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TIME INCONSISTENCY IN ENVIRONMENTAL POLICY: TAX EARMARKING AS A COMMITMENT SOLUTION*

Laura Marsiliani, Thomas I. Renström

Tax earmarking imposes a constraint on government policymaking, and may be desirable if it solves a time-inconsistency problem in tax policy. In a two-period economy, in which the policy decisions regarding taxes, public goods provision, and pollution abatement are taken by a majority-elected individual, we show how the time-inconsistency problem in environmental policy arises.

We demonstrate that the commitment equilibrium under no earmarking rules cannot be as fully implemented as a no-commitment equilibrium under earmarking rules. However, the earmarking rules do act as a partial commitment mechanism.

Keywords: Tax earmarking, fiscal policy, redistributive taxation, endogenous taxation, time inconsistency, environmental tax, pollution abatement.

JEL Classification: D62, D72, E62, H20

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Tax earmarking, or hypothecation, that is "dedicating specific revenues to the financing of specific public services," (cf. Buchanan, 1963) is a controversial subject, both in policy circles and among academic economists. Advocates of earmarking (for example lobby groups) argue that it can increase welfare.¹ Those who are against tax earmarking (mainly policymakers) claim that earmarking is an additional constraint to the management of fiscal policy, and would generally, as such, yield a lower optimum.² Despite the controversy surrounding tax earmarking, we do often observe it in practice. For example earmarking of environmental taxes for environmental protection is common in the European Union, the United States and other countries. In France, Germany, Italy and the Netherlands, earmarking for environmental projects is mostly used with respect to water pollution charges; in Japan, revenues from emission taxes are devoted to the compensation of the victims of the pollution; in British Columbia, the revenues from green taxes are allocated to a Sustainable Development Fund for the purpose of environmental protection. In Britain, the report of the House of Lords' Select Committee on Sustainable Development (1995) mentions the possibility of earmarking for expenditure on environmentally oriented programmes. One example is the UK landfill tax which includes the option of earmarking part of the revenue for investment and research on waste recycling. Also, the US Superfund law institutes an excise-tax on petroleum materials to pay for clean-up and disposal of hazardous waste.

One question immediately arises. Have these earmarking rules affected the decision upon tax rates and public expenditure? It may very well be the case that the earmarking rules were

¹ We should be careful when evaluating the arguments of various lobbies. For example, motorists may argue that a road tax should be fully earmarked for road improvements, while non-motorists may argue that the road charges should go to funding public transport. These arguments may have no rationale for economic efficiency or welfare, but merely express each group's desire to capture a larger share of the "public cake." The groups would in this case argue that *any* tax should go to their most preferred use.

² On these positions, see, for example, McCleary (1991), Teja and Bracewell-Milnes (1991), OECD (1996), and O'Riordan (1997).

neutral; for example if the government reduced or increased funding for that particular expenditure by changing the revenue allocation from other sources, or if earmarking rules were easy to change, or if they were chosen when the tax decision was taken. If this is the case, we cannot recognise the rule as earmarking; it is simply an optimal expenditure decision. Earmarking rules should therefore be constitutional to have any relevance. An example of constitutional earmarking is in the Minnesota Constitution as of 1981. Article XIV states that excise taxes on petrol, and taxes on motor vehicles using public highways should be paid into a highway user distribution fund. The Constitution states that the proceeds should be used solely for highway purposes, and it also states the exact percentage of the proceeds for each expenditure category.³

Attempts have been made in the academic literature to identify situations in which earmarking actually can be desirable. An early paper is Goetz (1968), who builds on Buchanan (1963). Goetz gives an example of a political-economy situation in which three groups of voters simultaneously vote on one tax decision and one expenditure decision. If two voter groups were able to co-ordinate, then they would vote for an alternative that gives both groups greater utility than under the status quo. Earmarking in Goetz's example rules out some of the alternatives and solves the co-ordination failure and is beneficial for the majority. However, earmarking, here, is not a constraint, it is, in fact, synonymous with "optimal allocation." Policy proposals are worked out in which the tax receipts are optimally allocated. Two recent papers view earmarking from different perspectives. Pirttilä (1998) argues that earmarking revenues from an environmental tax to compensate those who have to bear most of the tax burden may be desirable. Brett and Keen (1998) view earmarking as a way to prevent politicians with discretionary power over the use of the revenues from deviating from the original policy proposal.

³ See Minnesota Legislative Manual 1981-82, compiled by Joan Anderson Growe, Secretary of State, and published by the State of Minnesota at Saint Paul, p. 45, Article XIV, sec. 5, 9 and 10.

Our paper suggests an alternative rationale for tax earmarking. If there is a time-inconsistency problem in fiscal policy, earmarking constraints may actually be desirable, since they can act as a commitment mechanism.⁴ The purpose of this paper is to examine the time-inconsistency problem specifically related to an environmental tax,⁵ and determine whether tax earmarking can put constraints on the future tax decision in such a way that the commitment solution without earmarking (*second best*) can be obtained without commitment (*third best*) but with earmarking. We also wish to tackle the question of how earmarking rules affect the policy decisions, compared to the case without earmarking, but under no commitment. Our paper is novel in several respects. First, we view earmarking as a constraint. A government who sets tax policy does so subject to earmarking rules. These constraints will be binding in the analysis, so from the government's point of view, funds cannot be optimally allocated.⁶ Second, we introduce more than one tax instrument. In this way we can capture the attempt of a government to get out of the constraint by adjusting other tax instruments. Third, we allow for more than one public expenditure. This captures the possibility that the government changes its expenditure pattern. Fourth, we have consistency between individual preferences and policy making by using a simplified citizen-candidate model,⁷ where an individual, elected from the population, decides

⁴ A government's policy is dynamically inconsistent when, although being optimal at the outset, it is no longer optimal at a later date — even if no new information has appeared. This means that the government has no incentive to be committed to its original plans (see, for example, Kydland and Prescott, 1977).

⁵ The time-inconsistency problem in environmental policy has not received much attention in the literature. There are some recent papers which look at the issue when the problem arises due to firms' investment behaviour. See Biglaiser, Horowitz and Quiggin (1995), Abrego and Perroni (1999), and Gersbach and Glazer (1999).

⁶ There is an alternative political-economy literature in which constraints on governments may be desirable. This is when the government can be bribed by different interest groups (see, e.g., Grossman and Helpman, 1994 and Fredriksson, 1997). We have chosen not to incorporate this issue into our framework, since our source of inefficiency arises from time-inconsistency in policy. We should also bear in mind that when making the voting stage explicit in the Grossman-Helpman model, and by assuming that individuals are rational, the lobbying in equilibrium may have no effect on policy at all (see Besley and Coate, 1998).

⁷ See Osborne and Slivinsky (1996) and Besley and Coate (1997).

upon policy. However, our conclusions are unlikely to change if policy decisions were taken by a social planner, seeking to maximise social welfare. As long as this planner cares about distribution of utilities, the time-inconsistency problem prevails, and the planner (and consequently social welfare) would benefit from the constraints of earmarking. The paper is structured as follows. Section 1 introduces the economy and formalises the assumptions. Section 2 describes the economic equilibrium. Section 3 solves two bench-mark political-economic equilibria when the earmarking rules do not bind -- one when the majority-elected individual cannot commit to future taxation, the other when the majority-elected individual is able to commit. Section 4 solves for the political-economic equilibrium under binding earmarking rules. Section 5 concludes the paper.

1. The Economy

We shall specify a model of an economy that is rich enough to capture the effects of earmarking, and that formalises the time-inconsistency problem, but is simple enough to keep the analysis tractable. We will consider a tax system consisting of a linear labour tax, J^l , combined with a lump-sum transfer, T , (or exemption level of labour-income taxation), and an environmental tax, J^e , (a tax on an intermediate consumption good, such as energy).⁸ The tax receipts are used for provision of a public good, g , and for pollution abatement, z .

Earmarking will be conducted in the following way. A fraction of each source of tax revenue will be designated to each type of public expenditure. We will thus have two earmarking rules -- one for each tax.

Pollution, S , is generated by private consumption of a particular intermediate good, x . We

⁸ We do not include investment decisions and capital taxes to abstract from the problem of time-inconsistency in capital taxation. If capital taxation were modelled, earmarking would assume a role in correcting for the time-inconsistency problem in capital taxation as well, while our focus is on time-inconsistent environmental taxation.

may think of this good as energy, such as car fuel and heating. Individuals do not get utility directly from energy, but from the use of a product, h , that requires energy as an input. We will refer to such a product as a durable. For example, the individual chooses the heating system (oil, electricity, solar panels) to be installed in the house. The service provided by the durable good then depends on two variables: energy efficiency b and energy x . Energy efficiency is bought in the first period, and energy is bought in the second period. There are some properties of such a "service function" that we find plausible. First, the marginal services of the respective variable should be positive, but decreasing. Also, the marginal service of energy should be increasing with the use of energy efficiency (this is almost a definition of energy efficiency). The time-inconsistency problem arises as follows: when the government commits to a level of the future energy tax, it takes into account that a higher level of the tax causes individuals to switch from other types of consumption to more energy-efficient consumer durables. If the government can re-optimize in the future, then the stock of consumer durables is fixed, and there is no switch to more energy-efficient products. The individuals change only their use of their durables. The elasticity of the energy tax base is (predictably) smaller. In a Ramsey tax framework we would expect that energy would be overtaxed in the third best (when the government takes the tax decision after the individuals have chosen their consumer durables), because energy demand is less elastic.⁹

Individuals have preferences over period-one consumption, period-two labour supply,

⁹ We have chosen not to introduce a tax or subsidy on first period purchases of energy-efficient technology. It is important to notice that even if we allow for such a tax or subsidy, the time-inconsistency problem is unlikely to disappear. The reason is that the marginal benefit of energy efficiency is related to energy consumed in the second period. Thus, with or without first-period taxes, consumers have to predict the energy price in the future. Those expectations will form an explicit part in the government's optimisation problem if the government maximises in the first period. However, if the government maximises in the second period the individuals' expectations are history and do not constitute a constraint. Typically time-inconsistency problems are not related to the number of instruments. In economies where the government controls all consumer prices (i.e. when the government has a full set of taxes) the problem is still present.

period-two consumption (non-durable and durable), and period-two provision of public goods, as well as over a clean environment. Individuals are indexed by i and characterised by their productivity parameter γ^i , which we assume, can only take on two values: γ^h and γ^l , $\gamma^h > \gamma^l$. We assume that there is a large number of individuals of each type, but that the fraction of individuals of low productivity, n , is greater than the fraction of high productivity, $1-n$. Thus the decisive individual will have a productivity which is lower than average. This assumption implies that we have chosen to focus on political equilibria where the redistribution goes from rich to poor. We normalise the average productivity and the aggregate productivity to unity. In the first period, individual i (with ability γ^i) receives a lump-sum endowment W_0 (this can be thought of as labour income with labour being in inelastic supply), which is used for period-one consumption, c_0 , and for the purchase of the durable good, characterised by energy efficiency b^i at the price p per unit. In the second period, the individual supplies labour, l^i , and earns the pre-tax wage rate $\gamma^i w$, per unit of labour. The after-tax wage income plus a lump-sum transfer from the government is used for consumption and purchase of the intermediate good x^i to derive utility from the durable good. The price of consumption is normalised to unity and the consumer price of x is q .

Economic policy is carried out by a majority elected candidate under various constitutional arrangements. Each individual prefers the policy chosen by her own type, implying that in an election between a high- and low-productive candidate the low productive candidate would win. We have not explicitly modelled the choice of becoming a candidate, we just assume that there are no costs of candidacy and that one candidate of each type enters the election. Throughout the paper the decisive individual will thus be of the low-productivity type, and the political-equilibrium policy is the policy she most prefers.

1.1. Assumptions

A1 Individuals' Preferences. The utility function is assumed to be of the form

$$U_0^i = u(c_0) + \mathcal{S}U^i, \quad (1a)$$

$$U^i = \ln c^i + \theta \ln h^i - \eta l^i + \epsilon \ln g - \Psi(S), \quad (1b)$$

where $l^i \geq 0$, $\Psi'(S) > 0$, $\Psi''(S) \geq 0$, and the parameters \mathcal{S} , η , ϵ and θ are strictly positive.

A2 Individuals' Constraints. The individuals' budget constraints are

$$c_0^i + p b^i \leq W_0, \quad (2a) \quad c^i + q x^i \leq \omega \gamma^l l^i + T, \quad (2b)$$

where $\omega \equiv (1 - \mathcal{J})w$ and $q \equiv (1 + \mathcal{J})q$ are the consumer prices, \mathcal{J}^l the labour tax rate, \mathcal{J}^x the energy tax rate, and T the lump-sum transfer.

A3 Durable Goods. We assume that the services provided by the durable good take the form

$$h^i = (b^i x^i - \mu)^\sigma, \quad \mu > 0, \quad \sigma > 0. \quad (3)$$

A4 Production. A large number of firms produce c and x under the same linear technology

$$y = w\bar{l}, \quad (4) \quad c + \bar{x} = \tilde{q}y, \quad (5)$$

where w and q are constants, and $\bar{l} \equiv n\gamma^l l^i + (1 - n)\gamma^h h^i$ is labour in efficiency units.

A5 Pollution. Pollution is a function of the aggregate polluting factor \bar{x} , and abatement z

$$S = S(\bar{x}, z), \quad S_{\bar{x}} > 0, \quad S_z < 0, \quad S_{zz} \geq 0. \quad (6)$$

A6 Government's constraint. A fraction, $\alpha^j : 0 \leq \alpha^j \leq 1$, of the tax receipts from tax $j = \{l, x\}$ is used for pollution abatement z , and the fraction $1 - \alpha^j$ is used for public goods provision g :

$$z = \alpha^l [(w - \omega)\bar{l} - T] + \alpha^x (q - \tilde{q})\bar{x}, \quad (7a)$$

$$g = (1 - \alpha^l) [(w - \omega)\bar{l} - T] + (1 - \alpha^x) (q - \tilde{q})\bar{x}. \quad (7b)$$

A7 Representative democracy. The tax rates, J^l , T , J^x , and the spending decision, are determined by a majority-elected representative, under either of three constitutions:

- (a) the taxes are decided upon in period 0, and there are no earmarking rules,
- (b) the taxes are decided upon in period 1, and there are no earmarking rules,
- (c) the taxes are decided upon in period 1, subject to exogenous earmarking rules.

2. Economic Equilibrium

2.1. Second Period Individual Economic Behaviour

Maximisation of (1b) subject to (2b) gives the individuals' decision rules

$$\gamma^i l^i = \gamma^i (1 + \theta\sigma)/\eta - (T - qm^i)/\omega, \quad (8) \quad x^i = \theta\sigma\eta^{-1}(\omega\gamma^i)/q + m^i, \quad (9)$$

and indirect utility (up to an additive constant)

$$V^i = \theta\sigma \ln b^i + (1 + \theta\sigma) \ln \omega - \theta\sigma \ln q + \eta(T - qm^i)/(\omega\gamma^i), \quad (10)$$

where $m^i \equiv \mu/b^i > 0$. If m^i is large (i.e. if the individual has invested little in energy-saving technology), then the individual demands more energy and supplies more labour. The reason for the first is that the durable good simply requires more of x to provide the services if it is less energy efficient, and the individual finds it optimal not to reduce consumption of the durable too much to outweigh this effect. The individual also supplies more labour in such a situation because of the income effect: a less efficient technology makes all goods less affordable, and the individual finds it optimal to reduce her consumption of leisure, i.e. she works now more.

2.2. First-Period Individual Economic Behaviour

Maximisation of (1a) subject to (2a) and (2b) gives an individual's choice of the level of energy

efficiency as an implicit function of second-period energy price, q , second-period after-tax wage rate, ω , and second-period productivity,

$$q, \omega, \gamma^i) : -p u'(W_0 - p b^i) + \theta [\theta \sigma + \eta \mu (b^i)^{-1} q / (\omega \gamma^i)] (b^i)^{-1} \quad (11)$$

Taking the partial derivatives of (11) we have (see the appendix)

$$-b^i < \gamma^i \partial b^i / \partial \gamma^i = \omega \partial b^i / \partial \omega = -q \partial b^i / \partial q < 0. \quad (12)$$

Thus, we have the result that an individual who is endowed with a higher labour productivity will invest less in the energy-saving technology. The reason is that this individual will receive relatively large income in the second period, and can afford a high level of consumption. At the same time, the individual seeks to consume more in the first period as well. This is done by substituting energy efficiency for period-one consumption. This will imply that in the second period the individuals with higher productivity will consume more of energy -- not only because they receive larger income, but also because their durables have less energy efficient technology. Therefore, already at this stage of the analysis, we may suspect that there will be a redistributive conflict in the taxation of energy: the low productive individuals would gain relatively more by the taxation of energy. We also see that an increase in the energy price enhances investment in energy saving technology.

2.3. Aggregate Economic Behaviour

Second- and first-period aggregate economic behaviour is obtained by aggregating the individuals' quantities obtained in section 2.1 and 2.2, respectively. Aggregate labour (in efficiency units) and energy use, is obtained by summing (8) and (9) over the population

$$\bar{l} = (1 + \theta \sigma) / \eta - (T - q \bar{m}) / \omega, \quad (13) \quad \bar{x} = \theta \sigma \eta^{-1} \omega / q + \bar{m}, \quad (14)$$

where $\bar{m} \equiv n m^l + (1-n)m^h$. In the first period \bar{m} is a function of the taxes according to (11) (we have no closed-form solution for \bar{m}). In the next section we shall examine the time-inconsistency problem in environmental policy, when the earmarking rules are not binding.

3. Political-Economic Equilibria without Earmarking

We assume that the government's budget constraint is the sum of (7a) and (7b), so that the earmarking rules drop out. Given that constraint, and given the individuals' decision rules each individual's most preferred policy is the one that maximises her own indirect utility. The individual who is in the majority will implement her preferred policy. We will examine two different constitutions. In the first, the majority-elected individual can only choose policy in the second period (or can choose in the first, but has the possibility of re-optimising in the second). Under the second constitution, the individual can commit, in the first period, to the policy to be implemented in the second period. The first situation is usually referred to as the *third best*, since due to the lack of a commitment device, the equilibrium will be worse for the decisive individual than if commitment had been possible. The second situation is usually referred to as the *second best*. Thus, these two constitutions will give rise to different political-economic equilibria if the optimal policy is time inconsistent.

3.1. Endogenous Policy Under No Commitment

The decisive individual solves

$$\max_{\omega, T, q, g, z} V^* + \epsilon \ln g - \Psi(S(\bar{x}, z)), \quad (15)$$

subject to the sum of the constraints (7a) and (7b), where \bar{T} and \bar{x} are given by (13) and (14) respectively, \bar{m} is taken as fixed, and the productivity of the decisive individual denoted γ^* .

PROPOSITION 1. *Assume A1-A7, and no earmarking rules. If the majority-elected candidate cannot commit to future tax policy, then the following constitute the political-economic equilibrium*

$$g = \epsilon w \gamma^* / \eta, \quad (16) \quad \omega = w \gamma^*, \quad (17)$$

$$-\Psi'(s) S_z = \eta / (\gamma^* w), \quad (18) \quad q - \tilde{q} = \eta (q / \gamma^*)^2 \frac{\bar{m} - m^*}{\theta \sigma w} - S_x / S_z. \quad (19)$$

Proof: See the appendix.

Public-good provision is increasing in γ^* . The reason is that an individual with lower productivity has a higher marginal utility of income, and therefore prefers to increase the lump-sum transfer (or equivalently, increase the exemption level of income taxation), rather than providing more of the public good. Since ω is increasing in γ^* , this implies that the wage tax is decreasing with the productivity of the decisive individual. This is a standard result, and comes from the fact that a less productive individual has more to gain from redistributive taxation. Also, the environmental tax is greater the lower the productivity of the decisive individual is. The reason is the same as for the wage tax: redistribution from high energy consumers to low energy consumers. We should notice that we obtain the Pigouvian tax as a special case (i.e. the *first best*) when all individuals are the same, (i.e. $\gamma^* = 1$, $m^* = \bar{m}$). Then the tax is equal to the marginal pollution damage: $J^x = (q - q)/q = \Psi'(s) S_x$. In this case, the wage tax is zero and any funding in addition to the environmental tax receipts is obtained by lump-sum taxation, $-T$. We will compare the policy above with the one obtained under the second constitution.

3.2. Endogenous Policy under Commitment

The decisive individual, in finding her most preferred policy, still solves (15), but faces the

situation from the first period. We have the following result:

PROPOSITION 2. *Assume A1-A7, and no earmarking rules. If the majority-elected candidate can commit to future tax policy, then the political equilibrium wage tax and public goods provision are the same as under no commitment. The environmental tax is given by*

$$q - \tilde{q} = \eta(q/\gamma^*)^2 \frac{\bar{m} - m^*}{\theta \sigma w} - \frac{S_x}{S_z} - A \left(-\frac{\partial \bar{m}}{\partial q} q \right), \quad (20)$$

$$\text{where } A \equiv \left((1 - \gamma^*) q / \gamma^* + \eta(q/\gamma^*)^2 \frac{\bar{m} - m^*}{\theta \sigma w} \right) / \left(\frac{w \gamma^* \theta \sigma}{\eta q} - \frac{\partial \bar{m}}{\partial q} q \right) > 0 \quad (21)$$

which is lower than the tax under no commitment. The abatement level, z , is greater than under no commitment.

Proof: See the appendix.

Energy consumption, therefore, is *overtaxed* when no commitment is possible. We see also, when comparing (20) with (19) that the larger the difference between the median productivity and the average, the larger is the difference between the commitment and the no-commitment solution (since A is larger). Thus, inequality (in the form of skewness of the distribution) exacerbates the time-inconsistency problem. By inspection of (20) and (21) we also see that if all individuals are the same, the commitment and no-commitment equilibria coincide ($A=0$), and the energy tax is at the Pigouvian level. Thus, we verify that there is no time-inconsistency problem when our model coincides with the first best.

4. Political-Economic Equilibria under Earmarking Rules

Throughout this section we assume that the government cannot commit to tax policy, but that the

earmarking rules cannot be altered when the tax decision is taken. We have the following timing in mind. In the second period an election over candidates belonging to each of the two productivity types is held. The majority elected candidate implements her preferred tax policy but is forced to obey the earmarking rules. When taxes have been announced individuals decide upon work, energy purchase, and consumption. In the first period individuals purchase their desired level of energy efficiency, rationally predicting the election outcome in the future and rationally predicting the policy to be implemented.

The decisive individual maximises her own indirect utility subject to each of the government's budget constraints (7a) and (7b), taking earmarking rules and the individuals' investment in energy-efficiency as given. Denote the tax revenue from source $j=\{l,x\}$ as R^j . Whenever (7a) is fulfilled and $g=R^l+R^x-z$ holds, then (7b) also holds. The objective function of the individual is

$$V^* + \epsilon \ln(R^l + R^x - z) - \Psi(s(x, z)) + \lambda \{z - \alpha^l R^l - \alpha^x R^x\}, \quad (22)$$

where λ is the multiplier associated with (7b). The constraint binds if the earmarking rules, α^l and α^x , are set in such a way that, if the individual implements the taxes she found optimal in section 3.1 (i.e. the no-commitment case), the resulting expenditure levels of g and z will not coincide with those found optimal in the no-commitment case. There can only be two situations (in which the government's budget constraints are satisfied). Either z is overprovided, and g is underprovided, that is their levels are respectively greater and lower than their unconstrained no-commitment levels; or z is underprovided and g is overprovided. As we have written the constraint, λ is positive if z is overprovided, and negative if g is overprovided.

Maximising (22) with respect to T and z gives respectively

$$\epsilon/g = \eta/(\gamma^i w) + \alpha^l \lambda, \quad (23)$$

$$-\Psi'(s)S_z = \eta/(\gamma^i w) - (1 - \alpha^l)\lambda. \quad (24)$$

Compare (23) with (16). If some of the labour tax revenue goes to abatement, then if g is overprovided under third best tax policy (i.e. $\lambda < 0$), the individual chooses to overprovide g (i.e. not fully adjusting taxes so as to meet the third best provision level). The opposite is true if λ is positive. Only if none of the labour tax revenue goes to abatement the individual finds the third best level of g optimal. The reason is that the individual cannot then use the lump-sum tax to influence the allocation of funds to abatement. Compare (24) with (18). The assumptions made about disutility of pollution, and the pollution-abatement technology, guarantee that $-\Psi(S)$ is concave in z (which is needed for the first order condition to characterise a maximum), which implies that $-\Psi'(S)S_z$ is decreasing in z . Then if not all labour tax revenue is earmarked to abatement the individual finds it optimal to overprovide z if λ is positive (the opposite if λ is negative). Next, taking the derivatives of (22) with respect to ω and q , and using the optimality conditions above, we have (see the appendix)

$$1 - \omega/(\gamma^i w) = (\alpha^x - \alpha^l)\lambda(\bar{m}q + \theta\sigma\omega/\eta). \quad (25)$$

Equation (25) corresponds to equation (17). If z is overprovided (i.e. $\lambda > 0$) and environmental tax revenue is more earmarked to z than labour tax revenue is (i.e. $\alpha^x > \alpha^l$), then the after tax wage is smaller than its third-best level, that is labour is overtaxed. The reason is that g is underprovided when $\lambda > 0$, then it is more efficient to increase the tax which is more earmarked for the expenditure which is underprovided, in this case the labour tax. The opposite is true if $\lambda < 0$, i.e. if g is overprovided, then it is more efficient to reduce the tax which is more earmarked to g . Notice that there is a one-to-one relation between the sign of $(\alpha^x - \alpha^l)$ and whether labour is over- or undertaxed with respect to the third-best with no earmarking. This suggests that we have two

ways of using earmarking in getting closer to the second best, where the energy tax is lower. This could be done by either overproviding z (i.e. $\lambda > 0$) and earmarking more of the energy tax to abatement $\alpha^x > \alpha^l$, or overproviding g (i.e. $\lambda < 0$) and earmarking more of the energy tax to public goods, $\alpha^x < \alpha^l$. However, we can only get closer to the second best, not fully reach it:

PROPOSITION 3. *Assume A1-A7. If the majority-elected candidate cannot commit to future tax policy, then there are no earmarking rules, such that the political-economic equilibrium coincides with that under commitment and no earmarking.*

Proof: Obtaining the commitment-equilibrium quantities of g, z , and ω (at the same time) as a no-commitment equilibrium under earmarking rules, is impossible. If the commitment level of g is to be obtained we need $\alpha^l = 0$ (equation (23)), for the commitment condition for z to hold we must have $\alpha^l = 1$ (equation (24)). QED

The reason for the above is that it was only in the environmental tax that the time-inconsistency problem was present; if there are earmarking rules, however, the government would try to get around them, and this is done by adjusting *all* the taxes and the levels of the expenditures. It becomes evident that earmarking cannot merely change one decision, but will change all other decisions of the government, and those changes have to be taken into account in the analysis.

Equations (23), (24) and (25) describe the consequences of earmarking for public goods provision, the abatement rule and the wage tax. Next we will examine the effects on the energy tax. The derivative of (22) with respect to q , when (23), (24), and (25) have been used, can be written as (see the appendix)

$$\eta(q/\gamma^*)^2 \frac{\bar{m}-m^*}{\theta\sigma w} - \frac{S_x}{S_z} - (\alpha^x - \alpha^l)\lambda B + \left(\frac{w\gamma^*}{\omega} - 1 \right) C + (1 - \epsilon) \quad (26)$$

$$\text{where } B \equiv (\tilde{q} - S_x/S_z)(\bar{m}q + \theta\sigma\omega/\eta) + \bar{m}q^2/(\theta\sigma) + \tilde{q}\omega/\eta, \quad C \equiv \eta(q/\gamma^*)^2 \frac{\bar{m}-m^*}{\theta\sigma w}. \quad (27)$$

This equation is the analogue of (19) and (20). In comparing with (19) there are three extra terms. The term $(\alpha^x - \alpha^l)\lambda B$ concerns the incentive to adjust the energy tax due to scarcity/abundance of public expenditure. If this term is positive, the decision maker has an incentive to reduce q . This happens if either $\alpha^x > \alpha^l$ and $\lambda > 0$, or $\alpha^x < \alpha^l$ and $\lambda < 0$. In the first case z is overprovided and energy tax receipts are highly earmarked to z . In the second case g is overprovided and energy tax receipts are highly earmarked to g . Consequently it is more efficient to reduce the tax which is highly earmarked to the overprovided expenditure, in this case q . The term $(w\gamma^*/\omega - 1)C$ regards the effect of the labour tax. The labour tax, as well as the energy tax, takes care of redistribution. If earmarking rules cause changes (relative to third best) in labour taxation (see equation (25)), then they change the incentive for using q as a redistributive device. If $(\alpha^x - \alpha^l)\lambda > 0$ (< 0) then labour is under (over) taxed (see (25) and the comments following (25)), creating an incentive to use the energy tax for redistribution to a greater (lesser) extent. Thus, this indirect effect works against the direct effect of the previous term. In cases where $(\alpha^x - \alpha^l) \geq 0$ and $\lambda > 0$ we can show that the direct effect unambiguously outweighs the indirect effect. To induce lower taxation of x we typically have two choices: either $(\alpha^x - \alpha^l) > 0$ and $\lambda > 0$, or $(\alpha^x - \alpha^l) < 0$ and $\lambda < 0$. The last term, $(1 - \alpha^l)\lambda S_x/S_z$, regards the abatement level and is negative (positive) if $\lambda > (<) 0$ (provided $\alpha^l < 0$), i.e. if z is over(under)provided.

Thus, earmarking provides *double-edged incentives* in environmental taxation (while not in labour taxation). This comes from the expenditure on abatement. An increase in abatement (by

introducing overprovision through earmarking) reduces the marginal benefit from taxing energy. The energy tax performs two goals: redistribution and pollution reduction. If pollution is reduced through abatement this provides an extra incentive to reduce the pollution tax. This double-edged incentive is not present in public goods provision. Therefore overproviding public goods and earmarking the energy tax largely to public goods give an incentive to reduce the energy tax only because it is largely earmarked to the abundant public expenditure, but it does not provide the second incentive. In fact abatement is underprovided, and therefore actually it works against a reduction in the energy tax.

Consequently, in order to exploit this double-edged incentive, a larger fraction of the energy tax receipts than of the labour tax receipts should go to abatement, and the rules should be such that abatement is overprovided and public goods underprovided relative to their unconstrained quantities.

5. Summary and Conclusions

We have presented an economy featuring a time-inconsistency problem in the taxation of energy. In the no-commitment equilibrium (third best) energy is overtaxed relative to the commitment equilibrium (second best). We have demonstrated that earmarking rules can make the energy tax in the third best closer to the one in the second best. However, earmarking cannot be used to fully reach the commitment equilibrium. In this sense, tax earmarking serves as a partial solution to the time-inconsistency problem.

Earmarking rules that allocate a larger fraction of environmental tax receipts, than labour tax receipts, to abatement, and that give overprovision of abatement and underprovision of public goods (relative to their unconstrained third best levels) provide a double-edged incentive to the government for taxing energy less. First, since the rules induce a scarcity of funds for public goods

and an abundance of funds for abatement, if the third-best taxes were implemented, the government raises the taxes that are largely earmarked to the scarce expenditure, and lowers those taxes that are largely earmarked to the expenditure that is abundant. Second, since abatement is abundant the government has an incentive to tax pollution less (since pollution is abated more).

Also, our analysis suggests that the energy tax in the third best differs more than the one in the second best, the larger the difference is between the decisive individual and the average individual. This implies that the time-inconsistency problem may become more severe when there is more inequality (in terms of mean-median distance). Thus, everything else being equal, more unequal societies would have a stronger incentive to use earmarking as a commitment device.

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Appendix

Derivation of Equation (12)

Differentiating (11) with respect to the arguments gives

$$\Phi_{b^i} = p^2 u''(c_0) - [\theta\sigma + 2\eta\mu(b^i)^{-1}q/(\omega\gamma^i)](b^i)^{-2} < 0, \quad (28)$$

$$\Phi_{\gamma^i} = -\eta\mu q \omega^{-1} (b^i \gamma^i)^{-2} < 0, \quad (29) \quad \Phi_{q/\omega} = \eta\mu (\gamma^i)^{-1} (b^i)^{-2} < 0. \quad (30)$$

Then

$$\frac{\partial b^i}{\partial \gamma^i} \equiv \frac{-\beta\eta\mu q (\omega\gamma^i)^{-1} (b^i)^{-2}}{-p^2 u''(c_0) b^i + [\theta\sigma + 2\eta\mu q (\omega b^i \gamma^i)^{-1}] (b^i)^{-1}} < 0 \quad (31)$$

Furthermore, adding 1 on each side gives

$$\frac{\gamma^i}{b^i} \frac{\partial b^i}{\partial \gamma^i} \equiv \frac{-p^2 u''(c_0) b^i + \mathcal{S}[\theta \sigma + \eta \mu q (\omega \gamma^i)^{-1} (b^i)^{-2}]}{-p^2 u''(c_0) b^i + \mathcal{S}[\theta \sigma + 2 \eta \mu q (\omega b^i \gamma^i)^{-1}] (b^i)^{-1}} > \quad (32)$$

Next, by inspection of (28) and (29) we have

$$\frac{\gamma^i}{b^i} \frac{\partial b^i}{\partial \gamma^i} = -\frac{\omega}{b^i} \frac{\partial b^i}{\partial \omega} = \frac{q/\omega}{b^i} \frac{\partial b^i}{\partial q/\omega}. \quad (33)$$

Since (31) and (32) imply $-1 < \gamma^i (b^i)^{-1} \partial b^i / \partial \gamma^i < 0$, equation (12) follows.

Proof of Proposition 1 and 2

The policy described by (16)-(19) is the policy most preferred by the individual with labour productivity γ^* , and is obtained by solving (15). The first-order conditions with respect to T , ω , and q are

$$\frac{\partial V^*}{\partial T} + \frac{\epsilon}{g} \left[(w - \omega) \frac{\partial \bar{l}}{\partial T} - 1 \right] = 0, \quad (34)$$

$$\frac{\partial V^*}{\partial \omega} + \frac{\epsilon}{g} \left[(w - \omega) \frac{\partial \bar{l}}{\partial \omega} + (q - \tilde{q}) \frac{\partial \bar{x}}{\partial \omega} - \bar{l} \right] - \Psi'(s) S_x \frac{\partial \bar{x}}{\partial \omega} = 0, \quad (35)$$

$$\frac{\partial V^*}{\partial q} + \frac{\epsilon}{g} \left[(w - \omega) \frac{\partial \bar{l}}{\partial q} + (q - \tilde{q}) \frac{\partial \bar{x}}{\partial q} + \bar{x} \right] - \Psi'(s) S_x \frac{\partial \bar{x}}{\partial q} = 0, \quad (36)$$

respectively. Substituting for the derivative of indirect utility and the derivative of equation (13) into (34) gives (16). Maximisation of (15) with respect to z gives $\Psi'(S) = -\epsilon / (g S_z)$, which combined with (16) results in (18). Pre-multiply (35) by ω and use (16), and allow \bar{m} to be a function of policy, then we have

$$-\theta \sigma \left(1 - \frac{\omega}{w\gamma^*} \frac{\tilde{q}}{q} \right) + \frac{\eta q}{\omega \gamma^*} (m^* - \bar{m}) + \tilde{A} \omega \frac{\partial \bar{m}}{\partial \omega} = \Psi'(s) S \quad (37)$$

$$\text{where } \tilde{A} \equiv \eta q / (\omega \gamma^*) - \eta \tilde{q} / (w \gamma^*) - \Psi'(s) S_x. \quad (38)$$

Pre-multiply (36) by q and use (16), and allow \bar{m} to be a function of policy, to obtain

$$\theta \sigma \left(1 - \frac{\omega}{w\gamma^*} \frac{\tilde{q}}{q} \right) + \frac{\eta q}{\omega \gamma^*} (m^* - \bar{m}) + \tilde{A} \left(-q \frac{\partial \bar{m}}{\partial q} \right) = \Psi'(s) S_x \frac{\theta \sigma}{\eta q} \omega \quad (39)$$

Combining (37) and (39) (and use (12)) gives (17). Using (17) and (18) in (39), and premultiply by $q/(\theta\sigma)$, yields

$$q - \tilde{q} = \eta (q/\gamma^*)^2 \frac{\bar{m} - m^*}{\theta \sigma w} - \frac{S_x}{S_z} - \tilde{A} \frac{q}{\theta \sigma} \left(-q \frac{\partial \bar{m}}{\partial q} \right), \quad (40)$$

which can also be written as

$$q/\gamma^* - \tilde{q} + \frac{S_x}{S_z} = \frac{1 - \gamma^*}{\gamma^*} q + \eta (q/\gamma^*)^2 \frac{\bar{m} - m^*}{\theta \sigma w} - \tilde{A} \frac{q}{\theta \sigma} \left(-q \frac{\partial \bar{m}}{\partial q} \right) \quad (41)$$

Use (17) and (18) in (38) to obtain $A = \eta (q/\gamma^* - q + S_x/S_z) / (w\gamma^*)$, and using (41) gives an equation in A , which solved gives $A = \theta \sigma A / q$, (where A is defined in (21)). Then (40) becomes (20). (40) becomes (19) when $\partial \bar{m} / \partial q = 0$. QED

Derivation of (25)-(27)

Taking the first-order conditions of (22) with respect to $\xi = \{\omega, q\}$ we have

$$\frac{\partial V^*}{\partial \xi} + \left(\frac{\epsilon}{g} - \alpha' \lambda \right) \frac{\partial R^l}{\partial \xi} + \left(\frac{\epsilon}{g} - \alpha^x \lambda \right) \frac{\partial R^x}{\partial \xi} - \Psi'(s) S_x \frac{\partial x}{\partial \xi} = 0. \quad (42)$$

Alternatively (42) may be written as

$$\frac{\partial V^*}{\partial \xi} + \frac{\eta}{\gamma^* w} \left(\frac{\partial R^l}{\partial \xi} + \frac{\partial R^x}{\partial \xi} \right) + (\alpha^l - \alpha^x) \lambda \frac{\partial R^x}{\partial \xi} - \Psi'(s) S_x \frac{\partial x}{\partial \xi} = 0 \quad (43)$$

Let $\xi = \omega$ and use (10), (13) and (14) (and take \bar{m} as constant since there is no commitment), then

(43) becomes

$$\frac{1 + \theta \sigma}{\omega} - \eta \frac{T - q m^*}{\omega^2 \gamma^*} + \frac{\eta}{\gamma^* w} \left(\frac{-1}{\eta} + \frac{w T - q \bar{m}}{\omega} - \frac{\tilde{q} \theta \sigma}{q \eta} \right) + (\alpha^l - \alpha^x) \lambda \frac{q - \tilde{q}}{q} \frac{\theta \sigma}{\eta} - \Psi'(s) S_x \frac{\theta \sigma}{\eta q} = 0. \quad (44)$$

Let $\xi = q$ and use (10), (13) and (14) (still taking \bar{m} as a constant), then (43) becomes

$$-\frac{\theta \sigma}{q} - \frac{\eta m^*}{\omega \gamma^*} + \frac{\eta}{\gamma^* w} \left(\frac{w \bar{m}}{\omega} + \frac{\tilde{q}}{q} \frac{\theta \sigma \omega}{\eta} \right) + (\alpha^l - \alpha^x) \lambda \left(\bar{m} + \frac{\tilde{q}}{q} \frac{\theta \sigma \omega}{\eta} \right) + \Psi'(s) S_x \frac{\theta \sigma \omega}{\eta q^2} = 0. \quad (45)$$

Premultiply (44) by ω and (45) by q and sum the two equations then (25) is obtained.

Premultiplying (45) by $q^2/\theta\sigma$ gives

$$\frac{q^2}{\gamma^*} \frac{\bar{m} - m^*}{\theta \sigma} + \tilde{q} \frac{\omega}{\gamma^* w} + (\alpha^l - \alpha^x) \lambda \left(\frac{\bar{m}}{\theta \sigma} q^2 + \tilde{q} \frac{\omega}{\eta} \right) + \Psi'(s) S_x. \quad (46)$$

where second and third terms in (45) have been collected. Use (24) to substitute for $\Psi'(S)$, then

$$-q + \frac{\eta q^2}{\omega \gamma^*} \frac{\bar{m} - m^*}{\theta \sigma} + \frac{\tilde{q} \omega}{\gamma^* w} + (\alpha^l - \alpha^x) \lambda \left(\frac{\bar{m} q^2}{\theta \sigma} + \tilde{q} \frac{\omega}{\eta} \right) - \frac{S_x}{S_z} \left[\frac{\omega}{\gamma^* w} - (1 - \alpha^l) \lambda \frac{\omega}{\eta} \right] = 0 \quad (47)$$

or

$$-q + \frac{\eta q^2}{\omega \gamma^*} \frac{\bar{m} - m^*}{\theta \sigma} + \left(\tilde{q} - \frac{S_x}{S_z} \right) \frac{\omega}{\gamma^* w} + (\alpha^l - \alpha^x) \lambda \left(\frac{\bar{m} q^2}{\theta \sigma} + \frac{\tilde{q} \omega}{\eta} \right) + (1 - \alpha^l) \lambda \frac{S_x \omega}{S_z \eta} = 0. \quad (48)$$

Use (25) to substitute for $\omega/(\gamma^* w)$ in third term in (48), then

$$\begin{aligned}
-q + \frac{\eta q^2}{\omega \gamma^*} \frac{\bar{m} - m^*}{\theta \sigma} + \left(\tilde{q} - \frac{S_x}{S_z} \right) \left(1 + (\alpha' - \alpha^x) \lambda \left(\bar{m} q + \frac{\theta \sigma}{\eta} \omega \right) \right) \\
+ (\alpha' - \alpha^x) \lambda \left(\frac{\bar{m}}{\theta \sigma} q^2 + \tilde{q} \frac{\omega}{\eta} \right) + (1 - \alpha') \lambda \frac{S_x}{S_z} \frac{\omega}{\eta} = 0
\end{aligned} \tag{49}$$

or

$$\begin{aligned}
q - \tilde{q} = \frac{\eta q^2}{\omega \gamma^*} \frac{\bar{m} - m^*}{\theta \sigma} - \frac{S_x}{S_z} + \left(\tilde{q} - \frac{S_x}{S_z} \right) (\alpha' - \alpha^x) \lambda \left(\bar{m} q + \frac{\theta \sigma}{\eta} \omega \right) \\
+ (\alpha' - \alpha^x) \lambda \left(\frac{\bar{m}}{\theta \sigma} q^2 + \tilde{q} \frac{\omega}{\eta} \right) + (1 - \alpha') \lambda \frac{S_x}{S_z} \frac{\omega}{\eta}
\end{aligned} \tag{50}$$

or

$$q - \tilde{q} = \frac{\eta q^2}{\omega \gamma^*} \frac{\bar{m} - m^*}{\theta \sigma} - \frac{S_x}{S_z} + (\alpha' - \alpha^x) \lambda B + (1 - \alpha') \lambda \frac{S_x}{S_z} \frac{\omega}{\eta}, \tag{51}$$

where B is defined as in (27). Then (26) follows from (51).

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