instrument affecting the consumption–investment choice, such as the consumption tax in (16), with $\tau^C$ ultimately becoming a 100% subsidy ($\lim_{t \to \infty} \tau^C = -1$). However, this result cannot be proved without a strong—if intuitive—assumption on endogenous variables: that whatever policy instruments are used, $\rho$ exceeds $\lim_{K \to \infty} F_K$, the asymptotic, privately optimal return on capital; see Pezzey (2002).

A straightforward special case of the result is worth noting, however. It can be shown that a tax/subsidy path $\tau^C(t) = [1 + ((1/\alpha) - 1)C/K_0]^{1/(1-\alpha)}e^{-\rho t} - 1$, where $\tau^C \to -1$ as $t \to \infty$, converts the single-peaked, present-value-maximising path of the economy with discount rate $\rho$, $U(C) = C^{1-\alpha}/(1 - \alpha)$ and $F(K, R) = K^\alpha R^{1-\alpha} = \dot{K} + C$, found in Pezzey and Withagen (1998, p. 524), into the maximum constant consumption path, $C(t) = \dot{C} := \alpha\{K_0^{2\alpha-1} [(2\alpha - 1)S_0]^{1-\alpha}\}^{1/\alpha}$ for all $t$, found in Solow (1974), which of course satisfies Hartwick’s rule. This illustrates that, under constant discounting, policy intervention is generally required to achieve a path which satisfies Hartwick’s rule, contrary to the impression given by Solow (1986, p. 147).

The Separation of Production and Resource Management from Sustainability Policy in a Small, Open Economy with No Amenity

We now consider a variant of our basic model in Section III with a small, open economy with no amenity effects ($U_E = U_S = 0$), leaving $F_E < 0$ as the only environmental effect. (One could also have a stock externality on production, $F_S > 0$, and still reach the result below; the crucial condition is for consumption to be the sole determinant of utility.) The resource input to domestic production and emissions is no longer total resource extraction $R$, but $R^d := R - R^x$, where $R^x$ is net resource exports. To account for net imports $M$ of the consumption–investment good, instead of (4) we now have

$$F[K, R^d, E(R^d, a)] + M = C + \dot{K} + a. \tag{25}$$

The economy has a stock $K^f$ of foreign capital (possibly negative, i.e., debt) which earns a return at the world interest rate $r$, while its net resource exports $R^x$ are sold at world prices $Q^x$. Since the economy is small, both $r$ and $Q^x$ are exogenous, but may vary over time. Foreign capital grows as:

$$\dot{K}^f = rK^f + Q^x R^x - M; \quad K^f(0) = K^f_0, \text{ given}. \tag{26}$$
Extra control variables are now $M, R^d$ and $R^x$ instead of $R$. The Hamiltonian for the optimal sustainable economy thus changes from (7) to:

$$H = U(C) + \Psi^K[F(K, R^d, E(R^d, a)) + M - C - a] + \Psi^f(rK^f + Q^xR^x - M) + \Psi^S[G(S) - R^d - R^x].$$  \hspace{1cm} (27)

The result we seek can be obtained without even considering the intervention policies which would make the privately optimal path follow the optimal sustainable path. The first-order conditions determining the optimal sustainable path are (see the Appendix):

$$1/E_a(R^d, a) = F_E(K, R^d, a)$$  \hspace{1cm} (28)

$$Q^x = F_R(K, R^d, a) + F_E(K, R^d, a)E_R(R^d, a)$$  \hspace{1cm} (29)

$$r = F_K(K, R^d, a)$$  \hspace{1cm} (30)

$$r - G_S(S) = \dot{Q^x}/Q^x$$  \hspace{1cm} (31)

$$r = \sigma - \dot{U}_C(C)/U_C(C).$$  \hspace{1cm} (32)

This economy can thus be separated into two parts. The world interest rate $r$ and resource price $Q^x$ are exogenous, so the four variables $K, R^d, S$ and $a$ are in principle fully determined by the four equations (28)–(31), as are then production $F(\cdot)$, emissions $E(\cdot)$ and resource exports $R^x(\cdot)$. Thus the open economy’s production and resource management decisions are entirely unaffected by any goal of sustainability policy, as represented by the sustainability discount rate $\sigma$ in (32). $\sigma$ affects consumption $C$, which then also affects the economy’s net imports $M$ (via (25)) and its foreign capital $K^f$ (via (26)), but nothing else. For completeness, it can also be shown that, as in the fourth part of Section III, the only independent policy instruments worth considering are an emissions tax $\tau^E$, a resource stock subsidy $-\tau^S$ and a consumption tax $\tau^C$, which are then respectively determined by (12), (14) and (16), but with $U_E = U_S = 0$; see Pezzey (2002, App. 7).

The importance of this separation result can be seen by supposing that a small, open economy, with no sustainability policy but a full environmental policy, follows a socially optimal path where its natural resources are eventually completely depleted, and where development is unsustainable.

Implementing a sustainability policy will then make no difference at all to how resources and production are managed in this economy! The only result of the sustainability policy will be less consumption and more saving, with all the saving invested in foreign capital. This is essentially a version of Fisher’s (1930/1954, p. 271) “separation theorem”, where the separation of consumption and saving decisions from depletion and production decisions follows from the exogeneity of the interest rate and resource prices.

This scenario, where sustainability is achieved, despite the fact that domestic resources are stripped, by investing the stripping proceeds abroad, would contradict the claim that preventing unsustainability requires resource policies. This claim, based on assumed non-substitutability of human-made capital for natural resources, and promoted by Pearce (1988), Daly (1990) and many other subsequent authors as one of the cardinal rules of sustainability, is that domestic natural resources must be conserved in some way. However, our theoretical refutation of this, and derivation of what could in some cases be a “strip resources and invest abroad” policy, is not intended as a recommendation in practice. Such a policy would be optimal only in the highly unlikely event that neither resources nor emissions have any direct amenity value; that capital will always be substitutable for resources in domestic production; that all this is known with certainty; and that few other countries plan to adopt the same policy, so that no fallacy of composition occurs. If all countries adhered to the policy, there would obviously be no “abroad” left to conserve natural resources and accept incoming investments. A similar point is made by Brekke (1997, p. 62) and, with a two-period model, by Pezzey (1998).

VI. Conclusions

We have shown that environmental policy and sustainability policy are theoretically quite distinct. They not only have different goals, but also different instruments to achieve them. Environmental policy reflects a dynamic, governmental intervention to maximise social present value, by internalising the social values of “environmental” stocks and flows that agents ignore (externalise) when they privately maximise present value. Sufficient instruments for achieving this are first-best incentives (taxes or subsidies, with costs or revenues neutralised by lump-sum transfers) applied directly to the sources of externalities, and equal to their environmental values in equilibrium. Incentives applied to intermediate variables, such as taxes on resource depletion, or subsidies for emissions abatement, are theoretically redundant. It can also be shown that these conclusions are unaffected by extensions including cumulative pollutants, resource discovery and extraction costs, trade in goods and resources, and exogenous technical progress.
By contrast, sustainability policy aims to achieve some social improvement in intergenerational equity, such as making utility forever constant, non-declining or sustainable. If sustainability policy is combined with environmental policy, we call the result an optimal sustainability policy. Since the resulting economy is efficient, the sustainability policy component can always be represented as a shift from the representative agent’s individual utility discount rate to some other, probably lower, “sustainability discount rate” path. If, however, sustainability policy acts on its own, it will be inefficient in an economy with externalities, and cannot be represented in this way. For both efficient and inefficient cases, given the absence of explicit intergenerational transfers or directly manipulable interest rates in our model, the sustainability policy instrument represents an incentive such as a falling consumption tax, or a capital or investment subsidy, that affects the consumption–investment split over time. We illustrated this with more specialised examples, notably one where a small economy, acting in isolation, can achieve sustainable development while stripping its domestic natural resources down to zero, as long as its consumption is restrained and enough is invested in foreign capital stocks.

These results do not suggest that in a more realistic policy context, sustainability and environmental policies can or should be considered in separate, watertight compartments. The analysis is not complete: many important topics have been ignored, and remain for further work. Above all, it would be necessary to deal with the profound uncertainty about the limits to the substitutability of human-made capital for environmental resources. However, our analysis suggests adding a rather different focus than that found in most of the neoclassical economic literature on sustainability, which has thus far stressed definition, justification and measurement. The focus is also different from most of the relevant ecological economic literature, which has almost always assumed that limits to capital-resource substitutability are imminent, and has thus stressed protection of environmental resources. To be complete, sustainability analysis should also pay attention to policy intervention that will encourage adequate saving and investment.

Appendix

Optimal Sustainability Policy

An efficient and sustainable path. From the Hamiltonian (7), an interior solution in which \( C, a \) and \( R \) are chosen to maximise “sustainable” welfare \( W^*(0) \) in (10) subject to (2)–(5) will satisfy the first-order conditions:

\[
\Psi^K = U_C,
\]
\[ (U_E/U_C + F_E)E_a = 1, \]  
\[ (A1) \]

\[ \Psi^S = U_C[F_R + (U_E/U_C + F_E)E_R] =: U_C[F_R - \tilde{\lambda}], \text{say}, \]  
\[ (A2) \]

\[ \dot{U}_C/U_C = \sigma - F_K \text{ and } \dot{\Psi}^S/\Psi^S = \sigma - G_S - U_S/\Psi^S. \]  
\[ (A3) \]

Using (A2) this gives

\[ \dot{U}_C/U_C + (\dot{F}_R - \dot{\lambda})/(F_R - \lambda) = \sigma - G_S - (U_S/U_C)/(F_R - \lambda), \]  
\[ (A4) \]

\[ \Rightarrow (\dot{F}_R - \dot{\lambda})/(F_R - \lambda) = F_K - G_S - (U_S/U_C)/(F_R - \lambda), \]  
\[ (A5) \]

which is the form of Hotelling’s rule for this economy.

The privately optimal path with policy intervention. From the Hamiltonian (11), the first-order conditions are:

\[ \dot{\Psi}^K = U_C/(1 + \tau^C) \]

\[ \tau^a + \tau^E E_a = -1 \]  
\[ (A6) \]

\[ \tilde{\Psi}^S = \dot{\Psi}^K(F_R - \tau^R - \tau^E E_R) =: [U_C/(1 + \tau^C)](F_R - \tilde{\lambda}), \text{say}, \]  
\[ (A7) \]

\[ \dot{U}_C/U_C - \tau^C/(1 + \tau^C) = \rho - F_K \text{ and } \dot{\tilde{\Psi}}^S/\tilde{\Psi}^S = \rho + \tau^S/\hat{\Psi}^S. \]  
\[ (A8) \]

Using (A7) this gives

\[ \dot{U}_C/U_C - \tau^C/(1 + \tau^C) + (\dot{F}_R - \dot{\lambda})/(F_R - \lambda) = \rho + \tau^S/(F_R - \lambda), \]  
\[ (A9) \]

\[ \Rightarrow (\dot{F}_R - \dot{\lambda} - \tau^S)/(F_R - \lambda) = F_K. \]  
\[ (A10) \]

This is another form of Hotelling’s rule.

Environmental and sustainability policies combined. We now calculate the policy interventions that will indeed make the above two paths identical as assumed. Consider first the abatement tax \( \tau^a \). It is reasonable to assume there must be an emissions tax
(τ_E \neq 0), because otherwise the Hamiltonian (11) is a linear function of \(a\), and thus does not give an interior solution for \(a\). So while an abatement spending tax could be part of the policy solution, it cannot fully substitute for an emissions tax. If (A1) and (A6) are to represent the same path of development, then the obvious sufficient (but not necessary) instruments required are then

\[
\tau^E = -(U_E/U_C + F_E) = \lambda/E_R \text{ from (A2), which is (12),}
\]

and

\[
\tau^a = 0. \quad \text{which is (13).}
\]

Similarly, comparing the first equations in (A3) and (A8) requires

\[
-\tau^C/(1 + \tau^C) = \rho - \sigma. \quad \text{which is (16).}
\]

Comparing (A9) and (A4) requires:

\[
-\tau^C/(1 + \tau^C) + (\dot{F}_R - \dot{\lambda})/(F_R - \lambda) - (\dot{F}_R - \dot{\lambda})/(F_R - \lambda) = \rho - \sigma + \tau^S/(F_R - \lambda) + G_S + (U_S/U_C)/(F_R - \lambda), \quad \text{which with (16)}
\]

\[
\Rightarrow (\dot{F}_R - \dot{\lambda})/(F_R - \lambda) - (\dot{F}_R - \dot{\lambda})/(F_R - \lambda) - \tau^S/(F_R - \lambda)
\]

\[
= [(U_S/U_C) + (F_R - \lambda)G_S]/(F_R - \lambda).
\]

The obvious sufficient (though not necessary) solution is if \(\lambda = \tilde{\lambda} = \tau^R + \lambda\) (from (A7) and (12)), in which case

\[
\tau^R = 0, \quad \text{which is (15),}
\]

and

\[
-\tau^S = U_S/U_C + (F_R - \lambda)G_S
\]

\[
= U_S/U_C + [F_R + (U_E/U_C + F_E)E_R]G_S \quad \text{which is (14).}
\]

**Formulae for Capital or Investment Tax instead of Consumption Tax**

Next we explain claims about the relationship among \(\tau^K\), \(\tau^I\) and \(\tau^C\) made in the fourth part of Section III. With a capital tax \(\tau^K\) added to the set of policy instruments, the Hamiltonian for the privately optimal path with policy intervention becomes:

\[
H = U(C, \tilde{S}, \tilde{E}(R,a)) + \tilde{\Psi}^K[F(K, R, \tilde{E}(R,a)) - C - a]
\]

\[
- \tilde{\Psi}^K[\tau^C C + \tau^K K + \tau^a a + \tau^R R + \tau^S S + \tau^E E(R,a) - \Omega] + \tilde{\Psi}^S[G(\tilde{S}) - R].
\]

Equations (A8) and (16) are then replaced by

$$\dot{U}_C/U_C - \dot{\tau}^C/(1 + \tau^C) = \rho - F_K + \tau^K \text{ and } -\dot{\tau}^C/(1 + \tau^C) - \tau^K = \rho - \sigma,$$

(A11)

so a capital subsidy $-\tau^K = \rho - \sigma$ can in theory substitute perfectly for a falling consumption tax $-\dot{\tau}^C/(1 + \tau^C) = \rho - \sigma$ as an instrument of sustainability policy.

To explain the replacement of a consumption tax $-\dot{\tau}^C$ by an investment tax $\dot{\tau}^I$, it is simplest to change from consumption $C$ to investment $I$ as a control variable. The individual then perceives a production split

$$F(K, R, E(R, a)) = C + I + a + \tau^I I + \tau^K K + \tau^a a + \tau^R R + \tau^S S + \tau^E E(R, a) - \Omega,$$

(A12)

so the Hamiltonian $\tilde{H}$ for the policy intervention economy is then

$$U[F(K, R, E(R, a)) - (1 + \tau^I)I - a - \tau^K K - \tau^a a - \tau^R R - \tau^S S - \tau^E E(R, a) + \Omega, \tilde{S}, \tilde{E}(R, a)] + \tilde{\Psi}K + \Psi^S \tilde{G}(\tilde{S}) - R].$$

Two first-order conditions are then

$$\tilde{\Psi}K = (1 + \tau^I)U_C \text{ and } \tilde{\Psi}K = \rho - (F_K - \tau^K)U_C/\tilde{\Psi}K$$

$$\Rightarrow \dot{U}_C/U_C + \dot{\tau}^I/(1 + \tau^I) = \rho - (F_K - \tau^K)/(1 + \tau^I).$$

(A13)

Comparing (A13) and (30) gives

$$\dot{U}_C/U_C = \sigma - F_K = \rho - (F_K - \tau^K)/(1 + \tau^I) - \tau^I/(1 + \tau^I), \text{ and hence (17).}$$

Three Paths

From (19), production, capital and consumption all grow at the same asymptotic rate:

$$g_F = \alpha g_K + (\gamma + \chi)g_R + \nu = g_C = g_K \Rightarrow (1 - \alpha)g_C = (\gamma + \chi)g_R + \nu$$

(A14)

The socially optimal path. We have the following:

$$\text{(A3), (20) } \Rightarrow -\eta g_C = \rho - F_K,$$

(A15)
(A5) with \( \lambda = G_S = U_S = 0 \), but with an extra term \( -F_S/F_R \) on the RHS,

\[
\begin{align*}
\frac{d}{dt}(\gamma F/R) &= \gamma F/R = \frac{F_K - F_S/F_R}{(A16)} \\
g_C - g_R &= F_K - (\chi F/S)/(\gamma F/R) \\
\Rightarrow g_C &= F_K + (1 + \chi/\gamma)g_R. \quad (A17)
\end{align*}
\]

Equations (A15), (A17) and (A14)

\[
\Rightarrow (1 - \eta)g_C = \rho + (1 + \chi/\gamma)g_R = \rho + [(1 - \alpha)g_C - \nu]/\gamma \\
\Rightarrow g_C = [(\nu - \rho\gamma)/(1 - \alpha - (1 - \eta)) < 0 \text{ from (21)} (22)
\]

The privately optimal path with sustainability policy \((\tau^C)\) only. Equations (A14) and (A15) still hold, while \( F_S = \chi F/S \) is ignored, so (A17) becomes

\[
g_C = F_K + g_R \quad (A18)
\]

\[
(A8), (20) \Rightarrow -\eta g_C - \tau^C/(1 + \tau^C) = \rho - F_K. \quad (A19)
\]

Equations (A18), (A19) and (A14)

\[
\Rightarrow (1 - \eta)g_C - \tau^C/(1 + \tau^C) = \rho + [(1 - \alpha)g_C - \nu]/(\gamma + \chi) \\
\Rightarrow g_C = [(\nu - (\rho + \tau^C/(1 + \tau^C))(\gamma + \chi)]/[1 - \alpha - (1 - \eta)(\gamma + \chi)]. \quad (23)
\]

The privately optimal path with sustainability policy \((\tau^C)\) and environmental policy \((-\tau^S)\). From (A10) with \( \tilde{\lambda} = 0 \), and (A16), the environmental policy is a resource stock subsidy \(-\tau^S = F_S = \chi F/S \) (not constant), which causes (A17) to be reinstated, while (A19) still holds. So (A14), (A17) and (A19)

\[
\Rightarrow (1 - \eta)g_C - \tau^C/(1 + \tau^C) = \rho + [(1 - \alpha)g_C - \nu]/\gamma \\
\Rightarrow g_C = [(\nu - (\rho + \tau^C/(1 + \tau^C))(\gamma + \chi)]/[1 - \alpha - (1 - \eta)(\gamma + \chi)]. \quad (24)
\]

The Optimal Sustainable Path in a Small, Open Economy

From the Hamiltonian (27), the first-order conditions are

\[
\Psi^K = U_C,
\]

\[ 1/E_d(R^d, a) = F_E(K, R^d, a) \] which is (28),

\[ \Psi^S = U_C(F_R + F_E E_R), \]

\[ \Psi^I = \Psi^K, \]

\[ \Psi^S = U_C Q^x, \quad (A20) \]

\[ Q^x = F_R(K, R^d, a) + F_E(K, R^d, a)E_R(R^d, a) \] which is (29),

\[ \dot{U}_C/U_C = \sigma - F_K, \]

\[ r = F_K(K, R^d, a) = \sigma - \dot{U}_C(C)/U_C(C) \] which are (30) and (32), and

\[ \sigma - G_S = \dot{\Psi}^S/\Psi^S = \dot{U}_C/U_C + \dot{Q}^x/Q^x. \]

Use (A20), (32)

\[ \Rightarrow r - G_S(S) = \dot{Q}^x/Q^x \] which is (31).


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