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"Public goods, labor supply and benefit taxation"

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Abstract

A benefit tax is a tax whose amount is determined in accordance with the benefits received. It is well-known that an increase in the tax burden reduces individual welfare due to its negative effect on private consumption, but the public finance literature commonly disregards the positive effects that an increase in public goods provision (that follow the increase in taxes) can have on taxpayers' welfare. This paper first considers an economy in which a proportional labor-income tax is used to finance the provision of (pure) public goods, and describes a "second-best benefit" tax solution to the tax-expenditure problem that is efficient and satisfies the benefit principle of taxation. The analogous "first-best benefit" tax solution can be obtained with the same procedure under lump-sum taxation. The tax burdens under these solutions are set individually to maximize each taxpayer's surplus given the contributions of all taxpayers and no free riding. The solutions provide natural benchmarks to separate the problems of efficiency and redistribution.

Keywords Public goods · Labor supply · Labor-income tax · Benefit taxation

1 Introduction

A benefit tax is a tax whose amount is determined in accordance with the benefits received from the public goods and services financed with the tax. Benefit taxes are associated with the benefit principle of taxation, which together with the ability-to-pay principles have been regarded for centuries as the guiding principles of "fair"

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taxation, [1] and they also seem to be considered as fair by taxpayers. [2] Benefit taxes are also recommended on efficiency grounds, because they can mimic the competitive market solution to the problem of determining optimal prices and quantities. The most prominent example of a benefit tax is the Lindahl (1919) equilibrium, in which the taxpayers' contributions to the financing of each monetary unit spent on the public goods are equal to their marginal willingness to pay. This solution seems to involve a *quid pro quo* in a way that satisfies some desirable equity norms (Buchholz & Peters, 2007) and efficiency conditions for competitive markets, while it is consistent with the Samuelson (1954) first-best optimal amount of public goods (see Samuelson, 1955).

Despite its advantages, and even though the incorporation of notions of fairness into optimal tax systems remains an aspiration, [3] benefit taxation has been "sidelined" in modern optimal income tax theory (Scherf & Weinzierl, 2020, p. 387) and the principles of fair taxation do not yet play a relevant role in the theory of public goods (Buchholz & Peters, 2008). Arguably, a reason might be that the available benefit tax solutions do not properly address some relevant distributional concerns. For instance, under the Lindahl solution a high-income taxpayer that receives substantial welfare gains from public goods would be assigned a negligible tax burden if the individual benefits from public goods are negligible *at the margin*. It follows that a high-income taxpayer can free ride under the Lindahl solution, an outcome that appears to contradict the benefit and the ability-to-pay principles of fair taxation and therefore would go against common distributional equity considerations.

This paper considers a simple economy with heterogenous taxpayers where the provision of (pure) public goods is financed either with a labor-income tax or with a lump-sum tax, and presents two solutions to the tax-expenditure problem that satisfy the benefit principle of taxation, called here the second-best benefit tax solution and the first-best benefit tax solution, respectively. These solutions differ from the Lindahl solution in that the tax burden of each taxpayer is not fully assigned at the margin, but instead in accordance with their *total* individual benefits and costs from public goods. [4] Tax burdens are set individually at the level where, provided the contributions of all taxpayers, the surplus of each taxpayer is maximized without free riding. The outcomes can be more acceptable in terms of distributional justice because all

[1] The ability-to-pay principles of taxation state that tax burdens should be based on wealth and income. There are several ways to relate tax burdens to wealth and income; for instance, another (more specific) principle known as 'equal sacrifice' suggests that tax burdens should impose equal losses to taxpayers, either in terms of absolute, relative, or marginal utility. See Musgrave (1959) for a detailed discussion and historical account of the benefit and ability-to-pay principles (also called approaches) to taxation.

[2] Based on a survey conducted to 2,500 United States residents between 2015 and 2016, Weinzierl (2017) found that between 62% and 79% of respondents preferred benefit-based taxes over an alternative logic to set tax burdens based on social welfare functions that exhibit diminishing marginal social welfare of income.

[3] See Fleurbaey and Maniquet (2018) and Saez and Stantcheva (2016) for examples of the use of marginal social welfare weights to account for society's concerns for fairness in the classical optimal tax framework.

[4] As in this paper, Moulin (1987) also considers inframarginal benefits to determine individual tax burdens. Still, the discussion will remain focused on the more widely known Lindahl solution, while the advantages of the proposed solution with respect to the Moulin's contribution will be discussed in Sect. 5.

taxpayers maximize their surplus by contributing to the financing of the public goods in accordance with their means and the benefits they receive from public goods. At the same time, the solutions are efficient in the sense that they maximize the welfare of all taxpayers without requiring any interpersonal comparisons of utility. Indeed, the first-best benefit tax solution also leads to the first-best optimal amount of public goods described by the Samuelson condition.

Most of the theoretical presentation focuses on the case of proportional labor-income taxation and the derivation of the second-best benefit tax solution. The derivation of the first-best benefit tax solution under lump-sum taxation is simpler and can trivially follow from the second-best case.

The theoretical analysis exploits the rather simple effects that public goods can have on labor supply, which have mostly been neglected in the literature on the labor supply responses to fiscal policies. Theoretical models of the labor supply response to taxation commonly assume that changes in tax burdens have no effects on the amount of public goods, and that the preferences for public goods are weakly separable from the preferences for leisure and private goods (see, for instance, Meghir & Phillips, 2010, and Keane, 2011). These assumptions are useful to simplify the analysis of labor supply decisions but prevent taxes from having any positive effect on welfare. As widely recognized in traditional labor supply models, an increase in the tax burden reduces individual welfare due to its negative effect on private consumption; however, it is also true that higher taxes can lead to more public goods that commonly have a positive effect on individual welfare. [5] Considering both costs and benefits, the individual net welfare effect of a higher tax burden may well be positive.

The benefit tax solutions presented in this paper require all taxpayers to contribute to each additional monetary unit of public expenditure that provides them with positive individual net benefits. At any possible amount of public goods, those taxpayers that prefer a greater amount contribute with equal increases in their income shares (under the labor-income tax) or tax amounts (under the lump-sum tax), while those that do not prefer a greater amount receive a tax adjustment that keep their marginal costs equal to their marginal benefits. This 'social contract' ensures that all taxpayers contribute to the public goods only as long as they receive net benefits, that no taxpayer free rides, and that no taxpayer contributes to the public goods beyond the amounts that maximize their individual welfare under these conditions.

Graphically, when public goods are allowed to change with the tax policy, the individual budget line from the leisure-private goods plane turns into an exogenous three-dimensional budget surface, and when the assumption of weak separability is relaxed (and so public goods are allowed to affect labor supply decisions), taxpayers preferences of any form can be represented by three-dimensional indifference surfaces. Under common assumptions, the point of tangency between the budget surface and the indifference surface with the highest attainable level of welfare is associated with a positive tax burden and the maximum level of individual surplus that can be

[5] Several authors have explored the consequences of allowing public goods to change with the tax rates and to affect individual labor supply decisions and the optimal amount of public expenditure. A brief review of the relevant literature is presented in Sect. 2.

reached without free riding; where free riding is understood as receiving net welfare gains while assuming smaller tax adjustments than other taxpayers.

Mathematically, each individual benefit tax burden is set at the level where the individual welfare cost from a marginal reduction in private goods is equal to the individual welfare benefit from a marginal increase in public goods; at that level the taxpayer is indifferent between marginal changes in private and public goods. Under lump-sum taxation, the sum of the first-order conditions associated with the first-best benefit tax solution is equal to the Samuelson condition. Under the proportional labor-income tax, the sum of the first-order conditions associated with the second-best benefit tax solution is equivalent to the marginal *efficiency* cost of funds (for a case with individualize tax rates). This concept was first defined by Mayshar and Yitzhaki (1995), who decomposed the marginal cost of funds, a measure of the marginal welfare costs of tax revenue used to determine the optimal provision of public goods and services in the absence of lump-sum taxation, into the marginal efficiency cost of funds and the Feldstein's (1972) "distributional characteristic", which represents the distributional effects of taxation on the marginal cost of funds.

Since both the first-best and the second-best benefit tax solutions are efficient and obtained without making interpersonal comparisons, the two solutions provide a conceptual benchmark where the problems of efficiency and distribution can be naturally separated. Nevertheless, these solutions are not devoid from the notion of "fairness", because all taxpayers are subject to the same rules while maximizing their individual surpluses (given others' contributions) without free riding. In this context, the benefit tax solutions could be used to justify a *minimum* degree to tax progressivity, while other equity requirements could justify deviations from those solutions featuring greater degrees of tax progressivity.

Overall, the paper connects three distinctive ideas that can be evaluated either jointly or separately. One is that the benefits from the public goods financed with taxation should be incorporated into the labor-leisure choice, and that in doing so we should recognize the presence of positive net welfare benefits from tax and expenditure policies as normal and expected. Another is the allocation of tax burdens in accordance with the fist-best and second-best benefit tax solutions, which can be judged in terms of their distributive consequences. The last is the normative role proposed for these benefit tax solutions, which could serve as benchmarks (of minimum tax progressivity) to discuss and evaluate redistributive policies.

The rest of the paper is structured as follows. Section 2 provides a short historical review of the attempts to incorporate the preferences for public goods into models of labor supply responses to taxation. Section 3 formally considers public goods in the labor supply response to the labor-income tax and shows that, as long as all taxpayers that gain from additional public goods are assigned higher tax rates, taxpayers generally maximize their individual welfare with positive tax rates. Section 4 uses this insight to characterize the vector of individual labor-income tax rates that satisfy the benefit principle of taxation. Section 5 formally defines the second-best and first-best benefit tax solutions, compares them to related results in the literature, and discusses their normative role. The last section identifies some challenges and possible areas of further research.

2 Costs and benefits of labor-income taxation: a glance at the literature

The effect of government expenditure on labor supply has been the focus of extensive debate for several decades. Lewis (1957, p.76), for instance, suggested that failing to consider the increase in (equivalent) income associated with greater public expenditure would be the same as to assume that the government spends all tax revenues on goods that are "dumped in the ocean". To date, however, time allocation models commonly used in public finance theory assume that taxpayers disregard additional public expenditure (the marginal benefits of taxation) in their labor supply responses to the labor-income tax.

Arguably, the practice of disregarding the effects of government expenditure on labor supply models has been associated with a lack of clarity about how these effects fit into labor supply theory. One source of confusion seems to have started with Lewis (1957) himself, who argued that as long as tax revenues are used to provide valuable goods to the community, the net income effect of a labor-income tax on aggregate labor supply would be zero, and concluded that the tax increase would only have a substitution effect. The same idea was further developed by Gwartney and Stroup (1983), leading to a rather unusual number of critical reactions. One of the most relevant points of contention, shared among others by Bohanon and Van Cott (1986) and Gahvari (1986), was that even if it is true that the additional public goods provision can be interpreted as an increase in equivalent income, this increase is not equivalent to a greater purchasing power in the leisure-private goods plane.

Following this controversy, the literature largely rejected the idea that the net effect of tax and expenditure policies on aggregate labor supply would consist only of the substitution effects of taxation. However, the notion that the marginal benefits of taxation could significantly affect labor supply behavior has gained widespread support among economists. The so called "budget effects" of the labor-income tax on labor supply, as opposed to the partial "tax effects," have been analyzed on theoretical grounds by Lindbeck (1982), Snow and Warren (1989), Gahvari (1991), Ahmed and Croushore (1996) and Conway (1997). Their work showed not only that the effect of government expenditure on labor supply could be relevant, but also that it reduces the marginal welfare costs of taxation, which in turn alters the optimal provision of public goods. Several scholars have also recognized that the labor supply response to public expenditure is an important determinant of the *optimal* tax and expenditure policies. Snow and Warren (1996), Ahmed and Croushore (1996), Dahlby (1998), Slemrod and Yitzhaki (2001), and Gahvari (2006) are some of the most influential articles incorporating that response into the expressions defining the marginal cost of funds, a measure of the marginal welfare costs associated with the optimal amount of public expenditure. They all allowed for government expenditures to affect labor supply, which requires removing the assumption of weak separability of public goods in the utility function.

The empirical literature on the effects of public expenditure and (more specifically) public goods on labor supply is more recent. In what seems to be the first attempt to analyze this problem empirically, Conway (1997) showed that the effect of different types of government spending on labor supply is significant, although the sign of the influence varies for men and women in accordance with the type of spending, which includes public goods as well as publicly provided private goods. Later, Ortona et al. (2008) provided empirical evidence about the positive effects that public goods provision might have on labor supply. More work is needed in order to better understand the overall effects of fiscal policy on labor supply, but these studies suggest that research solely focused on the partial effects of taxation on disposable income are not accounting for all the relevant determinants of labor supply.

3 Labor supply response to the labor-income tax when public goods matter

Despite substantial progress in understanding the effects of public expenditure on labor supply behavior, public goods are still largely disregarded in the labor supply literature. For instance, in their review of the literature on the effects of taxation on labor supply, Meghir and Phillips (2010) did not consider public goods (or public expenditure) as a relevant determinant of labor supply. Similarly, time allocation models generally assume that changes in public goods provision have no effects on labor supply behavior, which is consistent with assuming that they are weakly separable from leisure and private goods. As Browning et al. (2000) explained, under this assumption the change in public goods provision does not alter the indifference map in the leisure-private goods plane, facilitating the analysis in that two-dimensional setting. The problem is, however, that public goods *can* affect the relative preferences between leisure and private goods, and they can also have an effect on their own on labor supply decisions.

This section relaxes the assumption of weak separability of public goods. As a result, marginal changes in public goods provision are allowed to modify the preference relations between leisure and private goods, and to create "public-income" effects on labor supply.

A taxpayer $i = 1, \ldots, N$ is assumed to derive utility u^i from leisure time ρ^i, the consumption of a private good x^i, and a non-rival and non-excludable (pure) public good G. Assuming no savings, the labor decision is $l^i = \kappa - \rho^i$, where κ is the time constraint, and $x^i = (1-t)\,w^i l^i + m^i$ is the individual budget constraint, where t is the tax rate, w^i is the taxpayer's wage rate, and m^i is non-labor-income. The individual maximization problem can be written as:

$$\max_{l^i} u^i = u^i\left\{\kappa - l^i, (1-t)\,w^i l^i + m^i, G\right\}, \text{ for any } i = 1, \ldots, N$$

from which the first-order condition is:

$$u^i_\rho = (1-t)\,w^i u^i_x, \text{ for all } i = 1, \ldots, N \tag{1}$$

where the subscripts represent partial derivatives with respect to the denoted variables. The literature usually assumes that G is weakly separable from x^i and ρ^i in the utility function u^i, which implies that labor is not affected by changes in G, in which case the labor supply function is:

$$l^i = l^{Ai}\left(w^i,\ m^i, t\right),\ \text{for all}\ i = 1, \ldots, N. \tag{2.a}$$

However, without the assumption of weak separability, condition (1) implicitly defines the individual labor function as:

$$l^i = l^{Bi}\left(w^i,\ m^i, t, G\right), \text{for all}\ i = 1, \ldots, N$$

in which G is recognized as a determinant of labor supply.

Assuming a balanced government budget, or that tax revenue is used up to pay for public goods, the budget constraint of a government that relies exclusively on a common proportional labor-income tax to collect revenue is given by:

$$G = t\sum\nolimits_{i=1}^{N} w^i l^i(\cdot) \tag{3}$$

where G appears to be a function of t and the other parameters that affect labor supply. Writing this conclusion as $G = G(t)$ to simplify notation, the individual labor supply can be rewritten as:

$$l^i = l^i\left(w^i,\ m^i, t, G(t)\right), \text{for all}\ i = 1, \ldots, N \tag{2.b}$$

from which is clear that the tax rate affects individual labor supply through two channels. One is the traditional direct effect that reduces private income, which has a substitution and a "private-income" effect, and the other is an indirect effect that does not alter the purchasing power of the taxpayer, but can affect the relative preferences between leisure and private goods and can also have its own "public-income" effect on labor supply. The total effect of t on l^i is:

$$\frac{dl^i}{dt} = \frac{\partial l^i}{\partial t} + \frac{\partial l^i}{\partial G}\frac{dG}{dt}, \text{for all}\ i = 1, \ldots, N \tag{4}$$

where $\partial l^i/\partial t$ is the (direct) partial effect of t, considered traditionally as the labor supply response to taxation –as defined in (2.a), and the second term in the right-hand side is the (indirect) effect of t, given by the (direct) partial effect of G multiplied by the additional amount of G that can be financed with additional tax revenue.

Note that dG/dt is exogenous from the individual taxpayer's perspective. The individual does not need to know how other taxpayers are affected by, or react to, the tax rate; what is relevant to each taxpayer is only how much G changes, because this variable affects their individual utility. Based on (3), the effect of a marginal increase in the tax rate on tax revenue is:

$$\frac{dG}{dt} = \sum\nolimits_{i=1}^{N} w^i l^i + t\sum\nolimits_{i=1}^{N} w^i \frac{dl^i}{dt}. \tag{5}$$

Considered together, Eqs. (4) and (5) describe the simultaneous nature and mutual dependency of the taxpayers' and government's decisions: In (4), the term dl^i/dt depends on dG/dt, and in (5) dG/dt depends on all individuals' labor responses dl^i/dt. However, the fact that taxpayers are too "small" to individually affect total tax revenue allows to get around potential endogeneity problems. While an individual taxpayer' decision has no discernible effect on G (individuals can only have relevant effects on G when they act *together*), all individual taxpayers' decisions can be affected by a change in G. Causality runs from G to l^i, not from l^i to G.

Assuming for simplicity that the marginal labor responses to public policies (to the tax rate t and to public goods G) are constant, we can introduce Eq. (4) into (5), and solve for dG/dt to obtain:

$$\frac{dG}{dt} = \frac{\sum_{i=1}^{N} w^i l^i + t\sum_{i=1}^{N} w^i \frac{\partial l^i}{\partial t}}{1 - t\sum_{i=1}^{N} w^i \frac{\partial l^i}{\partial G}} \tag{6}$$

where the marginal effect of t on G is expressed in terms of partial derivatives only and there are no reverse causality loops. The result in (6) can be interpreted as the final (long-term) effect of t on G, found after all "rounds" of the labor responses of all taxpayers to the tax rate (dl^i/dt, for all $i = 1, \ldots, N$) affecting dG/dt, followed by dG/dt affecting the responses of all taxpayers to the tax rate, have been completed, and therefore G has converged to its final level. This result should provide a good approximation of the total effect of G when describing the effect of "small" marginal changes in t; however, it is not necessarily valid when the change in t is "big" and partial derivatives are not constant. In that case $\partial l^i/\partial t$ and $\partial l^i/\partial G$ should be allowed to change for all $i = 1, \ldots, N$ as growing levels of G may affect taxpayers' responses to public policies.

Figure 1 presents a contrast between the traditional approach to individual labor supply response to taxation implicit in (2.a), which disregards the effects of public goods, and the approach associated with (2.b), which accounts for the effects of public goods on labor supply. The optimal individual decision under no labor-income tax is at ε_0, where the highest attainable indifference curve u_0 is tangent to the budget constraint BC_0. Any increase in the tax rate t would reduce individual's i after-tax wage rate, rotating the budget constraint downward over the point of no labor-income (κ, m). The figure presents 3 additional budget constraints (BC_1, BC_2, and BC_3), which are associated with increasing tax rates ($0 < t_1 < t_2 < t_3$).

Under the assumption of weak separability of G, an increase in t and the subsequent increase in G does not affect the individual preferences for ρ and x. Consequently, indifference curves in the ρ-x plane cannot cross. When this assumption is relaxed, however, individual preferences for ρ and x can be altered by the level of G, and thus the indifference curves associated with different levels of G *can* cross because they are effectively in different ρ-x planes. This is the case with u_1, which is tangent to budget constraint BC_1 at the individual optimum ε_1. Another important difference between the approaches under (2.a) and (2.b) is that under the latter, if the individual welfare benefits from additional public goods are greater than the individual welfare costs from the loss of private consumption, then the taxpayer is better

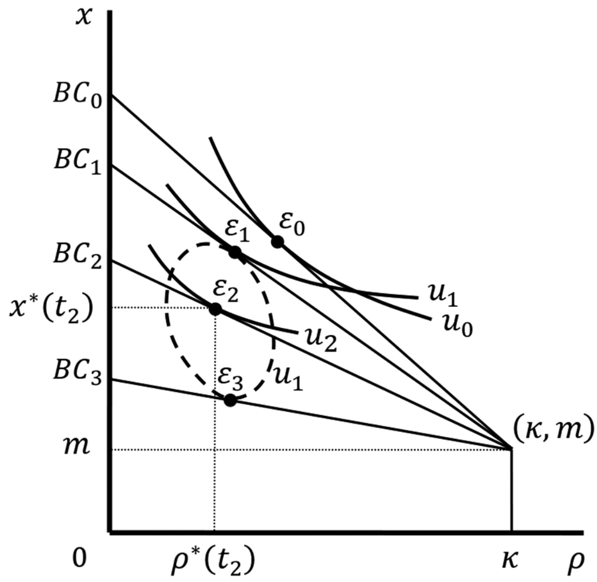


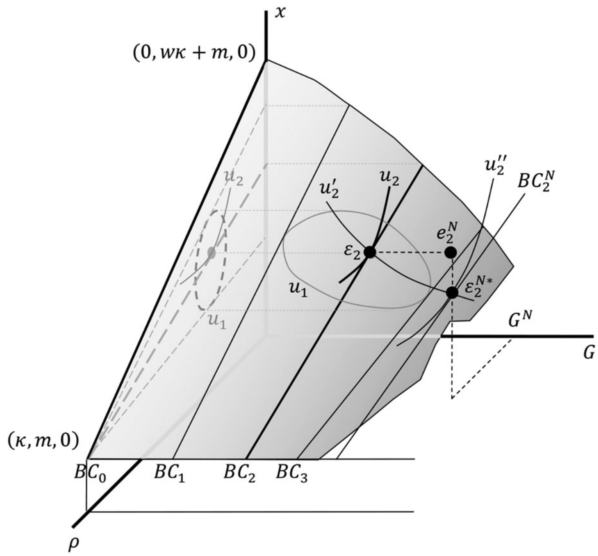
Fig. 1 Labor supply response to the labor-income tax

off after the application of the tax ($u_1 > u_0$ in Fig. 1). It follows that, if the individual welfare benefits from additional public goods are greater than the individual welfare costs from the loss of private consumption, the individual will *prefer* higher tax rates. From that taxpayer's perspective, there will be tax rates that are "too low" and others that are "too high", and under certain assumptions there will be only one tax rate that leads to the "most preferred" level of public goods and the highest possible level of individual welfare. In Fig. 1, individual welfare may be maximized at ε_2, where that tax rate is t_2 and utility is u_2, and any tax rate lower or higher than t_2 would lead to a lower level of welfare. For instance, the dashed curve u_1 shows all the points that may lead to the same level of utility than the indifference curve u_1; this curve shows that, in this case, t_1 and t_3 lead to the same level of individual welfare, which is lower than u_2.

In this framework, global maximization of each individual's welfare is possible and it is associated with positive labor-income tax rates. Figure 2 presents the same analysis in the ρ-x-G space. The key elements of Fig. 1 can be seen at the left (and "back") of Fig. 2, and correspond to projections from the tridimensional welfare maximization analysis into the traditional ρ-x plane. Higher tax rates are associated with greater levels of the public good, pushing the corresponding budget constraints (in their corresponding ρ-x planes) to the right. Considered together, all the budget constraint lines produce *one* exogenous budget constraint *surface* in the ρ-x-G space. [6]

[6] Of course, the individual cannot "purchase" a perceptible amount of public goods individually. Instead, the interpretation of the budget constraint surface is that, for any given tax rate, the individual faces one budget constraint containing the affordable combinations of leisure and private income, while having access to a given (exogenous) amount of public goods that also affects utility.

Fig. 2 Optimal individual tax rate in the ρ-x-G space



Similarly, individual preferences in the ρ-x-G space can be represented by indifference (level) *surfaces*. Indifference surfaces are not drawn (for graphical clarity), but three "cuts" at the level u_2 are shown, two in different ρ-x planes (u_2 and u_2'') and one in a x-G plane (u_2'). In addition, the 'curve of intersection' u_1 represents the intersection between the indifference surface at u_1 and the budget constraint surface.

Assuming that the budget constraint surface is strictly concave, and that the indifference surfaces are strictly convex, there should be one and only one point at which the highest attainable indifference surface is tangent to the budget constraint surface. [7] In Fig. 2 this point is ε_2, which can be reached with t_2 and where utility is u_2 (the same optimal solution presented in Fig. 1). At this point the individual welfare benefits from additional public goods are equal to the individual welfare costs from reduced private goods, or equivalently, the real income gained from additional public goods is equal to the real income lost from a reduction in private goods consumption. [8]

If the tax rate remains at t_2 for *all* taxpayers (or if all taxpayers are identical) then, provided the amount of public goods that can be financed with the contributions of all taxpayers at that rate, u_2 would correspond to the maximum possible level of welfare for that individual (or all identical individuals). If, instead, the tax rate keeps

[7] If the budget constraint surface is not strictly concave, or if the indifference surfaces are not strictly convex, multiple tangency point may be possible over alternative levels of utility. This possibility will be considered in the next section when explaining the tax rate "adjustments" necessary to keep the taxpayer's individual surplus constant in order to prevent free riding.

[8] Importantly, this does not mean that the respective public-income *effect* and the private-income *effect* on labor supply offset each other, as suggested by Lewis (1957) and Gwartney and Stroup (1983). The public-income and the private-income effects on labor supply are independent from each other (they depend on individual preferences) and can be either positive or negative, while the substitution effect is necessarily negative, and we cannot know a priori what the sign of the final (net) effect on individual (or aggregate) labor supply will be.

increasing for all taxpayers, then the individual analyzed in Figs. 1 and 2 would reach lower and lower levels of utility as the relevant budget constraints (in subsequent x -G planes) shift further away from u_2.

A special case, which is useful to consider as a reference for the analysis in the next section, consists of fixing t_2 for this individual taxpayer, and keep increasing the tax rate to other taxpayers that have not yet reached their (initial) tangency points. With a fixed t_2 this taxpayer would face no additional costs but would enjoy higher levels of utility as additional amounts of public goods are financed with other taxpayers' contributions. After all N taxpayers have been assigned a tax rate and the final amount of the public good has been determined, denoted here by G^N, [9] and assuming for easy of exposition that the labor decision is unaffected, then this individual taxpayer would reach point e_2^N, associated with a level of utility higher than u_2 (on a higher indifference surface, which is not shown). At that point the individual would be enjoying positive externalities from the contributions of other taxpayers to the public goods and could be said to be free riding because is not being taxed for those benefits.

4 The labor-income tax as a benefit tax

Assume initially that the labor-income tax rate t is zero for all taxpayers, such that $G = 0$. Assume also that the individual marginal welfare gains from additional public goods are decreasing in t, that the individual marginal welfare losses from lower consumption of private goods are increasing in t, and that all taxpayers receive net welfare gains with the first marginal increases in t. Then the tax rate t is increased for all taxpayers, until one taxpayer, here identified as taxpayer 1, no longer receives a *net* marginal welfare gain because the marginal welfare gain from additional public goods is equal to the marginal welfare loss from reduced private consumption. This tax rate is initially assigned to taxpayer 1 (only) and denoted as t^1. The tax rate t continues to increase for the *other*$N-1$ taxpayers, further increasing G and thus providing additional welfare gains to all taxpayers, including taxpayer 1.

In order to satisfy the benefit principle of taxation, and thus to avoid free riding, the additional gains received by taxpayer 1 should be offset by additional marginal increases in t^1, which are expected to remain below t. The tax rate t is then increased until a second taxpayer, taxpayer 2, receives no net marginal welfare gain and is initially assigned a tax rate t^2. Then t continues to increase for the other $N-2$ taxpayers, while t^1 and t^2 continue to be adjusted upward to stay at their respective utility levels. The process continues until all taxpayers have been assigned positive individual tax rates that ensure that the benefits and costs of taxation are equalized at the margin for each taxpayer.

In general, for any given change in the amount of public goods, the condition that determines both the initial level and the adjustments of the labor-income tax rates assigned to each taxpayer i is $du^i/dt^i = 0$. Using (1), and defining $\bar{t}$ as the vector of

[9] Note that, provided the contributions of all taxpayers, G^N is the amount of public goods preferred by the "last" taxpayer N.

individual tax rates that are simultaneously being increased to all taxpayers (including t^i), such that $dG/d\bar{t} = \sum_{i=1}^{N} dG/dt^i$, [10] this condition is reduced to:

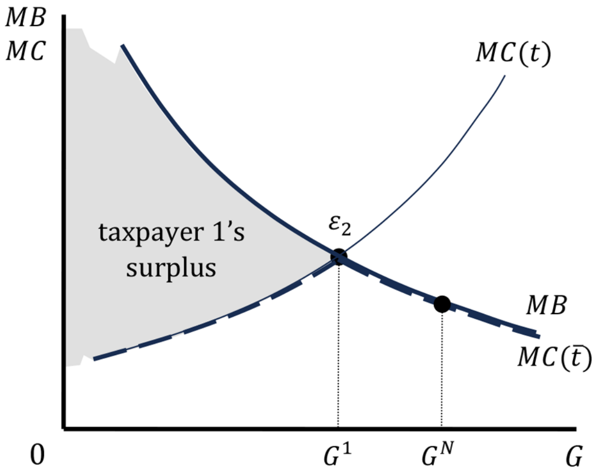
$$\frac{dG}{d\bar{t}} u_G^i = w^i l^i u_x^i, \text{ for all } i = 1, \ldots, N \tag{7}$$

which explicitly shows the equality between marginal welfare gains from additional public goods and marginal welfare losses from reduced private consumption at the optimal benefit-based labor-income tax rate. Once a taxpayer is assigned a tax rate, say for instance taxpayer 1 is assigned t_2 as shown in Figs. 1 and 2, [11] then further increases in that tax rate in accordance with (7) will keep the level of utility unchanged (at level u_2 for this taxpayer) as G increases with the contributions of all other taxpayers.

Figure 3 displays the individual surplus of taxpayer 1 under this solution. Provided that marginal benefits from public goods (MB) are decreasing in G, and that the marginal costs from lower private consumption (MC) are increasing in G, the initial tax rate that maximizes their net benefits or surplus is t_2, found at their "initially preferred" level of public goods given the contributions of all taxpayers and no free riding, at G^1.

Further increases in t for all taxpayers, including taxpayer 1, would lead to higher marginal costs for taxpayer 1 as represented by the function $MC(t)$, and therefore to a reduction of taxpayer 1's welfare. However, after finding t_2 the upward marginal adjustments to the individual tax rate are set only to equate individual marginal costs and benefits, such that the effective marginal cost function for taxpayer 1 is $MC\left(\bar{t}\right)$, leaving taxpayer 1's level of utility unchanged at u_2. These adjustments continue until taxpayer 1 is assigned a benefit-based tax rate t^{1*} at G^N. In Fig. 2, this tax rate

Fig. 3 Individual surplus from the provision of the public goods



[10] Recall that changes in G are exogenous from the taxpayer's perspective, and therefore it is irrelevant to any individual taxpayer what tax rates are applied to other taxpayers, or their behavioral responses.

[11] The superscript is momentarily omitted to make the notation consistent with the discussion in the previous section.

is found at the equilibrium point ϵ_2^{N*}, where $t^{1*} > t_2$ and the corresponding budget constraint BC_2^N is tangent to the indifference curve u_2'' in the ρ-x plane at G^N.[12] Note that if no adjustments are made to the initial tax rate t_2, taxpayer 1 could possibly reach a point like e_2^N in Fig. 2 and receive additional net welfare gains from free riding equal to the area below MB and between the levels of public goods G^1 and G^N in Fig. 3.

The general rule underlying this solution is that every taxpayer that gains from additional public goods pays a higher tax rate, and that no taxpayer is required to pay, at any margin, more than the benefits received. This solution satisfies the benefit principle because the tax burdens are fully justified by the benefits received from the public goods financed with the taxes collected.

Provided the amount of public goods that can be financed with the contributions of all taxpayers, the *values* of the final tax rates t^{i*}, $i = 1, \ldots, N$, can loosely be interpreted as implicitly ranking all taxpayers in terms of their relative preferences for public goods, from the one who prefers the lowest amount of public goods to the one who prefers the greatest.[13]

Note also that, in practice, it is not necessary to follow the steps described in this section (e.g., start with $t = 0$) to obtain the optimal vector of individual tax rates. Based on (7), the general rule to determine t^{i*} is simple: Each taxpayer i should be assigned the tax rate that leads that taxpayer to be indifferent between marginal increases in private and public goods; taxpayers that obtain net benefits with a higher tax rate should pay a higher tax rate in accordance with the benefit principle, and taxpayers that obtain net losses from a marginal increase in the tax rate should pay a relatively lower tax rate.

5 Relations with the literature

Rearranging (7), and adding up the conditions for all N taxpayers, the condition for the optimal provision of public goods in accordance with the benefit-based labor-income tax rates is:

$$\sum_{i=1}^{N} \frac{u_G^i}{u_x^i} = \frac{\sum_{i=1}^{N} w^i l^i}{dG/d\,\bar{t}}. \tag{8}$$

The left-hand side is the sum of marginal rates of substitution between public and private goods, the measure of marginal social welfare benefits from public goods found in the Samuelson (1954) condition, which describes the optimal amount of public goods in the presence of costless lump-sum taxation. The right-hand side can

[12] For easy of presentation, the final equilibrium of taxpayer 1 at ϵ_2^{N*} has been assumed to be on the same indifference curve u_2' (in the x-G plane) at which t_2 was found, but this does not need to be the case.

[13] If their place in the rank has not been affected by the tax adjustments, then the one who prefers the lowest amount of public goods would be taxpayer 1, and the one who prefers the greatest would be taxpayer N. However, if the ranking has changed, then this interpretation may require some value judgements.

be interpreted as the marginal *efficiency* cost of funds described by Mayshar and Yitzhaki (1995), defined in this case for individualized tax rates. The latter showed that the marginal costs of funds, a measure of the marginal welfare costs of taxation used to determine the optimal amount of public expenditure in the absence of lump-sum taxes, is equal to the marginal efficiency cost of funds times the Feldstein's (1972) distributional characteristic, which is a factor describing the effects of the distributional impacts of taxation on the welfare costs of taxation. The Feldstein's (1972) distributional characteristic is absent from (8) because the individual benefit-based tax rates are obtained without making interpersonal utility comparisons; optimality as defined by this solution is independent from equity considerations.

The optimal amount of public goods described by condition (8) can be defined as:

$$G^N = \sum_{i=1}^{N} t^{i*} w^i l^i \left(w^i,\ m^i, t^{i*}, G^N \right). \tag{9}$$

This amount need not be equal to the amount obtained under the Samuelson condition, because condition (8) is obtained under the labor-income tax, not under lump-sum taxation. The amount in (9) is also different from the optimal amount described in the literature on the marginal cost of funds, even when the distributional characteristic is inconsequential. The main reason is that the solution obtained in the marginal cost of funds' literature requires one unique tax rate applied to all taxpayers. As a result, the marginal social benefits are based on the social welfare function and measured as the ratio of the sum of marginal utilities from public goods over the sum of marginal utilities from private goods, not the sum of marginal rates of substitution. In addition, marginal tax revenue $dG/d\,\bar{t}$ can be expected to vary with the vector of individualized tax rates.

Condition (8) describes a unique cost sharing solution where, given the contributions of all taxpayers and no free riding, the welfare of every individual is maximized without making interpersonal comparisons of utility. This solution to the public goods problem can be regarded as "strictly efficient", as it is set at the maximum level of social welfare that can be reached without imposing any value judgement to the distribution of welfare. All taxpayers benefit from others' contributions to the public goods without free riding, while no taxpayer contributes more, at any margin, than the benefits received. Given that this solution is obtained with the proportional labor-income tax (not a lump-sum tax), it is here labeled as the *second-best benefit* tax solution under the proportional labor-income tax.

At this point it should be apparent that if the same procedure used in Sect. 4 to determine the tax burden under the proportional labor-income tax is applied in a scenario with only lump-sum taxes, then given the exogenous budget surfaces obtained without changes in the relative prices of leisure and private goods, the maximization of all taxpayers' surpluses would be obtained at the first-best optimal level of public goods characterized by the Samuelson condition. Indeed, considering the first-order condition for the optimal labor supply decision under a lump-sum tax, $u^i_\rho = w^i u^i_x$, and denoting $\bar{s}$ as the vector of individual lump-sum tax amounts s^i being assigned to taxpayers $i = 1, \ldots, N$, then the analogues of Eqs. (7) and (8) can be written as:

$$\frac{dG}{d\bar{s}}u_G^i = u_x^i, \text{ for all } i = 1, \ldots, N,$$

$$\sum_{i=1}^{N} \frac{u_G^i}{u_x^i} = 1. \tag{10}$$

Equation (10) is the Samuelson condition describing the first-best optimal amount of public goods in a framework where the production function has been omitted while monetary units are allowed to be costlessly transferred from each taxpayer to the public sector, such that $dG/d\bar{s} = N$. For the same reasons stated before for the case of the proportional labor-income tax, the solution in (10) is now labeled as the *first-best benefit* tax solution.

Among available benefit-based cost-sharing schemes, Moulin (1987) seems to provide the most similar solution to the first-best and second-best benefit tax solutions in (10) and (8), as he also determined tax burdens based on inframarginal individual benefits and required the net welfare gains from public goods to be positive for all taxpayers. Moulin introduced the concept of egalitarian-equivalent level of the public good and defined it as "the highest level of public good such that consuming [it] for free yields a feasible utility distribution". Tax burdens are set to make each taxpayer indifferent between the free (individually costless) egalitarian-equivalent level and the total (individually costly) amount of the public good, while the sum of all tax burdens is equal to the cost of providing the public good.

The presence of common values of the egalitarian-equivalent and the total amounts of the public good for all taxpayers prevents the Moulin solution from being necessarily consistent with the Samuelson condition. The reason is that total tax revenue increases associated with reductions in the egalitarian-equivalent level or increases in the total amount of the public good can become enough to cover the cost of the public good at points that do not satisfy the Samuelson condition.

Another difference is that under the benefit tax solutions presented in this paper the marginal individual contributions increase with the level of public goods, especially when that level has not yet reached the level preferred by the taxpayer, while under Moulin solution all individual contributions are only justified by amounts greater than the egalitarian-equivalent level. From the perspective of an individual taxpayer, the egalitarian-equivalent level can be perceived as arbitrary because it depends on others' preferences for and the costs of the public good. It is possible for a taxpayer to accumulate significant net benefits from an amount of the public good below the egalitarian-equivalent level, and negligible benefits after that level, leading to a negligible share of the costs of the public good. Such a situation would be considered free riding under the first-best and second-best benefit tax solutions.

5.1 Benefit taxation versus *marginal*-benefit taxation

The Lindahl solution is arguably the most relevant result in the benefit tax literature: "The traditional approach to benefit determination relies on Lindahl prices" (Hines, 2000, p. 483), and more generally, "Lindahl (1919) is the foundational formal treatment of benefit-based taxation" (Scherf & Weinzierl, 2020, p. 389). This solution, however, is based on a restrictive definition of benefit, as it considers only the *marginal* benefits (at the prevailing amount of public goods) to determine tax burdens, not the *total* benefits received by each taxpayer.

Indeed, the Lindahl solution assigns each taxpayer a tax burden *per monetary unit* of public expenditure equal to the marginal benefit received *at* the optimal amount of public goods. In contrast, the first-best and second-best benefit tax solutions are based on *total* benefits and maximize the surplus (net benefit) of each taxpayer, provided the contributions of all other taxpayers and no free riding. Under these solutions, *each additional monetary unit* of public expenditure is financed by equal tax amount or tax rate increases to those taxpayers that would prefer greater amounts of public goods, and by marginal tax adjustments that do not affect the welfare level of taxpayers that would have chosen lower amounts of public goods. All the tax increases associated with (inframarginal) net marginal welfare gains are therefore accumulated into growing individual *total* net benefits and tax burdens, while none of these increases reduce individual welfare. Since individual tax burdens depend on total benefits received, it is not possible to obtain a situation in which a high-income taxpayer that is receiving a substantial amount of (total) benefits from public goods is assigned a low tax rate based on low marginal benefits, as it would be the result under the Lindahl solution.

The presence of a taxpayer surplus in the relation between tax burdens and benefits from government expenditure has for long been acknowledged in the public finance literature (see, for instance, Aaron and McGuire 1970, Piggott and Whalley 1987) and the benefit tax literature (Moulin, 1987), but relatively recent contributions do not necessarily adhere to this approach. For instance, Hines (2000) proposes a tax sharing scheme based (implicitly) on the premise that the provision of public goods does not generate a surplus. Inspired by the efficient private market solution, his model requires all taxpayers to pay the same price for the provision of public goods, but compensates each of them for the individual utility lost from taxation. Since the solution to his model requires a positive sum of compensations, the presumption seems to be that greater tax burdens are not associated with more welfare. As explained, the problem with this approach is that if taxes are not used to finance worthwhile government expenditures and thus are associated with welfare increases, then they are not justified to begin with.

Assigning equal tax shares to all taxpayers has, in general, also been justified based on a marginal-benefit approach. Hines (2000) and other authors like Brennan (1976) argue that in order to reproduce the efficiency conditions of private markets, each taxpayer should pay the same price for each (think about monetary) unit of public good. Considering that by their very nature public goods are provided in the same amount to all taxpayers, an equal price per unit of public good implies an equal tax amount for every taxpayer. Consequently, these authors criticize the Lindahl solution because it defines different prices to different taxpayers. Hines (2000, p. 486) states that this is a "serious limitation", and Brennan (1976, p. 397) that "[t]o use Lindahl pricing would discriminate between individuals according to the intensity of their preferences for public goods".

Even though benefit taxation is commonly associated with Lindahl (1919), and other authors share the marginal-benefit approach to tax sharing, this does not mean that benefit taxation *must* be based on marginal benefits. As shown in this paper, benefit taxation can also be based on total benefits and the maximization of individual surpluses, and such an approach can have important advantages.

5.2 Comparative distributional effects

In order to illustrate how the welfare effects of the first-best and second-best benefit tax solutions differ from other cost-sharing rules available in the literature, this section provides the results of a numerical simulation. We consider five taxpayers with different degrees of preferences for public goods, who are ranked from taxpayer 1, who does not benefit from public goods, to taxpayer 5, who benefits the most. All the taxpayers who positively value public goods exhibit diminishing marginal utility from public goods. The preferences of four of the taxpayers are represented by the utility function:

$$u^i = x^i \rho^{\,i} + b^i \rho^{\,i} \sqrt{G}\,,\; i = 1,\ 2,\ 3,\ 5$$

where b^i varies to represent relative preferences for public goods, and it is equal to 0 for taxpayer 1, 0.25 for taxpayer 2, 0.75 for taxpayer 3, and 3 for taxpayer 5. The preferences of taxpayer 4 are represented by the utility function:

$$u^4 = x^4 \rho^{\,4} + \rho^{\,4}\left(4\sqrt{G} - G\right)$$

This taxpayer values highly the initial amounts of public goods but, other things equal, the marginal benefits decline quickly and become zero (total benefits reach a maximum) when the amount of public goods is 4; after this point the marginal benefits turn negative and total benefits decrease.

As in the previous theoretical discussion, the public goods' cost function is omitted for simplicity, and therefore the problem of finding the optimal amount of public goods is reduced to finding the optimal amount of public expenditure, which is associated with a constant marginal cost of 1 monetary unit. Also for simplicity, the wage rate w and non-labor income m are assumed to be 1 and 0, respectively. The time constraint κ is given a value of 20. Provided all the assumptions, taxpayers differ only in terms of their preferences for public goods, and the utility of every taxpayer takes a value of 100.0 when public goods are zero.

Table 1 presents the main results of the numerical simulation, which include the first-best and second-best benefit tax solutions, as well as the solutions described by Lindahl (1919), Moulin (1987), Brennan (1976) and the marginal cost of funds literature. [14] The tax burdens are expressed as monetary tax amounts in the solutions based on lump-sum taxes and as percentage rates in the solutions based on labor-income taxes. The utility levels of the five taxpayers are presented to compare their individual welfare levels under different solutions. The bottom of the table presents the differences between the utilities obtained under each alternative cost sharing solution and the first-best benefit solution, which seems to be an appropriate reference for comparison. Interpersonal utility comparisons and the sum of taxpayers' utilities are of no concern.

[14] The solution by Hines (2000) is excluded because it is based on assumptions incompatible with net welfare gains from public goods, and consequently produces non-comparable results.

Table 1 Results of numerical simulation

		taxpayer 1	taxpayer 2	taxpayer 3	taxpayer 4	taxpayer 5	G
Marginal rate of substitution (u_G/u_x):		$\frac{0}{2\sqrt{G}}$	$\frac{0.25}{2\sqrt{G}}$	$\frac{0.75}{2\sqrt{G}}$	$\frac{4}{2\sqrt{G}}$ - 1	$\frac{3}{2\sqrt{G}}$	
First-best benefit tax	tax amount:	0.00	0.44	1.00	0.91	1.66	
	utility:	100.00	100.63	105.06	133.33	148.15	4.000
Lindahl (1919)	tax amount:	0.00	0.25	0.75	0.00	3.00	
	utility:	100.00	102.52	107.64	144.00	132.25	4.000
Moulin (1987)	tax amount	0.00	0.21	0.62	0.69	2.49	
(ee=1.373) [1]	utility	100.00	102.95	108.98	135.88	138.24	4.000
Brennan (1976)	tax amount	0.80	0.80	0.80	0.80	0.80	
	utility	92.16	97.02	107.12	134.56	158.76	4.000
MCF	tax rate (%):	9.89	9.89	9.89	9.89	9.89	
	utility:	90.11	95.35	106.28	134.49	162.79	4.273
Second-best benefit tax	tax rate (%):	0.00	4.00	9.53	10.98	17.66	
	utility:	100.00	100.60	104.62	133.11	145.92	3.306
Individual utility change with respect to the First-best benefit tax solution:							
Lindahl (1919)		0.00	1.89	2.58	10.67	-15.90	
Moulin (1987) (ee=1.373) [1]		0.00	2.32	3.92	2.55	-9.92	
Brennan (1976)		-7.84	-3.60	2.06	1.23	10.61	
MCF		-9.89	-5.28	1.22	1.16	14.64	
Second-best benefit tax		0.00	-0.03	-0.44	-0.22	-2.24	

[1] ee: egalitarian-equivalent amount of public goods

Based on the sum of marginal rates of substitution between public and private goods, and a marginal cost of public goods equal to 1, the first-best optimal level of public goods provision, consistent with the Samuelson condition, is equal to 4. This is the same level of public goods that is obtained under the first-best benefit tax solution described in this paper and Lindahl (1919). The most striking difference between these two solutions is the tax amount assigned to taxpayer 4. This taxpayer receives a significant gain from the provision of public goods, but pays nothing under the Lindahl solution. This result is arguably unfair from the perspective of the other taxpayers, and it may be aggravated if taxpayer 4 is richer than the other taxpayers. Indeed, given our assumptions, significant increases of the wage rate and non-labor income only for taxpayer 4 would not change this taxpayer's tax burden under these two solutions. Notably, the first-best benefit tax assigned to taxpayer 4 is lower than the one assigned to taxpayer 3. This is explained by the fact that the change from the "initially preferred" amount of public goods by taxpayer 4 (equal to 2.5) to the final amount equal to 4 has a negative effect on this taxpayer's welfare.

For comparison, the Moulin solution is obtained for a total amount of public goods equal to 4, for which the egalitarian-equivalent amount of public goods is found to be 1.373. The Moulin solution does not suffer from the same problem of the Lindahl solution regarding the tax burden of taxpayer 4, but the two solutions are in this case similar in that they both assign taxpayer 5 a tax burden significantly higher than the first-best benefit tax solution.

To avoid discrimination based on preferences for public goods, the Brennan solution imposes an identical tax burden on all taxpayers; even taxpayer 1 should be taxed. This solution produces welfare losses on taxpayers with no or low preferences for public goods, and welfare gains on taxpayers with high preferences for public goods. A similar effect on taxpayers' utilities is found when a unique proportional labor-income tax rate is determined in accordance with the marginal cost of funds (MCF) literature.

The distributional effects of the second-best benefit tax solution do not appear to substantially deviate from the effects of the first-best benefit tax solution. Note that, different than under the first-best benefit tax, taxpayer 4 is being assigned a higher tax rate than taxpayer 3. This happens because the optimal level of public goods determined by the second-best benefit tax solution is lower than 4, such that a smaller tax rate reduction is needed to compensate taxpayer 4 for the disutility caused from "excessive" public goods.

5.3 Normative considerations

How the costs of public goods should be shared among taxpayers is a normative matter subject to a wide array of possibly conflicting considerations, and no argument in favor of the distributions of tax burdens determined by the tax benefit solutions introduced in this paper could settle that discussion. Instead, some clear advantages of these solutions are found in the principles with which they are obtained. These principles can be understood as a 'social contract' that applies to all taxpayers equally and exploits the nature of public goods, which generally require many to contribute for the benefit of most. This social contract can be stated either in terms of constrained self-interest: each taxpayer maximizes individual welfare without free riding; or in terms of constrained solidarity: every taxpayer contributes to the welfare of others without sacrificing their own. To the extent that this social contract is considered fair (and only to that extent), the first-best and second-best benefit tax solutions can also be considered fair. In addition, these solutions are efficient because, given no interpersonal comparisons of utility, the maximizing of all individual surpluses is equivalent to the maximization of social welfare.

Other common fairness requirements, like the ability-to-pay principles of horizontal equity, vertical equity, and equal sacrifice, are expectably *not* satisfied by the first-best and second-best benefit tax solutions. Horizontal equity, or the equal treatment (tax burden) of taxpayers with the same income; vertical equity, which states that taxpayers with higher income should pay more; and equal sacrifice, which consists of imposing the same burden in terms of utility, income, or consumption, are not satisfied because the tax burden is computed in accordance with the individual valuations of public goods' benefits, which might or might not be correlated across taxpayers with total utility, income, or consumption.

These ability-to-pay principles of taxation can be used to justify another common fairness requirement: the distributional neutrality of tax and expenditure policies. Interestingly, however, there is a reason to claim that the first-best and second-best benefit tax solutions satisfy distributional neutrality, and the same reason suggests that not satisfying the other ability-to-pay principles of taxation might not be very problematic. Since the benefit tax solutions are obtained without making interpersonal comparisons of utility, there have been no government intervention or value judgements imposed on those solutions. If the distributions of income or utility have been altered, it has been exclusively because of differences in taxpayers' preferences, which have been used to maximize their surpluses. All taxpayers have been made better off, and unless they care about their position in the social ranking, they would all consider these solutions preferable to a situation without public goods. The problem here, therefore, lies not in the merits of the solutions or their acceptance by taxpayers, but in an assumption implicit in the ability-to-pay principles of taxation, namely that the distribution that should be conserved is the one "before" the application of the tax and expenditure policies, not the one after. Consistent with this view, for instance, Kaplow (1996, 2006) introduced the notion of a benefit-offsetting tax adjustment, which is set equal to value of the benefit received from a public good, and suggested that the combined effect of that tax adjustment and the benefits of the public good would be distributionally neutral because the distribution of utility would remain unaffected.

Other attempts to define distributional neutrality in the context of public goods provision have been based on optimality conditions of the market economy, where optimal prices are set at the margin. For instance, Aaron and McGuire (1970, p. 909) argued that "the difference between the household's MRS and the tax it actually pays represents the entire income redistribution effect of public good supply", or equivalently, that the Lindahl solution is distributionally neutral. Brennan (1976) disagreed with this view and claimed that equal lump-sum taxes for all would be, at least approximately, distributionally neutral.

All in all, if we agree that a fair distribution of income or utility *after* the optimal amount of public goods is provided is equally or more relevant than the distribution before, and that a distribution based on the maximization of individual surpluses (as opposed to only marginal benefits) is acceptable, then the first-best and second-best benefit tax solutions can be considered both fair and efficient, and for that reason preferable to other existing benchmarks as a referent of distributional neutrality of tax and expenditure policies. To clarify, the benefit tax solutions are said here to be distributionally neutral not because they would not affect the distribution of income or utility, but because if they do, they would do so in an acceptable or even desirable manner; they would lead only to individual gains without the need to make interpersonal comparisons of utility.

The benefit tax solutions can serve as benchmark scenarios to discuss redistributive tax and expenditure policies, which can generally be defined as *deviations* from these solutions, justifiable on equity grounds by concerns not addressed in their derivation. For instance, there may be concerns about an unfair determination of wages, or an excessive concentration of non-labor income and wealth. In these cases, the benefit tax solutions could establish a minimum degree to tax progressivity that is justified as efficient, while these concerns can be used to justify additional degrees of progressivity in the system.

6 Discussion

The benefit tax solutions to the public goods problem presented in this paper are given by vectors of lump-sum amounts or labor-income tax rates that maximize welfare for each individual taxpayer, provided the contributions of all taxpayers and no free riding.

The implementation of the benefit tax solutions is challenging, as it requires information that is difficult to obtain. However, the solutions presented in this paper highlight the empirical nature of this challenge. The government does not need to know taxpayers' utility functions or to ask them to truthfully disclose their preferences for public goods. Instead, the information might be revealed by taxpayers' behavior, and empirical research could help finding the tax burdens at which taxpayers are indifferent between marginal increases in private and public goods. One well-known way in which taxpayers may reveal their relative preferences for public goods is by self-sorting themselves in communities with alternative private-public goods configurations (Tiebout, 1956). Other strategies to obtain that information may be based on voting outcomes, the taxpayers' willingness to pay for some insurances, legal and lobbying services, etc.

There also remain the tasks of properly identifying public goods and the public component of publicly provided (private) services, as well as their beneficiaries and the extent of their benefits. For instance, public education and public health programs provide private benefits to the direct beneficiaries and their families, but the benefits they create to other groups of society (positive externalities) in the form of more human capital, greater productivity, greater tax bases, more autonomous and constructive individuals, a richer supply of cultural expressions, etc., can be substantial, and we know very little about how these benefits spread across society. It is not correct to assume that the beneficiaries are only those receiving these services, or that those that are not directly receiving them are necessarily worst off after paying taxes, as a simple budgetary analysis of taxes and expenditures would suggest.

The benefits from some public goods might be consistent with a certain level of progressivity in the tax burdens obtained with the benefit tax solutions introduced in this paper. [15] For instance, the 'rule of law' can be considered a public good, set in principle to provide everybody with access to the same rights and responsibilities. However, if higher income individuals are having access to more legal services and political influence, which in practice can help them increase their effective rights and reduce their effective responsibilities, the resultant system can be expected to provide comparatively more benefits to those individuals. Another example of public goods is the legal system that helps allocating and enforcing property rights. Higher income individuals are likely to benefit more from such a system, and if for this reason they prefer more of these public goods, then they would be assigned greater benefit tax burdens.

Progressive taxation is in line with the 'classical version' of the benefit approach to taxation, coined by Musgrave (1959) and recently discussed by Weinzierl (2018). The classical version of the benefit approach was held, for instance, by Smith (1776), who advocated for prioritizing the use of benefit taxation, but also considered that income (i.e., the taxpayer's ability to pay) is a good proxy for the benefits received from public goods and services. According to this view, benefit taxes could be expected to be naturally aligned (to some extent) with taxes determined by the ability-to-pay

[15] The progressivity of benefit-based taxation has been analyzed theoretically, for instance, by Snow and Warren (1983), who found that the degree of progressivity in the Lindahl (1919) solution depends on the ratio of the income elasticity of demand for the public good to the price elasticity of demand for the public good.

principles of taxation. It follows that empirical research focusing on the correlation between income and the benefits from public goods could provide useful information about the degree of progressivity of the benefit tax solutions.

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