POLLUTION CHARGES AND INCENTIVES

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Most investigations of the consequences of environmental policies and Pigouvian taxes (pollution charges, in particular carbon taxes) using CGE models reveal an only modest impact on economic activity; some report even a positive economic side effects. Yet the slowdown in economic growth and in particular of productivity, see Conrad and Wastl (1995), suggest a stronger (negative) influence in particular if one accounts for the fortunately very low energy prices that accompanied the ambitious goals of environmental policies in the late eighties and nineties. This paper attempts to explain this apparent difference. In particular it will be shown that environmental policies, here investigated for pollution charges, call for a modification of incentives such that the power of optimal incentives is reduced to which the workers respond with less effort. This friction, which may add up to significant numbers for the economy at large, is neglected in both the theoretical literature and in the application of CGE-models. Accounting for this friction and the empirical evidence so far suggests to take the optimistic findings concerning the consequences of environmental policies on economic growth at least *cum grane salis*.

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Prologue

I am pleased to attend this workshop at the occasion of Professor Claus Conrad's birthday. I congratulate the organizers to have chosen a scientific event. Everybody who has met Professor Conrad at academic conferences, actually the only place where I have seen him, can confirm his energy, interest and temperament that defy his age and his ongoing enthusiasm for topical economic problems dwarfs that of many young researchers.

I wanted to address a topic on which Professor Conrad has worked too, and since Professor Conrad has made contributions to so many fields, there were various possibilities, e.g. with respect to energy conservation. I have chosen an issue where his empirical work changed my mind about the potential consequences of environmental policies.

1. Introduction

The economic consequences of environmental policies can be ranked in the following way:

- Environmental policies, in particular standards and taxes, need not harm the economy but may be actually beneficial. This creation of a win-win situation has been espoused most prominently by Michael Porter, e.g. in Porter and van der Linde. Lovins (1995a, 1995b), Lovins und Hawken (1999) argue that improving resource efficiency can be profitable; Lovins (1985) promised already gigabucks profits for energy conservation programs in the late seventies and through the eighties and nineties. This optimism is obviously supported by Greens, but more surprising, also by other politicians such as e.g. the former US-Vice-president Al Gore (1993), and even by some entrepreneurs, e.g. Schmidheiny (1992). This optimistic point of view is to some extent even shared by some economic institutions - the WIFO in Austria, Köppl-Kratena-Pichl-Schebeck-Schleicher-Wüger (1995), and the DIW in Germany that promise positive economic (not only environmental) consequences at least on unemployment in case of a 'green tax reform. This relates to the claim that environmental taxes, in particular energy taxes, allow for a second dividend. That is, environmental taxes do not only reduce emissions, but also improve the efficiency of the tax system by lowering the tax burden. In short, 'How to make lots of money and save the planet too', *The Economist*, June 3rd, 1995, 65 – 66.

- However contrary to the above expressed enthusiasm, a number of theoretical papers, starting with the seminal contribution of Bovenberg and DeMoij (1994), prove that environmental policies - even in its most market conform way of a pollution (or 'energy', 'carbon') tax - cannot raise output in an optimal second best setting. That is, the so-called double dividend hypothesis is, unfortunately, infeasible.

- This theoretical result derived in Bovenberg and DeMoij (1994) complies with applied general equilibrium models, yet these tend to report that the consequences of past environmental policies are rather modest, for example Wirl (1989for Austria, Wirl and Hoffmann (1993) for the FRG. A similar result holds in general equilibrium models quantifying the consequences of much debated carbon taxes, for example, Conrad and Schröder (1988) and Welsch and Hoster (1994) calculate that the impact of a German CO2 tax would be small on economic activity.

- Yet a number of purely empirical papers report a larger decline in economic growth and in particular in economic activity than the general equilibrium models suggest. Early examples for the United States are Gollob-Roberts (1983) and Färe-Grosskopf-Pasurka (1986) for power plants and Gray (1987) for the aggregate economy; these studies find that environmental regulation contributed significantly to the slow down of productivity growth. Conrad-Wastl (1995), of which the major results are re-produced in Fig.1, considers the more recent and German experience. This figure highlights the decline in total factor productivity for most sectors during 1986-1991, the period characterized by a much tougher environmental regulation. This observation contradicts strongly the claim of win-win, second dividends and alike and cautions the optimism associated with the results of general equilibrium models.

The purpose of this paper is to reconcile the divergence between general equilibrium models' results and observed declines in growths and/or productivity. The general equilibrium analysis reduces the analysis to a rather technical re-optimisation of the demand and input mix. Yet this assumption of a rather frictionless re-organisation of production processes ignores a crucial aspect: Controlling environmental inputs (or respectively, negative outputs like emissions, sewage, waste, etc.) complicates production management and thereby weakens incentives. This friction due to a weakening of incentives associated with environmental policies is of course ignored in the general equilibrium models and in related approaches but apparently shows up in the empirical data. The weakening of incentives is due to the fact that environmental concerns add additional tasks that result in less 'powerful' incentives. Section 2 introduces a principal-agent model assuming that environmental regulation is specified in its most economic form as a pollution charge. Section 3 considers different scenarios: no pollution charge, a pollution charge when pollution cannot be monitored at the level of each worker (but only for the entire firm), finally, both tasks, production and pollution, can be monitored by the management, the principal. Section 4 compares and discusses the results.

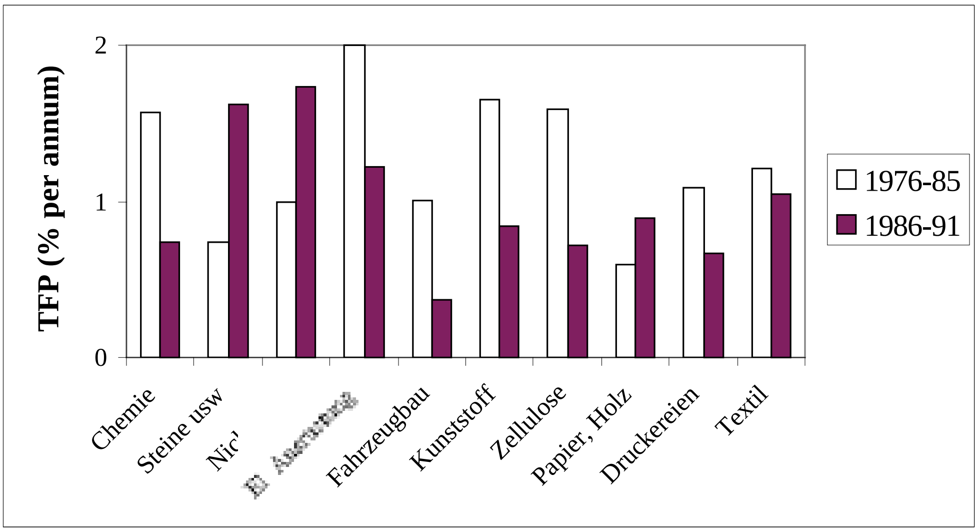

Fig. 1: Improvements of Total Factor Productivity (TFP) in Germany based on tables in Conrad-Wastl (1995).

2. The Model

The environmental policy consists of a linear pollution tax, τ, per unit pollution p. This in turn requires that the managers of firms and production units, the principals in our principal-agent framework, must account for an additional and so far ignored output of their production unit or entire firm The managers, interested in maximizing the firm's expected profit, entrust production to a team or group of workers. They offer the workers corresponding incentives to mitigate the agency relation resulting from private information that the agents possess about their individual productivity (hidden information) and efforts (hidden action) that cause disutility of labour.

Environmental concerns, in particular pollution charges, add a new dimension to the production process. It is assumed that pollution is observable at the level of the firm, because otherwise the instrument of a pollution tax is not implementable at all. However, two different assumptions are made with respect to the observability of pollution at the level of each worker:

- Pollution released by each individual worker cannot be monitored or is not monitored due to too high monitoring costs. This is a realistic assumption, at least in short and medium term. Indeed many firms do not measure pollution, the level of sewage, waste and alike, produced by a particular worker or at a particular location. However this information is of course observable at the level of the firm, since corresponding charges have to be paid. In this case, the agent has to carry out two tasks – producing and taking care of pollution – of which only one, production, is observable and can thus be a part of the incentive schemes. As a consequence, the environmental task must be indirectly addressed in way already raised in a different context in Holmström and Milgrom (1991).

- Pollution by each worker can be monitored (at zero variable costs). This set up transgresses the multi-tasking framework of Holmström and Milgrom (1991) because each task, producing and polluting, is observable and can be rewarded.

Given this straightforward set up, it is quite surprising that such managerial aspects and related frictions due to environmental policies are neglected in the corresponding literature and also in the policy analysis. Indeed, investigations of aspects of monitoring are restricted to regulatory issues, e.g. see the survey of Jaffe, Peterson and Portnoy (1995).

2.1 Agents – 'Workers'

The workers exercise the effort e that causes to them disutility $D(e, t)$. This disutility is increasing and convex in effort, $D_e \geq 0$ and $D_{ee} > 0$, and depends on the workers efficiency (or as it turns out, productivity). The individual productivity is the worker's private information, where t denotes the productivity type of a worker. More productive workers, the types with a larger t, face less disutility, $D_t < 0$, which holds also at the margin, $D_{et} < 0$. All following results apply also if t refers either directly to productivity or different circumstances that otherwise identical workers face. Hence, the assumption of 't' as a disutility parameter is not crucial. Indeed, we refer to the t as a productivity parameter, whether it is given by a worker's individual traits or by circumstances. Effort e can be devoted to production, q, and a, called abatement effort, that affects individual pollution either by taking care, prevention or literal abatement.

$$e = q + a. \qquad (1)$$

For simplicity assume that effort is measured in terms of output so that the output of individual worker is given by his efforts:

$$x = q. \tag{2}$$

The amount of pollution generated by a worker depends on output and abatement effort

$$p = P(x, a). \tag{3}$$

This function P is increasing and convex in output, $P_x \geq 0$, $P_{xx} \geq 0$, and declining and convex (to reflect the law of diminishing returns) in abatement efforts: $P_a < 0$, $P_{aa} > 0$. This assumption implies that prescribing output x and pollution p allows to infer the individual efforts q and a, because the determinant of the Jacobian of (2) and (3) equals $P_x > 0$ and is thus different from zero.

This invertibility between the outputs (x, p) and the efforts (q, a), i.e., $q = x$ and $a = A(x, p)$ so that $e = x + A(x, p)$, determines the worker's disutility associated with both task requirements, which is denoted by

$$\delta = \begin{cases} \delta(x, p, t) = D(x + A(x, p), t) & \text{for } a > 0. \\ \delta(x, t) = D(x, t) & \text{for } a = 0. \end{cases} \tag{4}$$

For the following, only the specification of δ is relevant and all underlying description that result in the same δ are equivalent. This is the reason, why attaching the private information parameter either to disutility, ability or circumstances, is irrelevant.

In order to differentiate between these two different assumptions about the information available to the principal, I use D in the case that pollution is not observable, and δ if pollution is observable. This reduction of δ to D applies to the benchmark - no pollution taxes - and to multi-tasking, when p is not monitored at the level of agent. The reason is that linking the wage w to output, the agent, sets $a = 0$, since individual abatement is costly to the agent but cannot be rewarded. The assumptions about the agent's implicit disutility δ, some of them already mentioned, are summarized below.

Assumptions: The (implied) disutility δ has the following properties:

$\delta_x > 0$, $\delta_{xx} > 0$, $\delta_t < 0$, $\delta_{xt} < 0$, $\delta_{xtt} \geq 0$, $\delta_{xxt} \leq 0$

$\delta_p < 0$, $\delta_{pp} > 0$, $\delta_{pt} < 0$, $\delta_{ptt} \leq 0$, $\delta_{ppt} \leq 0$, $\delta_{xp} < 0$, $\delta_{xpt} > 0$.

2.2 The principal - the manager or owner of a firm

The manager or owner of the firm, thus agency frictions between owners and mangers are assumed away in this analysis, maximizes the expected profit, revenues minus the expenses for pollution charges, and the wages w paid to the workers:

$$\pi = \mathrm{E}_t[x - \tau p - w] = \int_{\underline{t}}^{\bar{t}} [x(t) - \tau p(t) - w(t)] f(t) dt\,. \tag{5}$$

This objective (5) assumes implicitly that the firm is a price taker in output markets; without loss in generality we can set this price equal to 1. The expectation is taken with respect to the workers' private information, their productivity type t. As is common in this kind of literature, the principal has a prior distribution over the agents' types $F(t)$ with support over $[\underline{t}, \bar{t}]$ and density $f(t)$, otherwise the manager is unable to form expectations, such that the hazard rate

$$h(t) := f(t)/(1 - F(t)) \tag{6}$$

is monotonically increasing. The assumption of a distribution function stipulates that the number of workers is normalized to one and aggregate output corresponds to the mean output.

2.3 The First Best and the CGE approach

In the absence of environmental concerns, the first best solution results from:

$$\max_{x} x - D(x, t), \tag{7}$$

which is characterised by the following first order condition:

$$1 - D_x = 0. \tag{8}$$

Substituting the resulting production into the emission function P determines the corresponding pollution. Aggregating over the types using the density f determines then aggregate output and pollution.

Introducing pollution charges, the corresponding first best solution is obtained from

$$\max_{x,\, p} x - \delta(x, p, t) - \tau p \tag{9}$$

with the first order conditions:

$$\delta_x = 1, \tag{10}$$

$$\delta_p = \tau, \tag{11}$$

which are sufficient given the convexity of D. Indeed, this first best outcome (10) and (11) falls probably already below the CGE outcome. The reason is that (10) and (11) imply a reduction of efforts (the proof is a simplified version of the one in Section 3.3), while the CGE models leave the effort at least of those employed (and assuming anyway full employment) unchanged and just distribute the tasks (optimally) between production and abatement.

3. Optimal Contracts

The design of the optimal contracts must account for the agent's strategic reaction to the incentive, because the 'first best' is not implementable. The incentive schemes depend on the information available to the agent. I sketch the solution of this problem for the benchmark, no pollution charge, or $\tau = 0$, for details see e.g. Fudenberg-Tirole (1992), but skip the derivation of the first order conditions in the other two cases.

3.1 Status quo, no pollution charge

The optimal incentive (in its direct form) consists of production and wage schedules

$\{(x(t), w(t))$ for $t \in [\underline{t}, \bar{t}]\}$.

Confronted with this offer each individual worker pretends that type $\hat{t}$ that maximizes the personal benefit:

$U(\hat{t}, t) = w(\hat{t}) - D(x(\hat{t}), t)$,

since $e = q = x$. It is easy to see that the first best solution is not implementable, because the workers will not carry out their 'assigned' tasks. The reason is that demanding the first best output according to (8) yet offering a wage that just compensates for disutility, $w = D(x, t)$, will induce the workers to pretend a less efficient type, $\hat{t} < t$, probably the least efficient type, $\hat{t} = \underline{t}$, because this allows them to accrue rents, while truth telling results in zero net benefits to the agent. Invoking the revelation principle, the manager maximizes the expected aggregate profit π subject to the incentive compatibility constraint

$u(t) := U(t, t) \geq U(\hat{t}, t)$ for all $\hat{t} \neq t$,

and the individual rationality constraint:

$u(t) \geq u_0$.

As usual, the reservation wage u_0 accounting for the agents' outside options is exogenously given, independent of the types and normalized to zero, $u_0 = 0$; however, we will comment on institutionally set reservation wages in the final section. The revelation principle states that the restriction to contracts that induce the agent to reveal the true type does not lower profits. This in turn allows to eliminate wages from the objective, $w(t) = u(t) + \delta(x(t), t))$. Applying the envelope theorem to $u(t)$, the following control problem results for solving the benchmark, wage contracts absent pollution charges:

$$\max_{\{x(t)\}} \int_{\underline{t}}^{\bar{t}} [x(t) - D(x(t), t) - u(t)] f(t) dt \, , \tag{12}$$

$$\frac{du}{dt} = -D_t, u(\underline{t}) = u_0 = 0 \, . \tag{13}$$

Defining the corresponding Hamiltonian, $H = [x(t) - D(x, t) - u]f - \lambda D_t$, the following first order optimality conditions result according to Feichtinger – Hartl (1986):

$$H_x = (1 - D_x)f - \lambda D_{tx} = 0, \tag{14}$$

$$\dot{\lambda} = f, \ \lambda(\bar{t}) = 0 \, . \tag{15}$$

Integrating the costate variable differential equation (15) accounting for the transversality condition, $\lambda(\bar{t}) = 0$, yields $\lambda(t) = F(t) - 1$. Substituting this solution into the maximum principle (13) and introducing the already defined hazard rate, $h = f/(1 - F)$, yields the following characterization of the optimal prescription of production

$1 - D_x(x, t) = -D_{xt}(x, t)/h(t).$ (16)

This ‘relaxed program’, compare Fudenberg-Tirole (1992), is optimal if it is monotonically increasing in the efficiency parameter, which is ensured due to the assumptions:

$$\frac{dx}{dt} = \frac{\frac{D_{xtt}h - D_{xt}\dot{h}}{h^2} - D_{xt}}{D_{xx} - D_{xxt}/h} > 0. \tag{17}$$

The so far missing wage follows from integrating (13) using the normalized boundary condition $u_0 = 0$ and the definition of $u(t)$:

$$w(t) = \underbrace{\int_{\underline{t}}^{t} - D_v(x(v), v)dv}_{u(t)} + D(x(t), t)\,. \tag{18}$$

Eliminating the private information parameter t from the so far calculated schedules $\{(x(t), w(t))$ for $t \in [\underline{t}, \bar{t}]\}$ allows to express the wage as a (non-linear) function of the output, $w = W(x)$; an example will shown in Section 4.

3.2 Optimal Contracts when Individual Pollution is not Monitored

If the agent’s pollution cannot be monitored, the manager faces a multi-task problem similar to the one analysed in Holmström-Milgrom (1991). While Holmström-Milgrom (1991) restrict the analysis to linear contracts, general and consequently nonlinear contracts are derived in the folloing. A consequence of multi-tasking when one the tasks is not observable is that rewarding only the observable output produces the familiar result - you get what you pay for - that is not in the interest of the principal anymore. In particular, the incentive of the previous section that rewards production efforts optimally is not efficient anymore because its leads to too much pollution for which the firm must pay now. Since it is impossible to link rewards to the unobservable pollution, rewarding on the basis of aggregate pollution will not help in sufficiently large production units either. All the managers can do is to design incentives that are optimal accounting for this spillover from production on pollution. That is, the managers have to solve the following problem:

$$\max_{\{x(t)\}} \int_{\underline{t}}^{\bar{t}} [x(t) - \tau P(x(t), 0) - D(x(t), t) - u(t)] f(t) dt\,, \tag{19}$$

$$\frac{du}{dt} = -D_t, u(\underline{t}) = u_0 = 0\,. \tag{20}$$

The necessary optimality condition for an optimal ‘prescription’ of output can be expressed in the following way:

$1 - D_x = -D_{xt}/h + \tau P_x.$ (21)

Hence, the output assigned to each type is reduced accounting for the associated externality. The reason is that, a pollution charge lowers the effective price of output, $1 - \tau P_x$,which must equal the marginal costs, D_x - D_{xt}/h, which in turn consist of the agent’s costs of incremental effort, D_x, and the agency costs, $-D_{xt}/h$. As a consequence, pollution charges flatten the optimal incentive to which the agents respond with less efforts.

3.3 Optimal Contracts with Observable Individual Pollution

When pollution is observable, the multi-tasking argument does not apply anymore, since abatement can be directly rewarded. More precisely, the principal can prescribe both tasks – production quotas and pollution allowances as functions of the agents' types.

$$\max_{\{x(t),p(t)\}} \int_{\underline{t}}^{\bar{t}} [x(t) - \tau p(t) - \delta(x(t), p(t), t) - u(t)] f(t) dt, \tag{22}$$

$$\frac{du}{dt} = -\delta_t, u(\underline{t}) = u_0 = 0. \tag{23}$$

Nevertheless, still a reduction in efforts result. That is the reduction in output exceeds the intermediate friction due to necessary abatement. It is this additional managerial friction that is not accounted for in traditional approaches such as in the CGE models.

In this case, the first order conditions can be reduced to the following pair of implicit relations:

$$1 - \delta_x(x, p, t) = -\delta_{xt}(x, p, t)/h(t), \tag{24}$$

$$-\tau - \delta_p(x, p, t) = -\delta_{pt}(x, p, t)/h(t). \tag{25}$$

Solving this set of non-linear equations is in general impossible, unless for particular simple specifications (see next section). The second condition for the optimal level of pollution may be dominated by the boundary solution, $a = 0$, thus $p = P(x, 0)$.

The reduction in efforts after introducing a pollution charge is economically clear, since this amounts to a reduction in the price of output from 1 to $1 - \tau P_x$. Less obvious is, how far this holds once monitoring is possible. Indeed, an argument similar to Porter's would not exclude the possibility that monitoring allows for an improvement in efforts following his win-win 'logic'. In order to trace the impact of pollution charges on workers' efforts we have to compute

$$\frac{\partial e}{\partial \tau} = \frac{\partial x}{\partial \tau} + \frac{\partial A}{\partial x}\frac{\partial x}{\partial \tau} + \frac{\partial A}{\partial p}\frac{\partial p}{\partial \tau} = \frac{(P_a - P_x)x_\tau + p_\tau}{P_a} < 0. \tag{26}$$

This derivative is obviously negative, if the derivatives of production and pollution with respect to the pollution charge have the 'proper', expected signs, $x_\tau < 0$ and $p_\tau < 0$, since $A_x = -P_x/P_a > 0$ and $A_p = 1/P_a < 0$. Application of the implicit function theorem, see e.g. Rudin (1974), to the first order conditions (24) and (25), gives

$$\begin{pmatrix} x_\tau \\ p_\tau \end{pmatrix} = -\begin{pmatrix} -\delta_{xx} + \delta_{xxt}/h & -\delta_{xp} + \delta_{xpt}/h \\ -\delta_{xp} + \delta_{pxt}/h & -\delta_{pp} + \delta_{ppt}/h \end{pmatrix}^{-1} \begin{pmatrix} 0 \\ -1 \end{pmatrix} = \frac{1}{\det}\begin{pmatrix} \delta_{xp} - \delta_{xpt}/h \\ \delta_{xxt}/h - \delta_{xx} \end{pmatrix}. \tag{27}$$

This proves that the partial derivatives x_τ and p_τ have indeed the proper negative signs due to the assumptions about the (implied) disutility $\delta(x, p, t)$ if in addition the determinant (denoted det), which is necessary to calculate the inverse matrix,

$$\det = \{[\delta_{pp}\delta_{xx} - \delta_{xp}^2] - [\delta_{pp}\delta_{xxt} + \delta_{xx}\delta_{ppt}]h + \delta_{ppt}\delta_{xxt} + \delta_{xpt}[2\delta_{xp} - \delta_{xpt}]\}/h^2 \tag{28}$$

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is positive. This determinant is positive, if the first three terms, which are definitely positive for the made assumptions (the first due to the convexity of δ), outweigh the last and negative term. Therefore given this additional technical proviso that det > 0, which is hard to interpret given that it depends on mixed third order derivatives and satisfied in the following numerical examples (and other tried specifications), *pollution charges reduce workers' efforts even if pollution is individually monitored*[2].

Economically and intuitively, one expects also that

- additional monitoring leads to an increase in efforts compared with the multi-tasking agency set up when pollution is not observable at an individual level,

- this increase in efforts serves both 'outputs', goods' production x is increased and pollution p is reduced.

The reason for the first point is that the additional instrument will be only invoked if it reduces shirking. Indeed, a simple example will show that abatement is not always mandated for all agents so that in this case the results of the previous section apply ($a = 0$). The second point follows, because once abatement is optimal, the marginal production costs accounting for the external costs decline, $\delta_x < \tau P_x(x, 0)$, so that equating to the price yields a higher output. An arithmetic derivation is omitted due to the convincing economic logic and because establishing these properties theoretically is tedious and depends again on third order derivatives.

An interesting implication of this increase in efforts due to individual monitoring is that the expenditures for monitoring equipment are partially financed by the reduction in shirking. In other words, accounting for this feedback, investing in such equipment can turn out to be profitable, when a standard cost-benefit comparison suggests the opposite.

4. Comparison and Examples

A numerical example

$D(e, t) = \frac{1}{2}\gamma e^2/t$,

$P(x, a) = x/(1 + \alpha a) \Rightarrow P(x, 0) = x$ and $A(x, p) = (x/p - 1)/\alpha$,

$f(t) = 1/(\bar{t} - \underline{t})$, for $t \in [\underline{t}, \bar{t}]$, otherwise $f(t) = 0$, thus $(1/h(t)) = (\bar{t} - t)$,

is introduced to highlight the theoretical properties and the differences between the different outcomes. The model is normalized so that all redundant parameters are eliminated. Disutility D is simply quadratic in effort e and reciprocal to the type such that higher types experience less disutility. Pollution is linear in output and reduced by abatement efforts as assumed (i.e. satisfying the law of diminishing returns). This assumption is of course optimistic concerning

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[2] Porter's thesis cannot be entirely ruled out, if one introduces pollution as an additional signalling device.

the impact of environmental policies and pollution charges in particular since pollution is most likely convex in output. The crucial function of disutility implied by the tasks is given by

$$\delta = \tfrac{1}{2}\gamma[x + (x/p - 1)/\alpha]^2/t.$$

Clearly, δ satisfies all the assumptions. The final assumption is that the types are uniformly distributed, which leads to a particularly simple, since linear, inverse hazard rate. The purpose of this specification is to allow for plausible examples and for analytical solutions. An interesting consequence of this specification is that it allows for a differentiation between agents such that the less efficient, they produce anyway little of both, product and pollution, are exempted from abatement efforts.

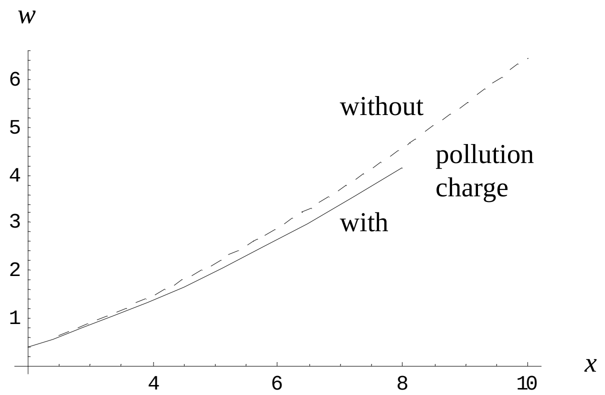

Fig. 2 Comparison of optimal incentives – wage w depending on output x - with and without pollution charges, when individual abatement cannot be monitored, $\underline{t} = 5, \bar{t} = 10, \gamma = 1$.

The scenario of multi-tasking leads right away to the solution of 'optimal' production that is quadratic in the types:

$$x = t^2(1 - \tau)/(\gamma\bar{t}).$$

The special case, $\tau = 0$, corresponds to the benchmark, no pollution charge. The relative reduction in output equals in this simple specification the tax rate. The reason for this is that the flattened incentive – see Fig. 2 - induces the workers to reduce efforts, i.e. to shirk. This response of workers providing less effort due to necessarily weakened incentives, which may add up to a significant share, is overlooked in the CGE and related approaches.

Allowing for abatement yields the production task:

$$x(t) = \frac{\gamma p\bar{t}(1 + \alpha p) + \alpha^2 p^2 t^2}{\gamma\bar{t}(1 + \alpha p)^2},$$

which depends only indirectly - via the necessary abatement to reach pollution p - on the tax τ due to the supposed linearity of P in x. Substitution of this production target into the condition for 'optimal' pollution (25) yields a cubic relation in p that allows for an analytical solution, which, however, is suppressed because this cumbersome expression adds little further economic insight.

Fig. 3 compares the efforts associated with the different scenarios. A stunning observation, although already established on theoretical grounds, is in this example that the slack introduced by pollution charges exceeds the actual abatement efforts by far. Reducing the efficiency of abatement efforts, setting $\alpha = 1$, implies that the rather inefficient types ($t < 7$, thus roughly $^2/_5{}^{th}$ of the labour force) should not worry about pollution at all and should thus produce as in the case of no monitoring. On the positive side monitoring allows to mitigate this negative impact of pollution charges substantially, i.e. to increase the efforts of the workers. In this example, the induced increased in effort is substantial, which underlines the claim that installing monitoring equipment can reclaim a significant portion of its costs by increasing efforts.

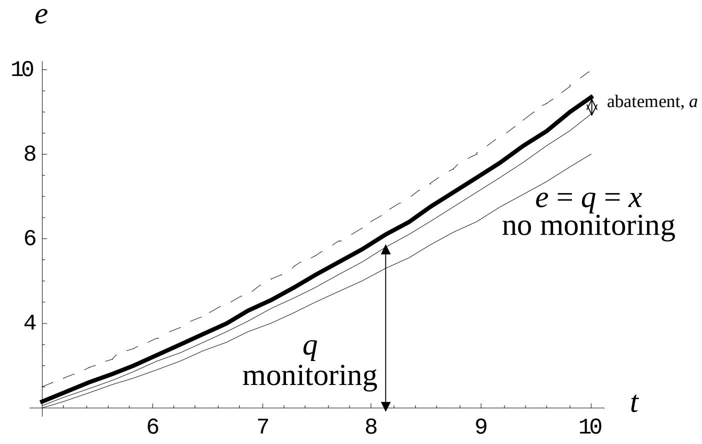

Fig. 3 Comparison of the efforts, e, for $\underline{t} = 5, \bar{t} = 10, \gamma = 1, \alpha = 10$,
dashing = no pollution charge

5. Final Remarks

An interesting feature of the model is that it provides a partial explanation of the meagre economic record – low growth and high unemployment rates, in particular in Europe – in the late eighties and early nineties despite the dramatic energy price cut 1986. That is, the simultaneous initiation of ambitious environmental policies aggravated by the managerial friction discussed in this paper explains the apparent 'asymmetry' to energy price changes: an increase in energy prices are more harmful than a decline is beneficial.

The further assumption - unions fixed the wages without accounting for the additional environmental burden, which was the case in most European countries - explains at least partially the worse unemployment record in Europe. The reason is that fixing the agent's reservation payoff u_0 (by minimum wages and unemployment benefits) yet introducing pollution charges reduces the 'efficiency' of 'marginal' workers to which the firms react by dismissing them, compare Wirl (2000).

This paper used asymmetric information to explain a difference between traditional reasoning and stylised facts. Unfortunately, the aspects of private information are neglected in many environmental policy issues. This oversight may be substantial, because private information often calls for a complete reversal of policy recommendations as noted Lewis (1996). A topical example in this direction is the neglect of possible strategic manipulations associated with 'flexible' mechanisms to reduce GHG emissions, like joint implementation and clean development measures, compare Hagem (1996), Wirl et al. (1998). The consequences of this oversight are observable in the case of conservation programs that did not deliver the promised 'gigabucks', Lovins (1985), but only 'stranded costs', see Wirl (2000). Another aspect that is in my opinion insufficiently treated in environmental economics concerns positive issues since the bulk of the literature seeks optimal interventions for benevolent, omnipotent in most case cases omniscient dictators. This is of course naive, and a recent exception is e.g. Fredriksson (2001).

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