BANK OF FINLAND DISCUSSION PAPERS

4/98

Jukka Pirttilä

Institute for Economies in Transition

15.4.1998

Earmarking of Environmental Taxes: Efficient, After All

SUOMEN PANKIN KESKUSTELUALOITTEITA • FINLANDS BANKS DISKUSSIONUNDERLAG

Suomen Pankki
Bank of Finland
P.O.Box 160, FIN-00101 HELSINKI, Finland
☎ + 358 9 1831

Jukka Pirttilä

Institute for Economies in Transition
15.4.1998

Earmarking of Environmental Taxes: Efficient, After All

ISBN 951-686-569-0
ISSN 0785-3572

Suomen Pankin monistuskeskus
Helsinki 1998

Earmarking of Environmental Taxes: Efficient, After All

Bank of Finland Discussion Papers 4/98

Jukka Pirttilä*
University of Helsinki and Bank of Finland**

Abstract

The paper analyses the benefits of earmarking the environmental tax revenues in a second-best world with asymmetry of information between government and taxpayers. Taxpayers are assumed to have taste differences over consumption of an environmentally harmful activity. The government, which cannot observe these preferences, pursues Pareto-efficient taxation involving compensation to the potential losers of tax policy. Within this framework, it is shown that earmarking environmental tax revenues on projects that are beneficial to the losers of the environmental policy may alleviate problems concerning asymmetric information and facilitate more efficient environmental policy.

Keywords: Environmental taxation, earmarked taxes, Pareto-efficient taxation, second-best analysis.

JEL Classification: H20, H23.

---

* I am indebted to Craig Brett, Helmuth Cremer, Erkki Koskela, David M. Newbery, Matti Tuomala, the participants at the Nordic Tax Seminar in Oslo and the Conference on the Political Economy of Tax Structure and the Relationship of Taxes to Benefits in St. Catherine's College, Oxford, and, in particular, Michael Keen for helpful comments. The views expressed in this paper are those of the author and not necessarily those of the Bank of Finland.

** Address: Bank of Finland, Institute for Economies in Transition, P.O. Box 160, 00101 Helsinki, Finland. E-mail: jukka.pirttila@bof.fi

Ympäristöverojen korvamerkintä: sittenkin tehokasta politiikkaa

Suomen Pankin keskustelualoitteita 4/98

Jukka Pirttilä
Helsingin yliopisto ja Suomen Pankki

Tiivistelmä

Tutkimuksessa tarkastellaan teoreettisesti ympäristöverojen korvamerkitsemisen mahdollisia etuja tilanteissa, joissa valtiovallan ja veronmaksajien välinen informaatio on epäsymmetristä. Veronmaksajilla oletetaan olevan erilaisia mieltymyksiä ympäristöä saastuttavan kulutuksen suhteen. Valtiovallan, joka ei voi havaita näitä mieltymyseroja, oletetaan pyrkivän Pareto-tehokkaaseen veropolitiikkaan, mikä mahdollisesti sisältää tukipalkkioita veropolitiikasta kärsiville veronmaksajille. Tutkimuksessa osoitetaan, että näissä olosuhteissa ympäristöverojen korvamerkitseminen sellaisten toimenpiteiden rahoitukseen, jotka ovat hyödyllisiä ympäristöpolitiikasta kärsiville, saattaa lieventää epäsymmetriseen informaatioon liittyviä ongelmia ja tehostaa ympäristöpolitiikkaa.

Asiasanat: ympäristöverotus, korvamerkityt verot, Pareto-tehokas verotus, second-best-analyysi

Contents

1 Introduction

Earmarking of environmental taxes, dedicating a share or totality of the environmental tax revenues to environmental items in the expenditure, is quite commonly encountered in real world environmental policy. In France and in Poland, emission tax revenues are used to provide funds for installing new pollution abatement technology, while in Denmark, 50% of the CO_2-tax revenues are reimbursed to taxpayers as compensation. More examples can be found from the US and Swedish environmental policy [OECD (1995) and (1996)]. Hence, there seems to be a widespread belief among policymakers that earmarking environmental taxes must involve some benefits. In addition, some (especially environmental groups) argue that earmarking is needed for rapid implementation of environmental objectives and promotion of additional benefits, such as more advanced technology [see e.g. Andersen (1994)].

Despite their popularity in practice, arguments in favour of earmarking are seldom heard in the economic theory. In general, earmarking is seen as a way to restrict government policy and, hence, leads to non-optimal decision-making. The fear is that earmarking distorts either the spending decision or the decision of tax levels, in the sense that environmental projects, financed solely by the environmental tax revenues, become under- or over-funded or, alternatively, tax rates become too high or low. As noted in the reviews by the OECD (1996) and McCleary (1991), earmarking imposes a constraint on the optimisation of the composition of the government budget, and is therefore not recommended. Both studies argue that only under certain special circumstances, such as when the 'ecotax' alone is insufficient to reach an environmental target or in a transitional economy, does earmarking possibly become a sensible policy option.

A few papers support the idea of earmarking. For example, Buchanan (1963) applies public choice considerations and regards earmarking as a more flexible means of deciding over the allocation of public funds, as it provides the citizens with an opportunity to separately vote for each item of public expenditure. In a recent paper, Brett and Keen (1997) provide a stimulatingly novel rationale for earmarking. They show that, if there is the possibility that politicians may try to increase their own utility at the expense of the social welfare and that the citizens are unable to monitor their politicians perfectly, earmarking of environmental tax revenues to a fund may provide a means to restrict the discretionary power of politicians and enhance the credibility of environmental policy. In a related area of analysis, Ahsan and Tsigaris (1997), Bös (1997) and Renström (1997) examine, broadly speaking, the impacts of exogenously given earmarking rules on economic behaviour.

The aim in this paper is also to consider the rationale for earmarking – not to provide a comprehensive picture of issues related to earmarking – in cases where earmarking might prove beneficial. As in much of the modern research in public economics, the idea is that asymmetry of information between the government and the taxpayers can result in a situation where a deviation from the simple, piecemeal, policy rule 'not to earmark' becomes useful. This result can be regarded as an application of the theory of the second-best, i.e. with imperfect information, it is not clear that those measures which in the first-best world must be avoided, should not be taken in a second-best situation.[1]

---

[1] See Boadway (1995) for a thorough review of the second-best analysis in public economics.

More precisely, in the first-best world we know that introducing an environmental tax on a harmful activity leads to a welfare increase for all agents even if some of them are hurt more by the increase in the environmental tax. This is because the government possesses all the relevant information on agents and can target lump-sum transfers for the losers of the policy. But if the government does not have this information, it cannot know for certain which agents are the actual losers of the policy. This opens up the possibility for some people, by changing their behaviour, to seek higher compensation than they could get in the first-best world. This behaviour can be harmful, such as an increase in the polluting activity, and it certainly leads to imperfect compensation possibilities, which may hamper environmental reforms that otherwise would have been beneficial. Spending the tax revenues on projects that benefit more those who genuinely suffer from the policy instead of direct transfers, in other words, earmarking the tax revenues, could then be a way to alleviate the compensation problems and facilitate more efficient environmental policy.

This paper develops these ideas within a simple model with heterogeneous households that differ in their preferences over the consumption of an environmentally harmful good. The objective of the government is to design a Pareto-efficient environmental taxation/government spending scheme. The models applied in this analysis draw on classic taxation models, including Diamond (1975), Stiglitz (1982) and Boadway and Keen (1993), modified to the case with heterogeneity arising from the differences in preferences, rather than income earning abilities. In the next section, the paper discusses the situation where the government can observe neither the type of households nor their actual consumption decisions, and is therefore restricted to implement linear tax schedules and uniform lump-sum transfers only. Section 3 proceeds to analyse the case along the lines of non-linear tax literature, whereby the consumption bundles of households are observed by the government, but not their preferences. Here, it becomes crucial to design the tax schedule subject to the self-selection constraints of the households. This requires that households find it optimal to select their own bundle and not to mimic the choice of the others. Section 4 examines which kind of earmarking could be beneficial in alleviating the self-selection problems under the non-linear taxation scheme. Section 5 concludes.

2 Earmarking under linear taxation

We consider a model with two types of households (l and h) that consume two goods, an environmentally harmful good, x_d^i, and a clean good, x_c^i. The share of the consumption of the environmentally harmful good in the budget is high for h-types households, and low for l-type. Assuming that the households earn the same and exogenous income, the difference in consumption choice follows from their different preferences over the two goods. Besides the consumption of the clean and dirty good, households' utility also depends on the level of the environmental quality, E. In this section it is assumed, for analytical convenience, that the utility functions are weakly separable between the consumption of the goods and the environmental quality. The direct and indirect utility function of a consumer i are given by $U^i = U^i(\theta^i(x_c^i, x_d^i), E)$ and

$V^i = V^i(q_c, q_d, Y^i, E)$, where q:s denote the consumer prices and Y^i the income of consumer i. The aggregate consumption of the dirty good damages the environment and, since there are assumed to be n^l type l consumers and n^h type h consumers in the economy, the environmental quality is given by

$$E = e\left(\sum_i n^i x_d^i\right), \quad e' < 0. \tag{1}$$

The objective of the government is to determine a Pareto-efficient level of the environmental tax, t_d. In order to balance its budget, the government reimburses tax revenues to households. Assuming linear technology in the production sector with constant producer prices p_c and p_d for the two goods, the consumer prices of the goods are, when the clean good is untaxed, $q_c = p_c$ and $q_d = p_d + t_d$.

Earmarking is introduced in the model by thinking that the government can provide a public good g that is more beneficial to the h-type households, i.e. individuals with a high preference on the polluting consumption. The government therefore possesses two options for rebates: direct lump-sum transfers (depicted by T^i) or the provision of the public good. To capture the fact that earmarking the revenues usually involves some costs, it is assumed that spending on g is never beneficial in a fully-efficient first-best world. Therefore, if, in the second-best optimum, part of the tax revenues is allocated to the provision of g instead of direct transfers, earmarking could arguably be desirable. The approach applied here is not, of course, the most direct way to formalise earmarking (i.e. the connection of a specific tax to a specific item in public spending). What the paper essentially captures is earmarking defined in a somewhat broader sense, that is, as a clear logical link between tax and spending decisions: the introduction of a new tax leads to a need to a particular spending decision because of the compensational concerns of the tax policy. Note also that a similar way to model earmarking is applied in the framework studied by Brett and Keen (1997). An obvious real world example here is the noise and air pollution caused by driving; case h-type households drive more, so they are harder hit by gasoline and vehicle taxes. Their losses could be mitigated by spending a certain part of these tax revenues on such investments as better roads, which would generally benefit h-type households more than those with a lower preference for driving.

In this section, earmarking is modelled under the assumption that public spending affects consumer utility in a special way, namely via their income level. Even if we apply a more standard approach with government spending entering the utility function as a separate argument, it does not change the basic conclusions (see Appendix A). The implications of this alternative formalization are also briefly discussed below. The provision of g is assumed to increase household income through an increasing and concave function b ($b' > 0; b'' < 0$). The fact that public spending is more beneficial for heavy consumers of the harmful good is captured by assuming that the effect of the spending on type l's income is multiplied by a factor α, $0 \leq \alpha < 1$. The consumers' exogenous incomes are then given by

$$Y^h = Y + T^h + b(g), \quad Y^l = Y + T^l + \alpha b(g). \tag{2}$$

2.1 First-best solution

To provide a benchmark case for the analysis, the first-best problem, whereby the government knows the type of the consumers and can therefore pursue differentiated lump-sum transfers, is solved first. As we concentrate on Pareto-efficient tax schedules, the government maximizes the welfare of *l*-type households, subject to a given level of utility to the *h*-types. This level can be interpreted as the utility *h*-type consumers enjoy in an uncontrolled market economy; the participation constraint of the *h*-type households hence captures the fact that the policy must be politically feasible. The corresponding Lagrange multiplier μ for the utility constraint is associated with the valuation of the utility of *h*-type households in the social welfare maximand. Note that when μ=1, the Pareto-efficient approach applied here corresponds to maximizing a Utilitarian social welfare function. The Lagrangian function of the optimization problem is written as:

$$\begin{aligned} L &= n^l V^l(q_c, q_d, Y + T^l + \alpha b(g), E) \\ &+ \mu n^h \left[V^h(q_c, q_d, Y + T^h + b(g), E) - \bar{V}^h\right] \\ &+ \gamma\left[\sum_i n^i t_d x_d^i(q_c, q_d, Y^i) - \sum_i n^i T^i - g\right] + \zeta g \end{aligned} \quad , \tag{3}$$

where $\zeta \geq 0$ is the multiplier of the non-negativity constraint of the level of public spending (as we want to incorporate the possible corner solution with $g = 0$). The government maximizes the Lagrangian function with respect to the environmental tax, lump-sum transfers, and the public consumption *g*. This yields the following first-order conditions:

$$-n^l \lambda^l x_d^l - \mu n^h \lambda^h x_d^h + \gamma \sum_i n^i x_d^i + \gamma \sum_i n^i t_d \frac{\partial x_d^i}{\partial q_d} + \psi e' \sum_i n^i \frac{\partial x_d^i}{\partial q_d} = 0 , \tag{4}$$

$$n^l \lambda^l + \gamma n^l t_d \frac{\partial x_d^l}{\partial Y} + \psi e' n^l \frac{\partial x_d^l}{\partial Y} - \gamma n^l = 0 , \tag{5}$$

$$\mu n^h \lambda^h + \gamma n^h t_d \frac{\partial x_d^h}{\partial Y} + \psi e' n^h \frac{\partial x_d^h}{\partial Y} - \gamma n^h = 0 , \tag{6}$$

$$\begin{aligned} &n^l \lambda^l \alpha b' + \mu n^h \lambda^h b' + \gamma n^l t_d \frac{\partial x_d^l}{\partial Y} \alpha b' + \gamma n^h t_d \frac{\partial x_d^h}{\partial Y} b' \\ &+ \psi e' n^l \frac{\partial x_d^l}{\partial Y} \alpha b' + \psi e' n^h \frac{\partial x_d^h}{\partial Y} b' - \gamma + \zeta = 0 \end{aligned} \quad , \tag{7}$$

where λ^i depicts the marginal valuation of the private income of household *i*, and $\psi = n^l V_E^l + \mu n^h V_E^h$ the social marginal valuation of the environmental quality. Substitution from (5) and (6) in (4) and some rearranging allows the optimal level of the environmental tax to be solved. This gives:

$$t_d = -\frac{\psi e'}{\gamma}, \tag{8}$$

which is equal to the standard Pigovian corrective tax. Inserting (8) into the first-order conditions for lump-sum transfers reveals that optimal transfers are determined by the principle that the marginal values of income to different households should be equalized:

$$\lambda^l = \gamma = \mu\lambda^h. \tag{9}$$

Note, however, that the Lagrange multiplier of the utility constraint affects the marginal value of household h's income. Using the conditions (8) and (9), the rule for the optimal level of public spending (7) can be rewritten as

$$\frac{\zeta}{\gamma} = 1 - \left(n^h + \alpha n^l\right)b'. \tag{10}$$

To interpret this formulation, recall first the approach that spending on g involves some efficiency loss, i.e. g is always larger than its influence on private income. In other words, $g > n^h b(g) + \alpha n^l b(g)$. If b is assumed to be concave, and $b(0)=0$, the derivative of the curve representing the influence of g on the income level, $n^h b' + \alpha n^l b'$ is always smaller than the slope of a curve giving the effect of a wholly efficient transfer on income (i.e. a 45-degree slope), which is equal to 1. This means that the right-hand side of (10) is always positive, implying a positive ζ and, from the complementary slackness condition, that the level of g should be zero in the first-best world.

These results restate the well-known properties of the first-best equilibrium, according to which the external impacts of the polluting activity are internalized by the Pigovian tax, and lump-sum transfers are the optimal way to redistribute income among different types of consumers. Therefore, with the assumption that providing g involves some efficiency loss, it is not optimal for the government to employ it as a redistributive (compensative) measure.

2.2 Second-best solution

We turn now to tax policy in the second-best situation, where the government no longer shares all the information on the households. Since it cannot observe the types and the consumption of the households, it is restricted to use only uniform lump-sum transfers ($T^l = T^h = T$). Maximizing the Lagrangian function with respect to T, we obtain the following condition:

$$n^l\lambda^l + \mu n^h\lambda^h + \gamma\sum_i n^i t_d \frac{\partial x_d^i}{\partial Y} + \psi e'\sum_i n^i \frac{\partial x_d^i}{\partial Y} - \gamma(n^l + n^h) = 0. \tag{11}$$

For interpretation, we define the net social marginal valuation of household *i*'s income, measured in terms of the government revenue, as $\delta^i = \frac{\beta^i}{\gamma} + t_d \frac{\partial x_d^i}{\partial Y} + \frac{\psi e'}{\gamma}\frac{\partial x_d^i}{\partial Y}$, where $\beta^i = \begin{cases} \lambda^l, for\ i = l \\ \mu\lambda^h, for\ i = h \end{cases}$. This concept, discovered by Diamond (1975), depends on the direct valuation of an increase in income (β^i), the impact of the extra income on tax revenue and, in the presence of the externality, the level of the environmental quality. Rearranging (11) and utilizing δ provides the following condition:

$$\bar{\delta} = 1, \qquad (12)$$

where $\bar{\delta}$ denotes the average value of the net social marginal valuation of income. Equation (12) may be readily interpreted. It states that, on the average, the marginal utility of income should be equal to cost of providing the income, which is equal to 1. Using the Slutsky equation $\frac{\partial x_d^i}{\partial q_d} = s_{dd}^i - \frac{\partial x_d^i}{\partial Y} x_d^i$ (where s_{dd}^i denotes the compensated own price effect of the demand of the dirty good) and substituting from the definition of δ, the condition for optimal t_d,(4), can be rearranged as follows:

$$t_d \sum_i n^i s_{dd}^i = \sum_i n^i (\delta^i - 1) x_d^i - \frac{\psi e'}{\gamma} \sum_i n^i s_{dd}^i . \qquad (13)$$

Denoting the covariance between the net social marginal valuation of household *i*'s income and the consumption of the environmentally harmful good by the same household by $\mathrm{cov}(\delta^i, x_d^i)$, (13) can be rewritten (with $\bar{s}_{dd}$ denoting the average value of the compensated own price effect) as

$$t_d = \frac{\mathrm{cov}(\delta^i, x_d^i)}{\bar{s}_{dd}} - \frac{\psi e'}{\gamma} . \qquad (14)$$

This tax rule includes the standard Pigovian part (now evaluated in the second-best situation) and a new component, the covariance term, which addresses the incomplete compensation possibilities of the government. The covariance term is an application of the tax rule developed by Diamond (1975) for many-person commodity taxation.[2] In addition, the result in (14) restates the additivity property of the taxation of externalities discovered by Sandmo (1975), whereby the externality-based part is added as a separate term to the commodity tax rule.

In contrast to the first-best case, the incomplete compensation possibilities of the second-best world imply that the net social marginal valuations of income can now vary

---

[2] Sandmo (1993) derives a partly similar formulation for the optimal linear income tax rate in the case where households have different preferences over the choice between work and leisure.

between the households. This means that the government must take the compensation policy into account in the level it sets the environmental tax. Supposing that h-type households suffer more from an increase in the environmental tax, there can be two reasons why the net social valuation of their income is larger than average. Horizontal equity may imply that the government wants to compensate the h-type households for their loss arising from the environmental policy. In this case, the covariance in the numerator becomes positive, and as divided by a negative term, the first term on the right is negative, hence decreasing the optimal value of the second-best environmental tax. Recall, however, that the net social valuation of income involves the multiplier μ, which complicates the comparison. Another case for δ^h to be large arises when the multiplier of the utility constraint of the h-type households takes a large value, and the government is forced to redistribute income to them in order to carry out the tax policy. In both cases, the level of environmental taxation is lowered to account for the distributional concerns.[3]

We now turn to the potential role of public expenditure g as a means of addressing the compensation policy. Even though earmarking was never beneficial in the first-best world, the fact that the second-best situation constraints redistributive policies may open up a possibility to obtain some gains by earmarking the revenues. To examine this, combine (7) and (11) and use the definition of δ to obtain

$$(n^l + n^h)\alpha b' - n^h\delta^h\alpha b' + n^h\delta^h b' - 1 + \frac{\zeta}{\gamma} = 0. \tag{15}$$

Rearranging and adding and subtracting $n^h b'$ yields

$$\frac{\zeta}{\gamma} = 1 - (n^h + \alpha n^l)b' + (1-\alpha)(1-\delta^h)n^h b'. \tag{16}$$

Compared to (10), equation (16) reveals that in the second-best situation, the rule for the optimal level of public spending now involves an extra term. While the two first terms on the right still imply, because of the efficiency loss, that ζ should be positive, the last term on the right is negative when the net social valuation of h-type income is larger than average (=1). The presence of this new negative term means that ζ might become zero in the optimum, if the compensation term is large enough and outweighs the losses from efficiency. In the second-best situation, it can very well be beneficial to earmark the revenues for compensation, depending on the relative magnitude of the ability of g to influence distribution of welfare (how much α differs from unity), and the costs of providing the public project.

Consider finally a special case where there is no loss in the provision of g, i.e. $(n^h + \alpha n^l)b' = 1$, which means that the sign of ζ depends on the compensation term only. With an efficient g, the public provision system, combined with appropriate funding through the lump-sum tax T, can provide a differentiated lump-sum tax structure to

---

[3] The analysis of the opposite case with δ^l large would proceed in a similar manner. This case could arise in a situation where μ is small, and the government can increase the welfare of l-type households by redistributing income to them.

the economy, since h-types always obtain higher utility from public spending. This seems to imply two cases. First, if the redistribution goes from the l-types to the h-ones, the system corresponds to the first-best situation, so we know, from the first-order conditions (5) and (6), that $\delta^l = \delta^h = 1$. Therefore ζ is equal to zero, public spending positive and earmarking used. Second, if the net social marginal valuation of l-type income is higher than average, the rule for ζ is always positive and earmarking is not used. The reason for this is straightforward: as we want to transfer income to l-types, g is an inefficient device because it benefits h-types more.

In conclusion, we see that, in contrast to standard thinking, earmarking tax revenues can be efficient even when there are some costs in spending the revenues on earmarked items instead of direct transfers. Note finally that the particular way of incorporating earmarking employed here abstracts from some features in the assessment of the benefits of earmarking. Most notably, earmarking probably influences the level of the harmful activity (for instance, if the road system gets better, it may increase road traffic). These considerations are illuminated in Appendix A, where the provision of the public good is modelled in a traditional way. The derived rule shows that the optimal level of earmarking depends on the feed-back effect on the demand of the harmful good and on the tax revenue impact. This extension does not, however, undermine the conclusion of the basic rationale for earmarking in the second-best situation.

3 Non-linear taxation of an externality

This section introduces another assumption concerning the asymmetry of information. Along the lines of many public economics models, it is assumed that the government can observe the choices of consumers, but not the types of consumers. This means that tax and compensation policy rules can be based on the consumption decision – the government may therefore pursue non-linear taxation of an externality. Note that a non-linear tax scheme for an externality may be generated, for instance, by a combination of a linear tax on the harmful commodity and differentiated lump-sum transfers. Therefore, this section aims to characterize solutions to the non-linear commodity taxation problem within the present model.

The difference now to the fully-efficient first-best world is that the transfers are based solely on observed consumption, not the preferences of households. If the government wishes to employ non-linear taxation, therefore, it is restricted by the self-selection constraints of households, stating that the households are better off in choosing a bundle designed for them than mimicking the choice of another type of consumer. For two types of consumers, the self-selection constraints can be written as

$$U^h(x_c^h, x_d^h, E) \geq U^h(x_c^l, x_d^l, E), \tag{17}$$

$$U^l(x_c^l, x_d^l, E) \geq U^l(x_c^h, x_d^h, E). \tag{18}$$

Because of the assumption concerning asymmetric information, a more detailed investigation of consumer preferences is required.

Figure 1 Households' indifference curves

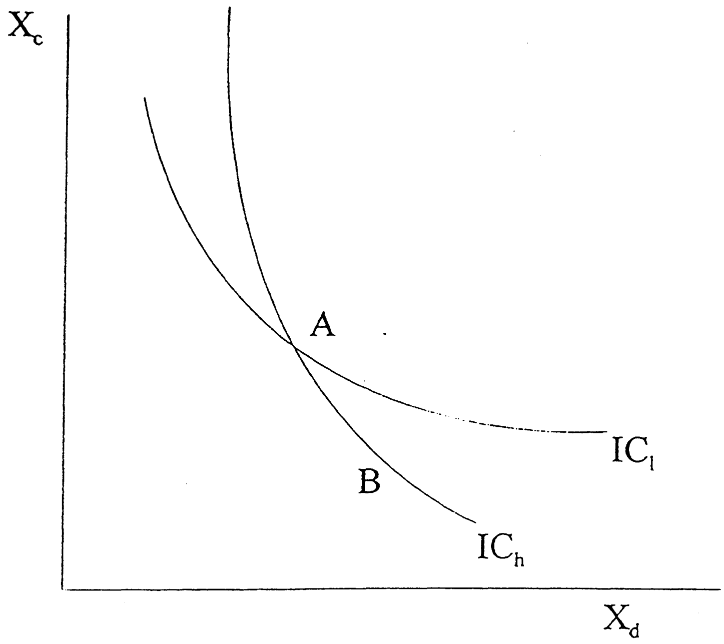

Figure 1 presents the indifference curves of the two household types. It assumes that the indifference curve for the *h*-type is always steeper than for the *l*-type in the (x_d^i, x_c^i)-space. The intuition for this is that the willingness of an *h*-type household to pay for the consumption of the dirty good is higher than that of an *l*-type. This assumption implies that the following single crossing property holds:

$$\frac{U_d^h}{U_c^h} > \frac{U_d^l}{U_c^l}, \tag{19}$$

where U_d^h, for instance, is the marginal utility of consuming the dirty good by a household of type *h*. It can be seen from Figure 1 that the self-selection constraints alone require that $x_d^h \geq x_d^l$ and $x_c^l \geq x_c^h$. Supposing that point A is the bundle meant for *l*-types, then the h-type consumption bundle that satisfies the self-selection constraint that an *l*-type does not want to mimic type *h* must lie in the area down and to the left of the indifference curve IC_l. Similarly, the self-selection constraint that an *h*-type does not mimic an *l*-type is satisfied in the area above and to the right of the indifference curve IC_h. Together these imply that the consumption of the dirty good must be higher for the *h*-type, and *vice versa* in the case of the consumption of the clean good.

It can also be deduced that both self-selection constraints cannot bind at the same time. Supposing still that A is the bundle chosen by the *l*-type, then a binding self-selection constraint (17) would require that point A and the choice of a true type-*h* consumer, B, must be on the same indifference curve. But a binding self-selection constraint (18) would then require that the utility for *l*-types from consuming B must be the same as from A, which requires either that the indifference curves of the agents are identical or that the indifference curves cross twice. As this violates the assumptions of the model, both self-selection constraints cannot simultaneously hold.

Unfortunately, without any additional assumptions, it cannot be deduced which self-selection constraint actually binds in the discussed tax framework. As in the standard income tax problem, it depends on the background assumption concerning the redistribution of income applied in the model. Consider first the case where the government tries to redistribute income from the *l*-type consumers to the *h*-ones. This corresponds to the case discussed above where, because of the aim for horizontal equity, the government compensates those who are heavily exposed to rising environmental taxation for their losses. Because of imperfect information, there are, however, limits to the redistribution: at some point, the designed consumption/compensation bundle for the *h*-types may become attractive from the viewpoint of the *l*-types, as well. Therefore, the self-selection constraint for the *l*-type households, equation (18), may, but not necessarily, bind. Note that the assumption about redistribution occurring from *l* to *h*-types is sufficient for the self-selection constraint (17) not to bind: mimicking *h*-type households would be obliged both to choose a sub-optimal bundle and enjoy lower level of income. Similarly, under the case where the government redistributes income from *h*-types to *l*-types, *h*-type households may or may not want to mimic the choice of the *l*-ones, and the potentially binding self-selection constraint is now the one in (17). Accordingly, *l*-type households would never like to mimic *h*-types under this redistribution scheme. To concentrate on the underlying idea in the paper that the high-type households need a larger compensation, it is assumed below that only the self-selection constraints for the *l*-types can bind, as they may want to obtain the higher compensation intended to those whose incidence on the pollution tax is higher. The analysis in the opposite case would go through in a similar fashion; the results are briefly presented in Appendix B.

We may now proceed to the optimization problem of the government. As is common within the non-linear tax literature, it is now formulated in terms of direct utility functions.[4] Marginal tax rates are expressed implicitly by solving the marginal rate of substitution between the goods from the model. Using the consumer budget constraints to rewrite the government budget equation, and assuming that (18) can bind, the Lagrangian form of the optimization problem would be:

$$\begin{aligned} L = {} & n^l U^l(x_c^l, x_d^l, E) + \mu n^h\left[U^h(x_c^h, x_d^h, E) - \overline{U}^h\right] \\ & + \phi n^l\left[U^l(x_c^l, x_d^l, E) - U^l(x_c^h, x_d^h, E)\right] \\ & + \gamma \sum_i n^i\left[Y - p_c x_c^i - p_d x_d^i\right] \end{aligned} \quad . \tag{20}$$

Note that in this section, it is assumed that there is no revenue requirement for the government, i.e. we do not analyse the optimality of earmarking yet. As we know that the fully optimal first-best solution within this framework is the same as in the previous section, we proceed directly to the second-best case, where the self-selection constraint

4 Indirect utility functions cannot be used, because a mimicker cannot choose the composition of his bundle, and the resulting utility level for a given income is not the optimal for him.

binds.[5] The first-order conditions are as follows (omitting arguments and denoting the mimicker with a hat symbol):

$$(n^l + \phi n^l)U_c^l - \gamma n^l p_c = 0\,, \tag{21}$$

$$(n^l + \phi n^l)U_d^l + \psi e' n^l - \gamma n^l p_d = 0\,, \tag{22}$$

$$\mu n^h U_c^h - \phi n^l \hat{U}_c^l - \gamma n^h p_c = 0\,, \tag{23}$$

$$\mu n^h U_d^h - \phi n^l \hat{U}_d^l + \psi e' n^h - \gamma n^h p_d = 0\,, \tag{24}$$

where ψ depicts again the social marginal valuation of the environmental quality. Without any separability assumptions, this is given by $n^l U_E^l + \mu n^h U_E^h + \phi n^l (U_E^l - \hat{U}_E^l)$, which in the most plausible case is positive. This term is analysed closer below in section 4.2 when discussing the merits of different earmarking possibilities.

As mentioned above, the model only provides implicit marginal tax rates for the goods. Using the clean good as the numeraire, and dividing (22) by (21), generates the following optimality condition for the choice of the low-type:

$$\frac{U_d^l}{U_c^l} = \frac{1}{p_c}\left(p_d - \frac{\psi e'}{\gamma}\right). \tag{25}$$

Equation (25) indicates that the choice for the low-type now involves no distorting element, only the externality-internalizing Pigovian element. Interpreted as a tax rule on the polluting good, the effective tax rate now, within the non-linear tax schedule, is the Pigovian tax only, compared to the two-component tax rule derived in the previous section. The choice for the h-type is thus determined by

$$\frac{U_d^h}{U_c^h} = \frac{1}{p_c}\left(p_d - \frac{\psi e'}{\gamma}\right) + \frac{\phi^*}{n^h}\left(\frac{\hat{U}_d^l}{\hat{U}_c^l} - \frac{U_d^h}{U_c^h}\right), \tag{26}$$

which follows from dividing (24) by (23) and some rearrangements; $\phi^* > 0$ is a shorthand for $\dfrac{\phi n^l \hat{U}_c^l}{\gamma p_c}$. The single crossing property of (19) then implies that the term in brackets is negative, and hence the marginal tax rate, perceived by high-consumption households, is smaller than that of l-type consumers. The self-selection term is, in other words, a subsidy that diminishes the increase in the tax rate on the polluting good arising from the Pigovian component. As the marginal tax rate changes towards a situation

[5] The self-selection constraint was implicitly present in the previous section as well. The fact that the government could not observe consumer choice resulted, however, in a situation where the self-selection constraint was trivial: every consumer, regardless of the compensation, could still pick his or her own bundle, and self-selection was guaranteed.

which actually encourages the consumption of the harmful good, the bundle of the *h*-type becomes less attractive for the potential mimicking *l*-type households, since the share of the dirty good in consumption becomes larger. Deterring mimicking in this way is thus a way to facilitate redistribution to high-consumption consumers.

Note finally that enhancing the *h*-type's consumption of the dirty good is not against the policy of internalizing the externality, since the environmental considerations are taken care of by the presence of the Pigovian component. However, the fact that the government has to deter mimicking by distorting the consumption choice of the *h*-type towards favouring larger consumption of the dirty good lowers the environmental quality compared to the fully efficient first-best solution. Intuitively, this suggests that earmarking the tax revenues for a project that would deter mimicking, but not pollute the environment, might turn out to be beneficial even under non-linear taxation of externalities.

4 Earmarking possibilities under non-linear taxation

We now analyse the potential role of earmarking as a device to ease the self-selection constraint that partly hampers government tax policy under non-linear taxation. We start by examining two cases that might be regarded as beneficial candidates for earmarking and demonstrate, in contrast with a *prima facie* impression, that their scope does not turn out be especially promising. First, we examine whether the case discussed above in the context of linear taxation, earmarking the revenues to provide a public good, still has merits under the more general framework of this section. The second case to be discussed is spending the revenues on some generally environmentally friendly items in the expenditure, which is sometimes suggested, especially by environmentalists, as another candidate for earmarking. Much more promising views are, however, provided by the third case analysed herein, earmarking the revenues to subsidising goods that are consumed in conjunction with the pollution consumption, but which are not in themselves environmentally harmful. Analysis of the last case in the main focus here. It is discussed in section 4.3.

4.1 Public good provision

The public good provision is modelled here in the usual way where it enters consumer utility function as an additional argument. Modifying the Lagrangian equation (20) (by inserting the public good with a producer price *r* into the government budget constraint and introducing a non-negativity multiplier ζ_g) produces the first-order condition for the optimal level of the public good

$$n^l U_g^l + \mu n^h U_g^h + \phi n^l (U_g^l - \hat{U}_g^l) - \gamma r + \zeta_g = 0. \tag{27}$$

Using the clean good as a numeraire, and substituting from the first-order conditions (21) and (23), we obtain:

$$n^l \frac{U_g^l}{U_c^l}\gamma p_c + \frac{U_g^h}{U_c^h}(\gamma n^h p_c + \phi n^l \hat{U}_c^l) - \phi n^l \hat{U}_g^l - \gamma r + \zeta_g = 0. \tag{28}$$

We next define the marginal rate of substitution between the public good and clean consumption as $MRS_{gc}^i = \frac{U_g^i}{U_c^i}$. Rearranging (28) yields the following expression for the public good provision:

$$\frac{\zeta_g}{\gamma p_c} = \frac{r}{p_c} - \sum_i n^i MRS_{gc}^i + \phi^* (M\hat{R}S_{gc}^l - MRS_{gc}^h). \tag{29}$$

This condition states that the optimal provision rule for the public good depends on the assessment of the costs of its provision (the first term on the right), the sum of the marginal rate of substitution (the second term) and a term which takes account of the impact of public good provision on the mimicking behaviour (the last term). The two first terms produce the Samuelson, first-best, principle of the provision rule; assuming again that in the fully efficient case the costs of provision always exceed its benefits, the difference of the two first terms is positive. Hence, ζ_g becomes positive as well, and the optimal level of g is zero. In the second-best situation, if h-type consumers really do place a higher value on the public good, the term in brackets becomes negative, and ζ_g may be zero as well. This means that, despite efficiency loss, the public good provision is welfare improving; it makes mimicking less attractive and relaxes the self-selection constraint. Note that the analysis here draws directly on the contribution in Boadway and Keen (1993), but with the difference that the heterogeneity in the model is now over the preferences, not the income earning ability, of consumers as in the optimal income tax problem.

In contrast to the income tax model, the potential effectiveness of public good provision as a redistributive device seems quite limited within the present model. The reason is that, as the true type-h household and a mimicker must choose the same consumption bundle, the only difference between them are the different preferences.[6] Therefore, in contrast to the analysis of earmarking in section 2, public spending on a project is only efficient if its valuation depends on the preferences of the goods, not on their actual consumption. In section 2, a relatively natural example of potentially beneficial earmarking was government investment in better roads; within this section, this simple example does not necessarily work, as the mimicker and the true high type households both drive the same amount.

---

[6] This is different to the standard income tax problem, where a mimicker only earns the same income than a true low-ability household, but may consume different goods as commodities are not usually non-linearly taxed.

4.2 Public spending on general improvement of the environment

Another candidate for earmarking, which could be encountered in real world policy discussion, is public expenditure on some general improvement of the environmental quality. This is modelled here by assuming that the government can spend the tax revenues on public abatement technology *A*, which improves the environmental quality through the function $E = e\left(\sum_i n^i x_d^i, A\right)$, $e_{X_d} < 0, e_A > 0$. The rule for the optimal provision of *A*, supposing that the producer price of A is p_A, and introducing the non-negativity constraint with a multiplier ζ_A, is the following:

$$n^l U_E^l + \mu n^h U_E^h + \phi n^l (U_E^l - \hat{U}_E^l) - \gamma \frac{p_A}{e_A} + \frac{\zeta_A}{e_A} = 0. \tag{30}$$

Using again the clean good as the numeraire, (30) can be rearranged to get a similar rule than in the case of a usual public good

$$\frac{\zeta_A}{\gamma p_c e_A} = \frac{p_A}{p_c e_A} - \sum_i n^i MWP_{Ec}^i + \phi^* (M\hat{W}P_{Ec}^l - MWP_{Ec}^h), \tag{31}$$

where $MWP_{Ec}^i = \frac{U_E^i}{U_c^i}$ denotes the marginal willingness to pay for environmental quality. The first term on the right denotes the marginal rate of transformation between one unit of the clean good and environmental quality, obtained through public investment in the abatement. Assuming again that this investment is not carried out in the first-best situation, the Samuelson rule of the public good 'environmental quality', captured by the sum of the two first terms, implies a positive ζ_A and a zero investment level on *A*. As before, the self-selection term (the third term on the right) may change this conclusion, if the true high type representative has a sufficiently large valuation of the environment.[7] Hence, if higher environmental quality relaxes the self-selection constraint enough to overcome the efficiency loss, earmarking the environmental tax revenues to a general clean-up project is welfare improving.

The potential merits of an investment in general abatement technology do not, however, seem especially promising within the present model. The reason is that it is hard to see why a mimicker, who gives a higher value to an environmentally friendly good, would not value the environmental quality as much as a representative of the type that consumes more of the polluting good. On the contrary, it seems more natural to predict that the *l*-type mimickers have a higher valuation of the environment, since this might actually be the underlying reason to consume less of the environmentally harmful good.

[7] The relative valuation of the environment by a true type and a mimicker has also been analysed before by Pirttilä and Tuomala (1997) in the context of an income tax problem.

Note also that the social valuation of the environmental quality in the tax rules, captured by the term ψ, can be modified to comprise the same kind of terms: the sum of the marginal willingness to pay for the environment, and a term taking account of the comparison between the environmental valuation by a true h-type consumer and a mimicker. The discussion above then suggests that the mimicking term lowers the value of ψ compared to the first-best formulation, where the mimicking term disappears. This indicates that the externality-internalizing term in tax rules (25) and (26) is not the same first-best Pigovian tax, but most likely a smaller, but still positive, component. Only when the preferences are weakly separable between the consumption of goods and the environmental quality does the self-selection term vanish so that the environmental part of the tax rule is determined simply by the Pigovian principle.

4.3 Goods consumed in conjunction with the polluting good

Intuition suggests that goods whose consumption depends on the demand for the polluting good, but which are not in themselves environmentally harmful, might be promising candidates for earmarking. The obvious case here is the quantity/quality choice in the consumption of the harmful activity. For example, improving the technology of automobiles might enable lower emissions for a given amount of driving. Providing better insulation for houses might help reduce the fuel consumption needed for heating.

To carry out the analysis of such goods, the model requires slight modifications. Here, we assume that the potentially earmarked good is a private good, and its level is chosen separately by both types of households. Further, we assume that the harmful activity is consumed in a 'package', whose utility is weakly separable from the other utility. Hence, the utility function of household i can be rewritten as $U^i = U^i(x_c^i, f(x_d^i, x_q^i), E)$, where x_q^i depicts the quality, x_d^i is now interpreted as the quantity of the polluting activity, and their valuation is determined by the sub-utility function f, which is assumed to be independent of the types of the consumers for analytical simplicity. The single-crossing condition is now expressed in terms of the valuation of the composite good f:

$$\frac{U_f^h}{U_c^h} > \frac{U_f^l}{U_c^l}. \tag{32}$$

The government's objective is to find Pareto-efficient non-linear tax schedules both for x_d^i and x_q^i. Denoting the producer price of the quality good as p_q, and the multipliers of the non-negativity restrictions for the provision of these goods as ζ_q^l and ζ_q^h for the low and high types, respectively, the Lagrangian form of the optimisation problem is rewritten as

$$
\begin{aligned}
L = {} & n^l U^l(x_c^l, f(x_d^l, x_q^l), E) + \mu n^h \left[U^h(x_c^h, f(x_d^h, x_q^h), E) - \overline{U}^h \right] \\
& + \phi n^l \left[U^l(x_c^l, f(x_d^l, x_q^l), E) - U^l(x_c^h, f(x_d^h, x_q^h), E) \right] \\
& + \gamma \sum_i n^i \left[Y - p_c x_c^i - p_d x_d^i - p_q x_q^i \right] + \zeta_q^l n^l x_q^l + \zeta_q^h n^h x_q^h
\end{aligned} \quad . \tag{33}
$$

The first-order conditions are hence the following:

$$(n^l + \phi n^l) U_c^l - \gamma n^l p_c = 0 , \tag{34}$$

$$(n^l + \phi n^l) U_f^l f_d + \psi e' n^l - \gamma n^l p_d = 0 , \tag{35}$$

$$(n^l + \phi n^l) U_f^l f_q - \gamma n^l p_q + \zeta_q^l n^l = 0 , \tag{36}$$

$$\mu n^h U_c^h - \phi n^l \hat{U}_c^l - \gamma n^h p_c = 0 , \tag{37}$$

$$\mu n^h U_f^h f_d - \phi n^l \hat{U}_f^l f_d + \psi e' n^h - \gamma n^h p_d = 0 , \tag{38}$$

$$\mu n^h U_f^h f_q - \phi n^l \hat{U}_f^l f_q - \gamma n^h p_q + \zeta_q^h n^h = 0 . \tag{39}$$

Note that the environmental quality still depends only on the quantity of the harmful activity, i.e. the consumption of the dirty good. Concentrating first on the choice of the l-type, dividing (35) by (34) reveals that the implicit tax rule on the dirty good for the type who is not mimicked involves again only the corrective, externality-internalizing term. The choice between the quality good and the clean good is determined by

$$\frac{\zeta_q^l}{\gamma p_c} = \frac{p_q}{p_c} - \frac{U_f^l f_q}{U_c^l} , \tag{40}$$

which can be derived by dividing (36) by (34). Proceeding consistently with the previous analysis, it is assumed that in the first-best world, the marginal rate of transformation always exceeds the marginal rate of substitution between the quality and the clean good, meaning that the multiplier on the left is positive and the optimal level of quality for the low type zero. Hence, (40) implies that no taxes or subsidies should be imposed on the quality consumption by the l-types.

Turning now to the taxation of the high-consumption household, division of (38) by (37) implies that the choice between the dirty and clean consumption is given by

$$\frac{U_f^h f_d}{U_c^h} = \frac{1}{p_c}\left(p_d - \frac{\psi e'}{\gamma} \right) + \frac{\phi^*}{n^h}\left(\frac{\hat{U}_f^l}{\hat{U}_c^l} - \frac{U_f^h}{U_c^h} \right) f_d . \tag{41}$$

The implicit marginal tax rate on the harmful good should again be smaller than the externality-internalising component, since the self-selection term is negative by the single crossing property in (32). The intuition provided in section 3 still applies: favouring the consumption of the dirty good decreases mimicking since the consumption bundle of

h moves away from l-type optimum. Naturally, a similar kind of a rule can be deduced for the quantity/clean good choice by dividing (39) by (37) and rearranging:

$$\frac{\zeta_q^h}{\gamma p_c} = \frac{p_q}{p_c} - \frac{U_f^h f_q}{U_c^h} + \frac{\phi^*}{n^h}\left(\frac{\hat{U}_f^l}{\hat{U}_c^l} - \frac{U_f^h}{U_c^h}\right) f_q . \tag{42}$$

Equation (42) indicates that, even if the costs of acquiring quality always exceed the benefits in the first-best world, the presence of the self-selection term in the second-best situation may imply that the optimal level of quality becomes positive (because ζ_q^h reduces to zero). As households do not buy the quality good at the producer price, quality should then be subsidized for the high-consumption type. The intuition is still the same: as a lower implicit marginal tax rate on the dirty good, a subsidy on quality makes the consumption bundle less attractive for the mimickers, which assists compensation (or redistribution) policy of the government. Since the redistribution possibilities are restricted in the second-best situation, providing a good that is more beneficial for high-consumer types (who suffer most from the environmental policy) is thus a form of compensation to those people. Earmarking the revenues on quality, even if it involves an efficiency loss, can therefore become welfare improving. Note that the logic in the argument here bears resemblance to the discussion on the role of public provision of private goods as a device to ease the self-selection constraint in the context of optimal non-linear income taxation. Recent contributions in this field include Blomquist and Christiansen (1997) and Cremer and Gahvari (1997), which also discuss some further references. An obvious difference of the present study to the optimal income tax literature is the assumption that indiduals differ in terms of their preferences of the polluting consumption, not in their income earning ability.

Because of the assumption about weakly separable preferences, the decision over quality and quantity (i.e. the dirty good) is determined solely by the f-function. As this function is the same for both types, the levels are given by

$$\frac{f_d}{f_q} = \frac{p_d - \psi e'/\gamma}{p_q - \zeta_q^i/\gamma}, \tag{43}$$

according to which the difference between the household types only depends on the value of the non-negativity multiplier, ζ_q^i. Equation (43) establishes a link between the value of ζ_q^i and equation (41) that gives the implicit marginal tax rate on the dirty good. Substituting for f_d from (43) enables (41) to be rewritten as

$$\frac{U_f^h f_d}{U_c^h} = \frac{1}{p_c}\left(p_d - \frac{\psi e'}{\gamma}\right) + \frac{\phi^*}{n^h}\left(\frac{\hat{U}_f^l}{\hat{U}_c^l} - \frac{U_f^h}{U_c^h}\right)\left(\frac{p_d - \psi e'/\gamma}{p_q - \zeta_q^h/\gamma}\right) f_q . \tag{44}$$

From here it can be seen that if earmarking becomes welfare-improving, the value of the non-negativity multiplier ζ_q^h reduces from strictly positive to zero, meaning that the middle term in (44), i.e. the term addressing mimicking, becomes smaller in absolute value, and hence, the implicit marginal tax rate on the dirty good for high-consumption type increases in comparison to the case where revenues are not earmarked. This suggests that environmental quality, as interpreted from the first-order condition, is higher under earmarking than in the 'normal' second-best case. Note, however, that the implicit marginal tax rate never rises *above* the first-best principle, since the self-selection term is also present under earmarking.

The conclusion concerning the level of environmental quality is interesting in the light of the various reasons given for earmarking in real world policy discussion. As mentioned in the introduction, environmentalists tend to argue that earmarking environmental tax revenues on cleaner technology is needed, since it improves the environmental quality faster. The result in (44) is in line with this argument, though the reasons for higher environmental quality and the optimality on the subsidy on the quality arise from different considerations. Another reason mentioned for earmarking was the case where an environmental tax alone is not sufficient to reach a predetermined requirement on the level of the environment. If imperfect compensation possibilities decrease the environmental tax too much, in the sense that obtaining this given level of the environment is not possible, earmarking part of the tax revenues on cleaner technology can, based on the results in this section, facilitate the accomplishment of this objective.

In brief, this analysis of the quantity/quality choice reveals that earmarking part of the environmental tax revenues on qualitatively better composite consumption of the harmful activity may be welfare improving as it provides an indirect way to compensate those consumers whose share on the polluting activity is large. This implies that the level of the compensative term in the marginal tax rate on the polluting (quantity) good can be reduced, enabling an improvement in environmental quality as the relative share of the dirty good decreases in the consumption decision of high-consumption households. Note finally that earmarking only concerns the quality purchases by the high-consumption type, as the choice of the l-type is not changed. Interpreted in terms of a tax rule, this suggests that the government earmarks part of the commodity tax revenues on subsidizing better quality for people whose consumption of the composite commodity is large. To illustrate, if the composite good is associated with providing the heating in accommodation, the insulation purchases by the high energy consumers should be subsidized from the energy tax revenue.

5 Conclusion

Earlier analysis of earmarking has concluded that, while it is not beneficial in general, it can nonetheless be given some rationale under special circumstances. The present paper elaborated this idea further, showing that, with asymmetry of information between the government and the taxpayers, earmarking of environmental tax revenues may actually be welfare improving.

This paper concentrates on a situation where the government is restricted to Pareto-efficient taxation only, so that it has to provide compensation to the losers of the tax policy. Analysing a model where the taxpayers differ in their preferences over the consumption of a polluting good, and where these preferences are consumers' private information, it is demonstrated that the level of environmental taxation is typically lower, and environmental policy less effective, than under fully-efficient first-best situation. This situation argues for earmarking: spending the tax revenues on projects that are beneficial to the losers of environmental tax policy may then alleviate the compensation problems and facilitate more efficient environmental policy. Even though earmarking is generally assumed to be cost-inefficient, the benefits in the form of better compensation possibilities can very well outweigh the costs in the second-best situation.

The analysis in this paper dealt with consumption externalities and commodity taxation. Another area in environmental policy that might be valuable for further study of earmarking would be pollution control in firms. Intuition suggests that subsidizing better abatement technology for firms whose abatement costs, and, hence, exposure to tighter environmental control, are high, might be another example of beneficial ways of earmarking the environmental tax revenues in a second-best situation.

References

Ahsan, S. M. and P. Tsigaris (1997) Earmarking of Taxes and Revenue Riskiness. Mimeo, Copenhagen Business School.

Andersen, M. S. (1994) *Governance by Green Taxes. Making Pollution Prevention Pay.* Manchester: University Press.

Blomquist, S. and V. Christiansen (1997) Price Subsidies versus Public Provision. Uppsala University, Department of Economics, Working Paper 1997:12.

Boadway, R. (1995) The Role of Second-Best Theory in Public Economics. EPRU, Copenhagen Business School, Discussion Paper 1995-6.

Boadway, R. and M. Keen (1993) Public Goods, Self-Selection and Optimal Income Taxation. *International Economic Review 34*, 463-478.

Brett, C. and M. Keen (1997) Political Uncertainty and the Earmarking of Environmental Taxes. Mimeo, University of Essex.

Buchanan, J. M. (1963) The Economics of Earmarked Taxes. *Journal of Political Economy 71*, 457-469.

Bös, D. (1997) The Incentive Effects of Earmarked Taxes. Mimeo, University of Bonn.

Cremer, H. and F. Gahvari (1997) In-Kind Transfers, Self-Selection and Optimal Tax Policy. *European Economic Review 41*, 97-114.

Diamond, P. A. (1975) A Many-Person Ramsey Tax Rule. *Journal of Public Economics 4*, 335-342.

King, M. A. (1986) A Pigovian Rule for the Optimum Provision of Public Goods. *Journal of Public Economics 30*, 273-291.

McCleary, W. (1991) The Earmarking of Government Revenue. A Review of Some World Bank Experience. *The World Bank Research Observer 6*, 81-104.

OECD (1995) Environmental Taxes in OECD-Countries. Paris: OECD.

OECD (1996) Implementation Strategies for Environmental Taxes. Paris: OECD.

Pirttilä, J. and M. Tuomala (1997) Income Tax, Commodity Tax and Environmental Policy. *International Tax and Public Finance 4*, 379-393.

Renström, T. I. (1997) Dynamic Tax Earmarking and Endogenous Fiscal Structure. Mimeo, University of Birmingham.

Sandmo, A. (1975) Optimal Taxation in the Presence of Externalities. *Swedish Journal of Economics 77*, 86-98.

Sandmo, A. (1993) Optimal Redistribution When Tastes Differ. *FinanzArchiv 50*, 149-163.

Stiglitz, J. E. (1982) Self-Selection and Pareto-Efficient Taxation. *Journal of Public Economics 17*, 213-240.

Appendix A:
Another formulation of earmarking under linear taxation

This section briefly describes how government expenditure can be modelled in a more standard way under the taxation scheme of section 2. The idea is that the utility of the households now depends directly on the level of a public good, g. Corresponding to the analysis in section 2, it is assumed that the marginal rate of substitution between the public good and private income is higher for the h-type households than for l-types. Within this model, this marginal rate of substitution is given by

$$MRS^i_{gY} = -\left.\frac{dY^i}{dg}\right|_{V=\bar{V}} = \frac{V^i_g}{V^i_Y} \tag{A.1}$$

Denoting the cost of public good provision as r, the Lagrangen of the optimization problem becomes:

$$\begin{aligned} L = {} & n^l V^l(q_c, q_d, Y, g, E) + \mu n^h \left[V^h(q_c, q_d, Y, g, E) - \bar{V}^h \right] \\ & + \gamma \left[\sum_i n^i t_d x^i_d(q_c, q_d, Y^i, g,) - \sum_i n^i T^i - rg \right] + \zeta g \end{aligned} \quad . \tag{A.2}$$

Maximizing with respect to g yields the first-order condition

$$n^l V^l_g + \mu n^h V^h_g + \sum_i n^i t_d \frac{\partial x^i_d}{\partial g} + \psi e' \sum_i n^i \frac{\partial x^i_d}{\partial g} - \gamma r + \zeta = 0 . \tag{A.3}$$

The first-best Samuelson rule for the public good provision can be derived within this model, if differentiated lump-sum transfers are feasible. To see this, use the definition in (A.1), substitute from the first-order condition for the (differentiated) lump-sum transfers (5) and (6) in (A.3), and recall that at the first-best optimum, t_d contains the externality-internalising component only, i.e. $t_d = -\frac{\psi e'}{\gamma}$. We then reformulate (A.3) to obtain

$$\frac{\zeta}{\gamma} = r - \sum_i n^i MRS^i_{gY} . \tag{A.4}$$

Equation (A.4) gives the Samuelson rule of comparing the marginal rate of transformation to the sum of the marginal rate of substitution in public good provision. Proceeding analogously to the main text, it is assumed that in the first-best world, the costs of provision always exceed the benefits, which implies that the left-hand side of (A.4) is positive, and the optimal level of the public good is zero. Because there is some efficiency loss in providing the public good, it is not beneficial to use it as a redistributive (compensationary) device, as targeted lump-sum transfers achieve the same objective without any costs.

Matters become more complicated in the main emphasis of the paper, the second-best setting, where only uniform lump-sum transfers are feasible. This implies that providing the public good has a potential rationale as a redistributive measure, since the *h*-type households enjoy more utility from its presence. To enable an analysis of these considerations, we need a modified rule for the public good provision.

In this task, the following Slutsky-type property, deduced by King (1986), proves beneficial:

$$\frac{\partial x_d^i}{\partial g} = s_{dg}^i + MRS_{gY}^i \frac{\partial x_d^i}{\partial Y}, \tag{A.5}$$

where s_{dg}^i denotes the impact of additional public good provision on the compensated demand of the polluting good. The property above can be derived by differentiating first $C^i(q_c, q_d, g, E, V) = Y^i$, with C depicting the expenditure function, to get $\frac{\partial C}{\partial g} = -MRS_{gY}^i$. In addition, differentiation of the identity relating the compensated and uncompensated demand functions, $x_d^i[q_c, q_d, g, E, C(q_c, q_d, g, E, u)] \equiv s_d^i(q_c, q_d, g, E, u)$, yields $\frac{\partial x_d^i}{\partial g} + \frac{\partial x_d^i}{\partial Y}\frac{\partial Y}{\partial g} = s_{dg}^i$. Combining these two results then gives the property in (A.5).

We proceed now to the reformulation of the first-condition for the public good provision by utilising (A.5) and the definition of β^i in (A.3) to obtain

$$\sum_i n^i \frac{\beta^i}{\gamma} MRS_{gY}^i + \left(t_d + \frac{\psi e'}{\gamma}\right) \sum_i n^i \left(s_{dg}^i + MRS_{gY}^i \frac{\partial x_d^i}{\partial Y}\right) - r + \frac{\zeta}{\gamma} = 0. \tag{A.6}$$

This can be modified further by recalling the definition of the net social marginal valuation of income, δ^i, and rearranging

$$\frac{\zeta}{\gamma} = r - \sum_i n^i \delta^i MRS_{gY}^i - \left(t_d + \frac{\psi e'}{\gamma}\right) \sum_i n^i s_{dg}^i. \tag{A.7}$$

(A.7) can still be rewritten as (along the lines of Diamond's (1975) commodity tax rule for a many-person economy)

$$\frac{\zeta}{\gamma} = r - \sum_i n^i MRS_{gY}^i - (n^l + n^h)\operatorname{cov}(\delta^i, MRS_{gY}^i) - t_d \sum_i n^i s_{dg}^i - \frac{\psi e'}{\gamma} \sum_i n^i s_{dg}^i, \tag{A.8}$$

where $\operatorname{cov}(\delta^i, MRS_{gY}^i)$ describes the covariance between the net social marginal valuation of income and the valuation of the public good, as given by the marginal rate of substitution. Equation (A.8) includes, first of all, the first-best Samuelson principle (the first two terms on the right) that imply a zero level of public good provision. The rule in (A.8) includes, however, additional terms that may change this conclusion. The second-term on the right captures the distributional rationale of providing g. If the net social marginal valuation of income of an h-type household is high (and recalling the caveats discussed in the main text), the covariance term becomes positive and reduces the costs of public good provision. This means that, interpreted from the first-order condition, the level of public good provision may become positive at the optimum. The reason is that g provides a way to compensate h-type households for their loss accruing from environmental policy with a good that benefits them more. The example given in section 2 still applies: the utility from road investments is higher for those who drive a lot, and is thus a potential candidate for an earmarked item.

The costs of public good provision in a second-best environment with distortionary taxation also depend on the impact of additional public good on the tax revenues of the government. This influence is captured by the fourth term in (A.8), revealing that if the investment in public good increases the level of polluting consumption, and hence tax revenues, economic costs of providing g decrease. However, with the presence of the harmful externality, raising the consumption of the dirty good damages the environment and implies that the benefits from g are reduced. This can be seen from the last term in (A.8), which, with $\frac{\partial x_d^i}{\partial g} > 0$, raises the costs of public good provision. These considerations are at heart of the analysis of earmarking the environmental tax revenues. Consider, for instance, the likelihood that higher road investments may have a feed-back effect on the level of driving thus dilute the environmental benefits of earmarking the tax revenues.

Some additional insight to the problem can be gained when the optimal tax rule for the commodity tax from equation (14) is combined with the rule (A.8). The presence of a second-best commodity tax implies that the environmental considerations are internalised with the externality-targeted component. Substitution from (14) in (A.8) reveals that with the commodity tax rate chosen optimally, the modified Samuelson rule for the public good provision may be written as

$$\frac{\zeta}{\gamma} = r - \sum_i n^i MRS_{gY}^i - (n^l + n^h)\operatorname{cov}(\delta^i, MRS_{gY}^i) - \frac{\operatorname{cov}(\delta^i, x_d^i)}{\bar{s}_{dd}} \sum_i n^i s_{dg}^i \,, \qquad \text{(A.9)}$$

which includes only the non-environmental part (the latter covariance term) from the commodity tax revenue term. As discussed in section 2, in the most probable case with the net social marginal valuation of household h's income high, this covariance term is actually a subsidy that lowers the level of pollution taxation due to distributional reasons. In (A.9), this means that the latter covariance term raises the costs of providing g. The intuition is that, as the external effects are internalized by the environmental part of the commodity tax, the net influence of an additional g on public revenues is negative; increasing the level of public good also increases the consumption of the harmful commodity and the need for funds that are used in subsidies, and, thus, the economic cost of public good provision.

Appendix B:
Tax rules when *h*-types can be mimickers

This section presents tax and earmarking rules when the binding self-selection constraint is assumed to be that of an *h*-type household. This case becomes possible when the government can redistribute income from *h*-type to *l*-type households. As the analysis proceeds analogously to the case presented in the main text, only the results are shown here. Let us consider first the implicit marginal tax rules. Assuming that (17) binds, and denoting the Lagrange multiplier associated with (17) as ξ, these tax rules are determined by:

$$\frac{U_d^h}{U_c^h} = \frac{1}{p_c}\left(p_d - \frac{\psi e'}{\gamma}\right), \tag{B.1}$$

$$\frac{U_d^l}{U_c^l} = \frac{1}{p_c}\left(p_d - \frac{\psi e'}{\gamma}\right) + \frac{\xi^*}{n^l}\left(\frac{\hat{U}_d^h}{\hat{U}_c^h} - \frac{U_d^l}{U_c^l}\right), \tag{B.2}$$

where $\xi^* = \dfrac{\xi n^h \hat{U}_c^h}{\gamma p_c}$. These results reveal that the tax rule for *h*-type households now involves only the corrective, Pigovian, component, whereas the choice of *l*-types is affected by a term arising from the self-selection concerns. By the single crossing property in (19), the self-selection term is positive, raising the marginal tax rate perceived by *l*-type consumers. The intuition is modified by the same fashion: mimicking can now be deterred by turning the choice of *l*-type households towards to the consumption of the clean good, which is less valuable to *h*-type households.

Considering the provision of a public good and investment in public abatement technology as earmarking possibilities gives rise to the following rules:

$$\frac{\zeta_g}{\gamma p_c} = \frac{r}{p_c} - \sum_i n^i MRS_{gc}^i + \xi^*(M\hat{R}S_{gc}^h - MRS_{gc}^l), \tag{B.3}$$

$$\frac{\zeta_A}{\gamma p_c e_A} = \frac{p_A}{p_c e_A} - \sum_i n^i MWP_{Ec}^i + \xi^*(M\hat{W}P_{Ec}^h - MWP_{Ec}^l). \tag{B.4}$$

Since the actual type representative and the mimicker both choose the same consumption bundle, the rejection of the view concerning the merits of the provision of a public good, depicted in equation (B.3), still applies.

The prospects of environmental investments, however, seem more promising. It might very well be the case that an actual type *l* person would give a higher valuation to environmental quality than a mimicker of type *h*. Thus, the last term in (B.4) would be negative. Under these circumstances, earmarking part of the environmental tax revenues to provide public abatement could be welfare-improving.

Consider finally the subsidies to the improvement of quality in the polluting consumption. Not surprisingly, quality purchases by h-type households should not be subsidized. For l-types, the rule for the optimal level of the quality good is determined by

$$\frac{\zeta_q^l}{\gamma p_c} = \frac{p_q}{p_c} - \frac{U_f^l f_q}{U_c^l} + \frac{\xi^*}{n^l}\left(\frac{\hat{U}_f^h}{\hat{U}_c^h} - \frac{U_f^l}{U_c^l}\right)f_q. \tag{B.5}$$

The crucial difference to the case discussed in the main text is that the self-selection term in (B.5) is positive as a result of the single-crossing property. $\zeta_q^l > 0$ and earmarking to subsidize quality is not welfare improving. Since potential mimickers give higher valuation to the quality good, the government would probably prefer to impose a tax on it, but in that case, its demand would be zero under the background assumptions of the model.

BANK OF FINLAND DISCUSSION PAPERS

ISSN 0785-3572