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Per-Olov Johansson

Stockholm School of Economics and CERE

Per-Olov.Johansson@hhs.se

Bengt Kriström

CERE

SLU-Umeå and Umeå University

Bengt.Kristrom@sekon.slu.se

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Department of Economics, Umeå Universitet
S-901 87, Umeå, Sweden

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Author:
Per-Olov Johansson
Stockholm School of Economics and CERE
Per-Olov.Johansson@hhs.se

Author
Bengt Kriström
CERE
SLU-Umeå and Umeå University
Bengt.Kristrom@sekon.slu.se

Abstract

In this note we discuss how to treat taxes in a cost-benefit analysis (CBA). In particular we relate the shadow price of taxes in CBA to the concepts the marginal cost of public funds MCPF) and the marginal excess burden (MEB) of taxes. In particular we demonstrate that the MCPF is equal to one plus the MEB for a marginal increase in a distortionary tax.

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1 Introduction

In a cost-benefit analysis of a public sector program one has to address the question how to treat taxes. In a sense this seems straightforward although possibly very complicated to handle in the real world due to a lack of data and estimates of relevant price and income elasticities. There is also a huge literature on closely related issues like the marginal cost of public funds (MCPF) and the marginal excess burden (MEB) of taxes. The MCPF measures the monetary welfare cost of raising an additional euro in the presence of distortionary taxation. The MEB is another kind of experiment where typically a hypothetical lump-sum payment is introduced. This payment keeps the individual on the same utility level as with a proposed increase in the income tax. According to Ballard and Fullerton (1992) one can speak of a Harberger-Pigou-Browning tradition or a MEB-tradition in which the marginal cost of public funds is always larger than unity and a Dasgupta-Stiglitz-Atkinson-Stern tradition or MCPF-tradition in which it may be larger or lower than one.

Many recent studies have focused on redistributive issues, see, for example, Sandmo (1998) and Gahvari (2006) while others have focused on the provision of a public good in the presence of an income tax[1]. If the tax is optimally chosen a typical result is that the studies confirm the Samuelson (1954) rule that the sum of consumers marginal willingnesses to pay for a public good should be equal to the marginal cost of providing the good. There is also an emerging literature on the MCPF concept in environmental economics where environmental taxation is analyzed in the presence of distortionary taxation; see, for example, Bovenberg and van der Ploeg (1994). A recent contribution by Gahvari (2006) addresses the MCPF concept within a Mirrlees (1971) second-best framework with heterogenous agents. For a full treatment of the concept of the MCPF the reader is referred to Dahlby (2008).

The purpose of this note is modest. Within a simple general equilibrium model of a single individual economy we derive simple cost-benefit rules that can be used to assess small increases in the provision of a public good under alternative tax regimes (lump sum, ad valorem, and income taxes). It is demonstrated that these rules can be designed so as to resemble the MCPF, at least when producer prices remain unchanged by the considered marginal projects. On the other hand, the concept of a MEB of taxes seems more difficult to relate to a traditional cost-benefit analysis. However, we are able to show that for a *marginal* change in the wage tax (one plus) the marginal MEB is equal to the MCPF. This is the main contribution of this note since it opens up the possibility to use computable general equilibrium models to estimate the MCPF for different distortionary taxes. We also

[1]The early contributions assumed a linear income tax; see, for example, Christiansen (1981), Hansson (1984), Stuart (1984), Fullerton (1991), and Ballard and Fullerton (1992).

propose a slightly different design of cost-benefit rules that we believe are easier to estimate than the one drawing on the MCPF-concept. Finally, we claim that the MCPF concept becomes 'polluted' and difficult to estimate if producer prices are allowed to adjust so as to maintain general equilibrium. An appendix addresses the treatment of taxes in a multi-individual society.

2 Some simple cost-benefit rules for a tax-distorted economy

Consider a society consisting of a number, here normalized to unity, of individuals with identical preferences and incomes[2]. The social welfare function of this society is written as[3]:

$$W = v(1, p \cdot (1+t), w \cdot (1-t_w), T, g) = V(p \cdot (1+t), w \cdot (1-t_w), T, g) \quad (1)$$

where $v(.)$ is the indirect utility function of the representative individual, the first commodity serves as numéraire so its price is normalized to unity, p is the producer price of a commodity that is subject to an ad valorem tax t, w is the wage rate, t_w is a proportional wage tax, T is a lump-sum income, and g is a public good or environmental quality which is used here to generate a cost-benefit rule for a tax-distorted economy. In order to simplify the exposition we will assume that producer prices remain unchanged and that firms earn zero profits. These seemingly strong assumptions will not affect the results presented in this note. This is so because the effects caused by small induced price adjustments will net out from general equilibrium cost-benefit rules. We leave the proof for section 6.

The government's budget constraint can be stated as follows:

$$T = t \cdot p \cdot x + t_w \cdot w \cdot \ell - w \cdot \ell^g \quad (2)$$

where x is a commodity, ℓ is labor supply, and labor ℓ^g is the sole input used in producing the public good.

Consider next a small increase in the provision of the public good keeping the tax rates t and t_w constant, i.e. letting T act as a residual "balancing" the government's budget. The associated change in social welfare is:

$$dW = V_g \cdot dg + V_T \cdot dT = V_g \cdot dg + \lambda \cdot dT \quad (3)$$

[2]The multi-individual case is considered in the appendix.

[3]We assume for simplicity that utility functions are well-behaved; see, for example, Boadway and Bruce (1984) or Myles (1995) for definitions of a well-behaved utility function.

where a subscript T (g) refers to a partial derivative with respect to T (g), and λ is the marginal utility of lump-sum income.

The associated change in the government's budget is:

$$dT = [p \cdot t \cdot \frac{\partial x}{\partial T} + t_w \cdot w \cdot \frac{\partial \ell}{\partial T}] \cdot dT + [p \cdot t \cdot \frac{\partial x}{\partial g} + t_w \cdot w \cdot \frac{\partial \ell}{\partial g}] \cdot dg - w \cdot d\ell^g = \alpha \cdot dT + \beta \cdot dg - w \cdot d\ell^g \qquad (4)$$

where the first (second) expression within brackets is denoted α (β). Thus changes in the lump-sum tax $(dT < 0)$ impacts on deadweight losses of distortionary taxes as is seen from the first expression within brackets. The second expression within brackets shows that also a change in the provision of the public good might affect demands and supplies of tax distorted commodities. Next, using equation (4) to eliminate dT from equation (3[4]) and multiplying through by $1/\lambda$ yields:

$$\frac{dW}{\lambda} = [\frac{V_g}{\lambda} + \frac{\beta}{1+\alpha}] \cdot dg - [\frac{1}{1+\alpha}] \cdot w \cdot d\ell^g \qquad (5)$$

where we have reversed the sign in front of of α in order for the expression to reflect a tax increase. Multiplying through by $1/\lambda$ converts the expression from (unobservable) units of utility to monetary units and yields our basic cost-benefit rule. The direct benefits expression $(V_g/\lambda) \cdot dg$ is the willingness-to-pay for the considered small project. However, there is also an indirect effect equal to $(\beta/(1-\alpha)) \cdot dg$ through the impact of the project's output on deadweight losses[5]. The direct cost of the project should be multiplied by a factor $k = 1/(1+\alpha)$ reflecting the impact of the project's costs on deadweight losses. Later on we will relate these 'adjustment' factors to the concepts of the marginal cost of public funds and the marginal excess burden of taxes. A small project for which $dW/\lambda > 0$ is socially profitable, i.e. its benefits exceeds its costs.

Let us next consider a Ramsey variation, see Ramsey (1927), according to which the project is financed through a change in the ad valorem tax (holding T constant). Proceeding in the same way as above the cost-benefit rule reads:

$$\frac{dW}{\lambda} = [\frac{V_g}{\lambda} + \frac{\beta}{1+\alpha^t}] \cdot dg - [\frac{1}{1+\alpha^t}] \cdot w \cdot d\ell^g \qquad (6)$$

[4]Lundholm (2005) derives a few rules using this approach but based on a different definition of the MCPF or what he terms the "social MCPF". In equation (14) we show that our rules incorporate what we consider to be the conventional definition of the MCPF.

[5]Using the production function $g = g(\ell^g)$ this indirect effect can be transferred to the cost expression.

where $\alpha^t = [(\frac{\partial x}{\partial q}) \cdot t \cdot p \cdot x^{-1} + t_w \cdot w \cdot \frac{\partial \ell}{\partial q} \cdot x^{-1}]$ with $q = p \cdot (1+t)$, i.e. the consumer price, and β contains the same terms as in equation (5). The reader should note that we could alternatively interpret x as a vector of goods that are subject to a value added tax (VAT). Then t is interpreted as the common VAT rate.

Finally, if the project is financed through an increase in the wage tax rate one arrives at the following cost-benefit rule for a small or marginal project:

$$\frac{dW}{\lambda} = [\frac{V_g}{\lambda} + \frac{\beta}{1+\alpha^{t_w}}] \cdot dg - [\frac{1}{1+\alpha^{t_w}}] \cdot w \cdot d\ell^g \tag{7}$$

where $\alpha^{t_w} = -[p \cdot t \cdot \frac{\partial x}{\partial w_n} \cdot \ell^{-1} + t_w \cdot w \cdot \ell^{-1} \cdot \frac{\partial \ell}{\partial w_n}]$ with w_n denoting the net or after-tax wage, and β once again contains the same terms as in equation (5).

If preferences are weakly separable in g the β-term vanishes[6] and we obtain a simple rule according to which one should compare the marginal willingness-to-pay for the project with its direct cost multiplied by a factor reflecting the impact of the project on marginal deadweight losses. Thus the cost-benefit rule reduces to:

$$\frac{dW}{\lambda} = \frac{V_g}{\lambda} \cdot dg - [\frac{1}{1+\alpha^i}] \cdot w \cdot d\ell^g \tag{8}$$

where a superscript i refers to the particular tax instrument used to finance the project. Later we will suggest an alternative decomposition of changes in tax revenues that might be more straightforward to estimate than cost-benefit rules involving α^i (for $i = T, t, t_w$) and β. However, let us now turn to a brief discussion of the marginal cost of public goods.

3 On the marginal cost of public funds

In order to illustrate the concept of the marginal cost of public funds we introduce the following Lagrangian:

$$L = V(.) + \gamma \cdot N(T, t, t_w, g) \tag{9}$$

where $N(.) = T - t \cdot p \cdot x - w \cdot t_w \cdot \ell + w \cdot \ell^g$. The aim here is to maximize social welfare subject to the government's budget constraint. However, before taking a look at the (first-order) conditions for a second-best optimum we provide a definition of the concept of the marginal cost of public goods,

[6] A utility function is weakly separable in g if it can be written as $U = U[f(x, \ell), g]$.

MCPF. Let us consider a project financed by adjusting the ad valorem tax t. Then, following Gahvari (2006) MCPF is defined as:

$$MCPF^t = \frac{1}{\lambda} \cdot \frac{\partial V/\partial t}{\partial N/\partial t} \tag{10}$$

Thus MCPF measures the monetary welfare cost of raising an additional euro in taxes. Similarly, one might define the marginal benefit of spending an additional euro on the public good, MBPG, as follows:

$$MBPG = \frac{1}{\lambda} \cdot \frac{\partial V/\partial g}{\partial N/\partial g} \tag{11}$$

In order to shed some further light on these concepts, let us introduce a couple of first-order conditions for a second-best optimum:

$$\begin{aligned} \frac{\partial L}{\partial t} &= \frac{\partial V}{\partial t} + \gamma \cdot \frac{\partial N}{\partial t} = 0 \\ \frac{\partial L}{\partial g} &= \frac{\partial V}{\partial g} + \gamma \cdot \frac{\partial N}{\partial g} = 0 \end{aligned} \tag{12}$$

Thus at a second-best optimum it holds that:

$$\frac{V_g}{\lambda} = MCPF^t \cdot \frac{\partial N}{\partial g} \tag{13}$$

It might be noted that if lump-sum taxation is available and $t = t_w = 0$, then the simple rule suggested by Samuelson (1954) applies, i.e. MCPF=1 so that the (sum of individuals') willingness-to-pay for the public good is equal to the marginal cost of providing the good.

The question arises how MCPF is related to our cost-benefit rules. Using equation (10), one finds after straightforward calculations that:

$$MCPF^t = \frac{1}{1 + \alpha^t} \tag{14}$$

where α^t is defined in equation (6). Thus the concept of the MCPF is relevant also for cost-benefit analysis. However, the reader should note that unless preferences are weakly separable in the public good, the cost-benefit rule will contain an additional "correction" factor (i.e. β) reflecting the public good's impact on tax wedges, just like the MBPG concept.

4 On the marginal excess burden of taxes

Measures of the marginal excess burden of taxes are typically formulated in terms of an equivalent variation, see, for example, Fullerton (1991), but let us add the compensating variation measure so as to obtain two different definitions:

$$MEB^{CV} = \frac{CV - \Delta N}{\Delta N} \tag{15}$$

or

$$MEB^{EV} = \frac{EV - \Delta N}{\Delta N} \tag{16}$$

where CV and EV are the compensating variation and equivalent variation, respectively, associated with a tax change, and ΔN is the change in tax revenue; below we will define these measures. Stuart (1984) and others estimate such measures[7]. This kind of experiment is quite different from the MCPF-experiment. The MEB concept replaces a distortionary tax by a hypothetical lump-sum payment or provides a lump-sum compensation for the tax increase while the MCPF, as mentioned above, captures the monetary welfare cost of collecting an additional euro in taxes. If the MEB concept is applied in a cost-benefit analysis the relevant approach is to multiply direct project costs by one plus the MEB.

In order to shed some further light on the interpretation of the marginal excess burden of an income tax we use the following equality to implicitly define CV:

$$V(p \cdot (1+t), w \cdot (1-t_w^1), T + CV, g) = V(p \cdot (1+t), w \cdot (1-t_w^0), T, g) \tag{17}$$

where superscript 1 (0) refers to the final (initial) income tax level. Thus the individual needs a compensation of at least CV in order to be as well off with the tax increase as without it. Similarly, we can define an EV measure of an tax increase:

$$V(p \cdot (1+t), w \cdot (1-t_w^0), T - EV, g) = V(p \cdot (1+t), w \cdot (1-t_w^1), T, g) \tag{18}$$

The EV is the maximum amount of money the individual is willing to pay in order to avoid the tax increase. A more general approach would allow prices to adjust following the change in the wage tax. Such general equilibrium measures can be estimated if a computable general equilibrium (CGE) model is available.

[7] Stuart (1984) uses the compensating surplus (CS), where supply of labor is kept constant following a change in the income tax.

The ratios stated in equations (15) and (16) can be defined by calculating the initial and final tax revenues[8]:

$$\Delta N = t_w^1 \cdot w \cdot \ell^1 - t_w^0 \cdot w \cdot \ell^0 \tag{19}$$

where the superscripts 1 (0) refers to the final (initial) levels of labor supply and tax rate.

Equations (17) and (18) suggest that the concept of the MEB is distinctly different from the MCPF concept, unless in special circumstances as discussed by Fullerton (1991). As pointed out by Gahvari (2006), the MEB refers to hypothetical lump sum payments/compensations that allows the individual to remain at a particular utility level. The MCPF, on the other hand, aims at capturing the actual changes in deadweight losses that a project causes.

However, the concept of the MCPF refers to *marginal* changes in a tax. Therefore, let us consider the case of the *marginal* MEB (denoted MEB^{t_w}). If the wage tax is altered marginally equations (17) and (18) reveal that $dCV = -dEV = dt_w \cdot w \cdot \ell$, provided they are evaluated at the same "point", i.e. at $t_w^1 = t_w^0$. Therefore, one might be tempted to conclude that the marginal MEB-measure is zero; recall that the direct change in tax revenue is $dN = dt_w \cdot w \cdot \ell$. However this ignores any induced adjustments in labor supply. Therefore[9]:

$$MEB^{t_w} = -\frac{\varepsilon}{1+\varepsilon} \tag{20}$$

where ε is the tax elasticity of labor supply. This yields a kind of Laffer-curve result, i.e. if supply is not "too" elastic ($\varepsilon > -1$), $MEB^{t_w} > 0$, while it is negative if supply is sufficiently elastic.

Equation (20) implies that $1 + MEB^{t_w} = 1/(1+\varepsilon)$. It follows that:

$$1 + MEB^{t_w} = MCPF^{t_w} = \frac{1}{1+\alpha^{t_w}} \tag{21}$$

where, α^{t_w} is defined in equation (7) with, by assumption, $T = t = 0$. Thus for a marginal project it makes sense to think in terms of adjusting for one plus the (marginal) marginal excess burden of taxes. It is equivalent to multiplying direct project costs by the marginal cost of public funds

[8]We follow Fullerton (1991), see his figure 1, in referring the tax change to the income tax only (but note that in that figure actual labor supply is left unchanged by the considered tax change). Moreover, there are other views of what is the relevant measure of the change in tax revenue. The reader is referred to Fullerton (1991) for details.

[9]$MEB^{t_w} = \partial MEB/\partial t_w = \frac{w\cdot\ell-(w\cdot\ell-t_w\cdot w\cdot(\partial\ell/\partial w_n)\cdot w)}{w\cdot\ell-t_w\cdot w\cdot(\partial\ell/\partial w_n)\cdot w} = -\frac{\varepsilon}{(1+\varepsilon)}$, where ε is the tax elasticity of labor supply; $\varepsilon = -(\partial\ell/\partial w_n)\cdot(t_w\cdot w)/\ell$. Assuming that $\partial\ell/\partial w > 0$, $MEB^{t_w} > 0$ if $0 > \varepsilon > -1$, i.e. if labor supply is not "too elastic".

This result generalizes to the case where $t > 0$, as in equation (7). This is seen by noting that:

$$1 + MEB^{t_i} = dEV/dN = \frac{1}{\lambda} \cdot \frac{\partial V/\partial t_i}{\partial N/\partial t_i} = MCPF^{t_i} \tag{22}$$

where a subscript i refers to tax i. Thus, our result is completely general. It follows that if a CGE model is available one could use a reasonably small change in tax rate i to obtain a rough estimate of $1 + MEB^{t_i}$, i.e. $MCPF^{t_i}$, holding all other tax rates constant. Repeating the procedure for the other taxes one obtains a vector of estimated values that could be applied in empirical studies.

Still, there might be induced effects also on the benefit side that a properly undertaken CBA must account for as the β-factor in equation (7) indicates.

5 An alternative way of handling taxes in a CBA

An alternative approach to the one outlined in section 2 would be to relate the taxes to what production or factor uses are crowded out by the considered project. For example, laborers that are drawn from other production activities are associated with an opportunity cost equal to $w \cdot (1+t)$ since this is the amount consumers ultimately are willing to pay for the commodities produced by the marginal worker. Similarly, laborers that would otherwise stay outside the labor force are now valued at their reservation wage, i.e. $w \cdot (1 - t_w)$.

In order to further illustrate this approach we use the social welfare function in equation (1) and assume, for simplicity, lump sum taxation, although the cost-benefit rule will contain the same terms regardless of the chosen tax instrument[10]. Then the cost-benefit rule will read as follows:

$$\frac{dW}{\lambda} = \frac{V_g}{\lambda} \cdot dg + p \cdot t \cdot dx + w \cdot t_w \cdot d\ell - w \cdot d\ell^g \tag{23}$$

where dx and $d\ell$ refer to the combined effects of changes in g and the chosen tax instrument. Now if labor supply remains constant, i.e. $d\ell = 0$, we can assume that the laborers needed for the production of the public good are drawn from production of commodity x. Then it holds that $p \cdot t \cdot dx = -t \cdot$

[10]However, the induced effects of the project on consumption and employment in equation (23) might depend on how the project is financed. This is obvious from the expressions for α, α^t, and α^{t_w} in section 2.

$w \cdot d\ell^g$, where we have used the first-order condition for profit maximization $p \cdot \partial f(\ell)/\partial \ell = w$ and the fact that $d\ell^d = -d\ell^g$, i.e. the loss in private sector employment is equal to the gain in public sector employment since, by assumption, $d\ell = 0$. The difference between consumers marginal willingness to pay (WTP) and the real marginal cost of crowded-out goods is equal to $p \cdot t$. This difference is an additional cost of the considered project. Thus the cost-benefit rule reads:

$$\frac{dW^{UBC}}{\lambda} = \frac{V_g}{\lambda} \cdot dg - w \cdot (1+t) \cdot d\ell^g \tag{24}$$

where a superscript UBC refers to an upper bound for the project's costs . This simple rule generalizes to the case with many different commodities and a value added tax since the value of the marginal product is equal to w in all sectors (assuming homogenous labor and perfect competition).

On the other hand if $d\ell = d\ell^g$ then leisure is crowded out so $dx = 0$. In this case we should value laborers at their after-tax (reservation) wage rate since $d\ell = d\ell^g$ in equation (23). Thus this lower bound rule reads:

$$\frac{dW^{LBC}}{\lambda} = \frac{V_g}{\lambda} \cdot dg - w \cdot (1-t_w) \cdot d\ell^g \tag{25}$$

where a superscript LBC refers to a lower bound for the project's costs.

These are simple 'rule of thumbs' and can easily be applied so as to obtain upper and lower bounds (ceteris paribus) for a project's societal costs[11]. They provide a possibly fruitful approach when estimates of α and β are not available.

6 Flexible prices

In order to illustrate the effects of endogenous producer prices and pure profits the social welfare function is written as:

$$W = V(p \cdot (1+t), w \cdot (1-t_w), T + \pi, g) \tag{26}$$

where $\pi = \pi(p, w)$ is the, by assumption well-behaved, profit function of the representative firm supplying x^s using labor ℓ^d as the only input (while it for simplicity is assumed that the firm producing the numéraire earns zero profits). For this Robinson-Crusoe economy it is assumed that the individual

[11]However, it cannot be ruled out that tax wedges are changed in such a way that the societal cost exceeds our upper bound or falls short of our lower bound.

and sole owner of firms treat profit income as a lump-sum income although profits are endogenous from the point of view of society.

In addition to effects captured by equation (23) we have the following effects:

$$\lambda \cdot (x^s - x^d) \cdot dp + \lambda \cdot (\ell^s - \ell^d - \ell^g) \cdot dw - \\ \lambda \cdot t \cdot x^d \cdot dp - \lambda \cdot t_w \cdot \ell^s \cdot dw + \\ \lambda \cdot t \cdot x^d \cdot dp + \lambda \cdot t_w \cdot \ell^s \cdot dw = 0 \quad (27)$$

where x^d denotes demand for x, ℓ^s denotes supply of labor, and dp and dw refer to the total changes caused by the change in g plus the change in the chosen tax instrument[12]. The two first terms vanish since prices, by assumption, clear markets. The consumer is affected by tax changes as p and w change (shown in the middle row) but these effects are exactly offset by the same effects but with opposite signs through the government's budget (shown in the final row[13]).

However, the concept of the MCPF becomes 'polluted' in the sense that induced price changes show up in the denominator as well as the numerator. Moreover these changes are *partial* in the sense that we evaluate $\partial V/\partial t$ and $\partial N/\partial t$ *ceteris paribus* while equation (27) accounts for the general equilibrium adjustments. Therefore, it seems as if the concept of the MCPF is less fruitful in contexts where producer prices change and firms earn pure profits. In addition it becomes extremely involved to estimate MCPF.

7 Concluding remarks

In this note we have investigated whether the concept of the marginal cost of public funds is suitable for use in a conventional cost-benefit analysis. Indeed if all producer prices are assumed to be constant and preferences are weakly separable in the public good it is legitimate to multiply a small project's direct costs by a factor reflecting the MCPF. However, if the separability condition is not satisfied one must in addition account for the impact of the public good on the magnitude of the tax wedges. Moreover, if producer prices adjust - as they typically do also for a small project in a general equilibrium context - the MCPF will be extremely complicated to estimate since it now also contains effects in both numerator and denominator of the price adjustments caused by the project. On the other hand, in a "conventionally"

[12]In this case, dx and $d\ell$ in equation (23) refer to the combined effects of changes in g, the chosen tax instrument, p and w.

[13]We have moved the term $\lambda \cdot \ell^g \cdot dw$ from the final ("government") row to the first row in equation (27).

formulated cost-benefit rule these induced effects net out as is seen from equation (27).

In addition, this alternative formulation of the cost-benefit rule can be used to derive reasonable upper and lower bounds for a project's social profitability. This approach is easier to implement than an estimate of the marginal cost of public funds. This is so because the MCPF approach requires estimates of quite involved price and income elasticities. It might be both time consuming and complicated to obtain all the data needed in such an exercise unless one simply choose to rely on rough macroeconomic estimates (where all data are aggregated to national averages).

Finally, we have shown that for a *marginal* change in the wage tax, the MEB concept is relevant for a cost-benefit analysis. However, it remains to be shown that the concept is relevant also if it is calculated from "large" tax changes in the way conventional definitions suggest.

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8 Appendix

In this appendix we briefly consider an economy consisting of $H > 1$ different individuals. Assume that the project under consideration is financed by uniform lump-sum taxation and that the social welfare function is Utilitarian. The welfare differential is written as follows:

$$dW = \sum_h [V_g^h \cdot dg + \lambda^h \cdot dT] = \sum_h V_g^h \cdot dg + \overline{\lambda} \cdot [t \cdot p \cdot dx^H + t_w \cdot w \cdot d\ell^H - w \cdot d\ell^g] \quad \text{(A.1)}$$

where $\overline{\lambda}$ is the expected or mean marginal utility of lump-sum income, a superscript H (h) refers to an aggregate or total quantity (individual h), and the same decomposition is used as in section 5[14]. Rearranging and multiplying through by the expected marginal utility of income, equation (A.1) can be stated as:

$$\frac{dW}{\overline{\lambda}} = \sum_h \frac{\lambda^h}{\overline{\lambda}} \cdot WTP^h + t \cdot p \cdot dx^H + t_w \cdot w \cdot d\ell^H - w \cdot d\ell^g \quad \text{(A.2)}$$

where $WTP^h = [V_g^h / \lambda^h] \cdot dg$ is individual $h's$ willingness to pay for the considered change in the provision of the public good. This WTP can be estimated using survey techniques like contingent valuation or choice experiments (conjoint analysis) or market based approaches like the travel cost method and the property value method. However, the problem is that the willingness-to-pay of each individual must be weighed using the individual's own marginal utility of lump-sum income relative to the average marginal utility of income. Unless the distribution of marginal utilities of income is relatively even across individuals, the sum of WTP^h will be a poor predictor of society's valuation of the project in question, even in the special case of a Utilitarian social welfare function. It should be noted that with the exception of the $\lambda^h/\overline{\lambda}$-term, equation (A.2) contains the same terms as equation (23).

If a commodity tax or income tax is used to finance the project it is not possible to factor out the marginal utility of income in the way that is done in equation (A.1) since consumption and labor supply levels vary across individuals, in general. Therefore evaluation of the project's benefits and costs becomes very involved unless it is assumed that λ^h is evenly distributed across individuals or x^h is the same for all in the case of $dt > 0$ or ℓ^h is the same for all in the case of $dt_w > 0$. In the last two cases, one can factor out $\overline{\lambda}$ in the same way as in equations (A.1) and (A.2). Still, in these cases one faces the problem in valuing benefits discussed above.

[14] Alternatively the cost-benefit rule can be expressed in terms of α and β as in section 2.