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The Marginal Cost of Public Funds: A Brief Guide

Abstract

When deciding on the social desirability of public investment, the cost of a project is sometimes adjusted by a factor known as the Marginal Cost of Public Funds (MCPF) which captures the cost of raising public funds through distortionary taxation. However, there is no scholarly consensus on either its definition or its quantification. The purpose of this paper is to provide a brief up-to-date guide to the theoretical background, practical application, and empirical quantification of the MCPF, taking into account some recent developments in the public finance literature.

JEL-Codes: D610, H410, H530, H210.

Keywords: benefit-cost analysis, public investment, excess burden, distortions, public goods, taxes.

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1 Introduction

What economic trade-offs are relevant when the government provides a public good? Economic textbooks usually explain that the provision should follow the so-called Samuelson rule (Samuelson 1954). This rule describes that social welfare is maximized when the public good is provided such that the sum of individuals' willingness to pay for an additional unit equals the marginal cost. However, this result assumes that the government can transfer resources from the private to the public sector without cost, that is, that the government has access to non-distortionary (lump-sum) taxes.[1]

At least since Pigou (1928), scholars have discussed how the rule for public good provision should be adjusted to account for distortionary taxation. However, there is still no agreement on how such an adjustment should be made. In this paper, I focus on the adjustment known in the literature as the Marginal Cost of Public Funds ($MCPF$).

The $MCPF$ is often perceived as a confusing concept by researchers and practitioners, and there are many different definitions in the research literature. The reason for this is that there are multiple ways of accounting for the behavioral effects of public investment and multiple ways of financing public investment, with different assumptions about what tax instruments that are available, how flexible they are, and how they are optimized by the government. The purpose of this paper is to provide a brief up-to-date guide to the $MCPF$ from a public finance perspective and to discuss some recent developments in the research literature.

The focal point in the bulk of the literature on the $MCPF$ has been the following equation (see for example Ballard and Fullerton 1992, page 118):

$$\sum_i MRS^i = MCPF \cdot p. \tag{1}$$

Equation (1) describes that in a social optimum, a public good is supplied such that the economy's total private marginal willingness to pay for an additional

[1] For this reason, the Samuelson rule is sometimes called a "first-best" result, which differs from the "second-best" where the government is forced to use distortionary taxes. In the early literature on optimal taxation (Ramsey 1927) it is assumed that lump-sum taxes are not available, without specifying why such taxes are not available. In the modern literature on optimal taxation (Mirrlees 1971), the constraints on tax policy follow instead from asymmetric information between the state and taxpayers.

unit ($\sum_i MRS^i$) is equal to the marginal cost p adjusted by the Marginal Cost of Public Funds ($MCPF$).

The $MCPF$ in (1) can be divided into three parts. The first part, discussed by Pigou (1928), is the deadweight loss that arises when a distortionary tax is used instead of a lump sum tax and is usually referred to as the Marginal Excess Burden (MEB). In a simple labor supply model, MEB is determined by the compensated labor supply elasticity.[2] The second part captures that the tax increase leads to an income loss that makes people poorer, which leads to income effects on both labor supply and consumption choices. The third part is the effects on individuals' behavior that arise from the public good. The latter two parts were highlighted by Stiglitz and Dasgupta (1971) and Atkinson and Stern (1974), and imply that $MCPF$ can be less than one if, for example, the income effects on the tax base are larger than the substitution effects so that the total effect of the tax increase on tax revenues is positive.

MEB reflects a thought experiment in which the tax is raised while each taxpayer receives a hypothetical compensation in the form of a lump sum transfer so that they can achieve the same level of utility as before the tax increase. Instead, $MCPF$ reflects a thought experiment in which the tax increase is used to finance a public good. MEB and $MCPF$ are equivalent if and only if: (i) there are no income effects of the financing tax on labor supply or the demand for private goods, and, (ii) there are no interactions between the public good and demand for private goods or labor supply. Since tax reforms are rarely designed to neutralize income effects, MEB is therefore mostly of theoretical interest.

How should the behavioural effects due to the public good (the third part of the $MCPF$) be handled? For example, an infrastructure investment may make work more attractive compared to leisure and thus mitigate income tax distortions on labor supply. It may also increase (or decrease) demand for taxed private goods and services in a way that increases (or decreases) tax revenues from consumption taxation. There are two main approaches in the research literature.

The first approach is to include the behavioural effects of the public good in the $MCPF$ which turns the $MCPF$ into what is commonly referred to as the

[2] Classical studies that have studied MEB are Harberger (1964, 1974), Browning (1976, 1987) as well as Hansson (1984). The $MCPF$ has been defined in several different ways in the research literature. Sometimes it is defined as $1 + MEB$, but this differs from how $MCPF$ is defined in this paper

Social Marginal Cost of Public Funds (SMCF). Variants of SMCF are studied by Wildasin (1984), Mayshar (1991), Snow and Warren (1996), Brent (2006) and Usher (2006). A disadvantage of the concept is that it is project-specific, which has been discussed by Sandmo (1998).[3]

The second way, which is most common for tractability reasons, is to assume that public investment does not affect the consumption of goods and services or the supply of labor. A formal way of expressing this is that the utility function is separable between the public good and both other goods and leisure. Although this is a questionable assumption for many investments, there is often a lack of empirical knowledge about how different public goods interact with demand for goods and labor supply. In light of this, separability may seem a useful simplification. This means ignoring, for example, that an investment in infrastructure increases demand for complementary taxed goods, such as vehicles.

Above is the "classical" way of defining $MCPF$ based on the Samuelson rule, which is usually called the Atkinson–Stern–Stiglitz–Dasgupta–definition. This definition focuses on the effects of compound budget-neutral reforms where taxes and spending are adjusted simultaneously. There is often an implicit assumption that public spending is financed by an adjustment of a proportional tax on labor income. In practice, however, there are many ways to finance a public investment, and each way will produce a different value of $MCPF$. Only in an optimal tax system is $MCPF$ independent of the marginal source of financing.

In the rest of the paper, I will focus on a specific definition of $MCPF$ introduced by Mayshar (1990) and further developed by Slemrod and Yitzhaki (1996, 2001) and Kleven and Kreiner (2006). This definition has been revived by the contributions of Hendren (2016), Finkelstein and Hendren (2020), and Hendren and Sprung-Keyser (2020) whose aim is to popularize the definition among empirical researchers evaluating the impact of public policies.

The alternative definition does not consider budget-neutral composite reforms. Instead, in line with Slemrod and Yitzhaki (2001), two "tax factors" are calculated, $MCPF$ reflecting the marginal cost to society of raising tax revenue to finance a public good, and Marginal Benefit of the Public Good ($MBPG$) reflecting the marginal benefit to society of spending an additional dollar on a

[3] An alternative is to record the effects of the public good on the "income side". This means that the $MCPF$ is not affected but of course requires that the income side is calculated correctly. What is recorded on the income side or the cost side affects what is interpreted as $MCPF$ but is irrelevant to the validity of the policy rule for the public good.

public good G. The decision rule is that spending on the public good should increase as long as $MBPG$ is higher than $MCPF$, and the optimal level is obtained when $MBPG = MCPF$. In other words, if spending on a public good is proposed to increase by 1 dollar, the first step is to calculate a tax factor $MBPG$ that describes the welfare effect of spending 1 dollar more on the public good. In a second step, a tax factor $MCPF$ is calculated that reflects the welfare effect of increasing some tax (or reducing spending on some other project) by 1 dollar.[4]

The alternative definition has several advantages over the "classic" one. First, the classical definition of $MCPF$ requires estimates of the elasticity of the tax base in response to combined reforms that change taxes and spending simultaneously. These elasticities are difficult to interpret, often project-specific, and are rarely estimated in empirical studies. Instead, the new definition uses separate estimates of the impact of taxes and government spending on the tax base. Second, the alternative definition is more flexible, as it allows projects to be financed in an arbitrary way, makes it easier to compare different projects with each other, and can also describe how one project is financed by a reduction in spending on another. A third advantage is that the separation in the alternative definition makes it easier when spending decisions and financing decisions are taken at different times, or by different branches of government.

The rest of the paper is organized as follows. Section 2 introduces and analyzes $MCPF$ according to Mayshar (1990) while section 3 discusses how empirical studies can be used to quantify the $MCPF$. Section 4 discusses extensions, such as the $MCPF$ for high-income earners, the role of the extensive margin, and how distributional considerations can be incorporated into the analysis. Finally, section 5 offers a concluding discussion. Appendix A describes other ways of presenting benefit-cost analysis and relates this to the $MCPF$ while appendix B discusses the $MVPF$ as presented by Hendren (2016).

[4] $MBPG$ is a benefit-cost ratio that reflects individuals' private willingness to pay for a project divided by the total cost to government (including any effects of the project on tax revenues) *without* taking any costs of distortionary tax financing into account. $MCPF$ and $MBPG$ are formally defined in the next section.

2 The Marginal Cost of Public Funds

Mayshar (1990) and Ballard (1990) define $MCPF$ as follows:

$$MCPF = -\frac{\text{Change in welfare in monetary terms}}{\text{Change in tax revenue}}. \tag{2}$$

Expression (2) describes the welfare effect of a project, expressed in dollars, divided by the effect on the government budget. $MCPF$ can be calculated for many types of reforms, not only tax reforms. In case $MCPF$ is calculated for a public project with an expected positive effect on social welfare, it is not so intuitive to describe it as a "cost", therefore we follow Slemrod and Yitzhaki (2001) and define an identical expression as:

$$MBPG = \frac{\text{Change in welfare in monetary terms}}{\text{Change in government expenditure}}. \tag{3}$$

Expression (2) is intuitive because a financing tax change has an expected *negative* effect on welfare and an expected positive change in *tax revenue*, while expression (3) is intuitive because public investment has an expected *positive* change in welfare and an expected positive increase in *expenditure*. However, it is sufficient to use one of the definitions for all projects because (2) and (3) are mathematically equivalent (one minus the change in tax revenue equals the change in government expenditure). The reason two measures are presented is purely for pedagogical reasons.

Motivated by similar pedagogical reasons, Hendren (2016), Finkelstein and Hendren (2020), and Hendren and Sprung-Keyser (2020) propose to use (3) for all reforms, and call this measure the Marginal Value of Public Funds ($MVPF$). The idea is to write $MVPF_G$ if it is a public investment and $MVPF_T$ if it is a tax. $MVPF$ is discussed in more detail in Appendix B.

If the private willingness to pay for a project is 2 dollars, the project costs 1 dollar and increases tax revenues in the long run by 50 cents, then $MBPG = \frac{2}{1-0.5} = 4$. Now consider a tax reform that finances this one dollar cost. Such a tax reform results in a private welfare loss of one dollar, and if it simultaneously reduces tax revenues by 20 cents, then $MCPF = -\frac{-1}{1-0.2} = 1/0.8 = 1.25$. Since $MBPG > MCPF$, implementing the project with the proposed financing implies an increase in social welfare.

2.1 MCPF in a simple labor supply model

Next, an expression for the $MCPF$ for a specific reform will be derived, namely a marginal increase in a proportional income tax. I consider a simple labor supply model without consumption taxes where leisure is a normal good (i.e., individuals demand more leisure if income increases, ceteris paribus). A representative individual with an hourly wage w chooses his labor supply h in order to maximise his individual welfare. The production technology is linear (one hour of work increases the output of the economy by w units) and there is perfect competition.

Since the tax change is small, the welfare effect of the tax change can be approximated by the reduction in disposable income.[5] Before the tax increase, the individual had an income of wh and the tax increase of dt therefore implies a reduction in disposable income of $wh \cdot dt$ and a welfare change equal to $-wh \cdot dt$ in monetary terms.[6] Turning to the denominator, government tax revenue is twh and the change in this is $\frac{d(twh)}{dt} \cdot dt$. We can therefore write (2) in the following way:

$$MCPF = -\frac{-wh \cdot dt}{\frac{d(twh)}{dt} \cdot dt} = \frac{wh \cdot dt}{(wh + tw\frac{dh}{dt}) \cdot dt} = \frac{1}{1 + \frac{t}{h}\frac{dh}{dt}} = \frac{1}{1 + \epsilon_{h,t}}, \qquad (4)$$

where in the last step we have expressed $MCPF$ in terms of an elasticity. It can be seen that $MCPF$ is a decreasing function of $\epsilon_{h,t}$, the uncompensated elasticity of labor supply with respect to t. Thus, whether $MCPF$ is greater or less than one depends on whether $\epsilon_{h,t}$ is negative or positive. A tax increase distorts labor supply, but at the same time has a positive income effect that increases tax revenues.

$MCPF$ in (4) can also be formally derived from a social optimization problem. Suppose that individuals choose consumption (c) and labor supply (h) in order to maximize their utility $u(c, h, G)$, where utility also depends on the level of a public good G. The budget constraint is given by $c = y + p_w h - p_c c$ where $p_w = (1 - t)w$ is the after-tax wage and y is non-labor income (e.g. wealth

[5]The tax change also affects individuals' labor supply, but since the tax change is small, this behavioral change will have a negligible effect on individuals' welfare. This follows from the envelope theorem in mathematical programming.

[6]Since we are considering a small tax change, $-wh \cdot dt = EV = CV$ where EV is the equivalent variation and CV is the compensating variation. Sometimes (2) is expressed as $MCPF = \frac{-EV}{dR}$ where dR is the change in tax revenue.

or partner income). We normalize the price and tax of consumption to 1, i.e., $p_c = 1$. The indirect utility function $V(p_w, y, G)$ is the value function to the *individual* optimization problem with the following Lagrange function:

$$\mathcal{H} = u(c, h, G) + \lambda(y + p_w h - p_c c), \tag{5}$$

where λ is the shadow price (Lagrange multiplier) of the individual budget constraint. Let $h(p_w, y, G)$ denote the Marshallian demand for h (the uncompensated labor supply function). The government maximizes the welfare of the individual by choosing the tax rate t and the level of public investment G. This results in the following Lagrange function for the government optimization problem:

$$\mathcal{L} = V(p_w, y, G) + \mu[twh(p_w, y, G) - p_G G], \tag{6}$$

where the marginal production cost of the public good is assumed to be equal to p_G and μ denotes the shadow price (Lagrange multiplier) of the government budget constraint. By exploiting the individuals' Lagrange function (5) to compute $\frac{dV}{dp_w}$ while using the envelope theorem, we obtain that the first-order condition for the government optimization problem with respect to t is:

$$\frac{d\mathcal{L}}{dt} = \frac{dV}{dp_w}\frac{dp_w}{dt} + \mu\left[wh + tw\frac{dh}{dt}\right] = (\lambda h)(-w) + \mu\left[wh + tw\frac{dh}{dt}\right] = 0.$$

If we divide by λhw and rearrange, we get

$$\frac{\mu}{\lambda}\left[1 + \frac{t}{h}\frac{dh}{dt}\right] = 1 \quad \Longleftrightarrow \quad \frac{\mu}{\lambda} = \frac{1}{1 + \epsilon_{h,t}}.$$

That is, we have that:

$$MCPF = \frac{\mu}{\lambda}, \tag{7}$$

where μ is interpreted as the social marginal value of public funds and λ as the private marginal value of private funds.

We can alternatively express (2) in terms of the elasticity of taxable income z (where $z = wh$) which is very common to estimate in empirical studies. We see immediately that:

$$MCPF = -\frac{-z \cdot dt}{\left(z - t\frac{dz}{d(1-t)}\right) \cdot dt} = \frac{1}{1 - \frac{(1-t)}{(1-t)}\frac{t}{z}\frac{dz}{d(1-t)}} = \frac{1}{1 - \frac{t}{1-t}\epsilon_{z,1-t}}. \quad (8)$$

Four key observations are in order. First, above I have considered a marginal increase in income tax for all individuals and the elasticity $\epsilon_{z,1-t}$ should be interpreted as the average elasticity of taxable income in the working population. However, one can consider a tax change only for a particular income group, and then a different measure of $MCPF$ is obtained. As mentioned earlier, only in an optimal tax system is $MCPF$ the same for different sources of marginal finance. In section 4.1 below, I derive $MCPF$ for an increase in the tax on labor income for high-income (top) earners. Second, it should be mentioned that the analysis here assumes "small" tax reforms so that we can ignore the effects of behavioral changes on individuals' utility. This is an important assumption, but at the same time necessary in order to link $MCPF$ to empirically observable elasticities. Third, we have limited the focus of the analysis to "intensive" adjustments (changes in working hours) among individuals who are already working. Kleven and Kreiner (2006) extends the concept of $MCPF$ to account for responses along both the intensive and extensive margins (the decision whether or not to participate in the labor force).[7] The fourth observation, which is perhaps obvious, is that if the aim is to estimate $MCPF$, one does not need to look specifically at empirical studies that have estimated $MCPF$; it is sufficient to start from studies that have estimated relevant elasticities.

2.2 Other tax instruments

In section 2.1, I studied changes in labor income taxation. Of course, it is also possible to find expressions for the $MCPF$ for other financing reforms, such as changes in consumption taxes or capital taxes. Under certain assumptions, changes in consumption taxation and income taxation are equivalent, but there are also differences.[8] An important difference is whether, for example, a public good is financed by a specific commodity tax, such as an increase in VAT on

[7] Such responses may be relevant if taxes are raised for low-income individuals, but are not particularly relevant for changes in taxes on high incomes.

[8] See Bastani and Koehne (2022) for an overview of the similarities and differences between labor income taxation and consumption taxation.

children's toys.[9] As toys for children reasonably occupy only a small part of individuals' budgets, the income effects of such a tax change are small. In the case of capital taxes, such as changes in capital income tax or corporate income tax, other models are needed to study the $MCPF$ (taking into account dynamic aspects such as savings behavior). We do not discuss such models here, but note that with such approaches the $MCPF$ would contain other elasticities about which we have limited empirical knowledge.

2.3 The policy rule for the public good

It is instructive to also derive the policy rule for the public good G. By taking the first-order condition with respect to G in (6) we get:

$$\frac{d\mathcal{L}}{dG} = \frac{dV}{dG} + \mu \left[tw\frac{dh}{dG} - p_G \right] = 0.$$

By dividing by λ and rearranging we get:

$$\frac{dV/dG}{\lambda} = \frac{dG}{\lambda} \left[p_G - tw\frac{dh}{dG} \right]$$

If we assume for simplicity that there are n identical individuals, and set $MRS^i = \frac{dV^i/dG}{\lambda}$ and utilize (7), that is, that $MCPF = \frac{\mu}{\lambda}$ we get:

$$\sum_i MRS^i = MCPF \cdot \left[p_G - tw\frac{dh}{dG} \right]. \tag{9}$$

The expression (9), which coincides with equation (3) in Atkinson and Stern (1974), illustrates that $MCPF$ according to Mayshar (1990) is identical to the classical definition presented in (1) if $\frac{dh}{dG} = 0$. A necessary and sufficient condition for this to hold is that the utility function u can be written in the form $u(c, h, G) = u(f(c, h), G)$ for any subutility function f. When the utility function can be written in this form, the marginal rate of substitution between labor and consumption is independent of the public good.[10] An important task for

[9]However, it is questionable whether it is a good idea to finance public investment with individual commodity taxes, as this creates distortions in people's consumption patterns, unless there are negative externalities that one wants to counteract at the same time.

[10]Note that (9) is a policy rule derived from a simultaneous variation in the income tax and the public good. $MCPF$ as we define it in this paper does not study such composite (budget neutral) reforms, but defines separate measures for the public good and the financing

future research is to study the causal effect of different public investments on labor supply.[11]

3 Empirical quantification

Let us now turn to the empirical quantification of the $MCPF$. Section 3.1 discusses elasticities of taxable income, section 3.2 discusses income effects on labor supply, and section 3.3 discusses implications for the $MCPF$.

3.1 Elasticities of taxable income

Formula (8) and (12) contain the elasticity of taxable income. There is a large empirical literature estimating elasticities of taxable income, and an introduction to this literature is provided by Saez et al. (2012). In general, elasticities of taxable income differ across studies, depending on the nature of the tax reform, the estimation approach used, the country studied, and the income groups affected. A meta-analysis of recent studies is provided by Neisser (2021).[12] For example, based on Swedish, Danish and Finnish tax reforms that affected broad groups of taxpayers, an elasticity of 0.2 could be deemed as reasonable.[13]

In the current context, it is important to note that what enters (8) and (12) is the elasticity resulting from a thought experiment where the marginal tax rate is increased in a proportional tax system without compensating households in the form of increased transfers. Such a reform has a negative substitution effect that is offset by a positive income effect (given the reasonable assumption that individuals demand less leisure and more work when income declines). When interpreting elasticities estimated using tax reforms, it thus becomes important to take into account that different tax reforms differ both in terms of which income groups are affected and in the relative importance of income and substitution

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tax. Therefore, no separation assumptions are needed to obtain an unambiguous measure of the $MCPF$.

[11] In a richer model with different consumption goods and different commodity taxes on them (differentiated commodity taxation), the effects of G on commodity taxes would also appear in (9), see Atkinson and Stern (1974).

[12] See also Aronsson et al. (2022a) for an overview and evaluation of different methods of estimating the elasticity of taxable income.

[13] See Blomquist and Selin (2010) that studied the major tax changes that occurred in Sweden from 1981 to 1991, Kleven and Schultz (2014) that studied the 1987 Danish reform, and Matikka (2018) that studied changes in Finnish municipal taxes from 1995 to 2007.

effects. It is therefore not always straightforward to link estimated elasticities to the simple tax change considered in section 2.1.

A complicating factor is the progressive (non-linear) income tax system. Suppose we are studying high-income earners who are located on the beginning of the second segment of a piecewise linear tax schedule and the considered tax change is a lower marginal tax on low incomes combined with an increase in the marginal tax on high incomes. The overall response among high-income earners will reflect both an increase in their marginal tax rate (a substitution effect leading to lower labor supply) and a reduction in the average tax rate due to the tax cut on low incomes (an income effect also leading to lower labor supply). Admittedly, the tax increase on the second segment makes high-income earners poorer (an income effect leading to higher labor supply), but for high-income earners who are just at the beginning of the second segment, this income effect will be negligible.

A conclusion one can draw is that income effects in empirical studies can be both positive and negative depending on whether individuals are poorer or richer overall as a result of the tax form being studied. It is therefore quite possible that studies finding different elasticities are consistent with the same magnitude of substitution effects but different magnitudes of income effects. Unfortunately, few studies are able to shed credible light on the role of income effects (see the discussion in the next section). Many studies therefore ignore the distinction altogether by starting from models where the utility function is linear in consumption, which means that the estimated elasticity is interpreted as a *compensated* elasticity that reflects substitution effects only.

One type of study where income effects tend to play a less significant role is so-called bunching studies (Saez 2010) where elasticities are estimated by locally analyzing behavior around kink points in the tax system (income thresholds where marginal income tax rates discontinuously change).[14] An example of such a study is Bastani and Selin (2014) who study the first central government income tax kink in Sweden (located in the upper middle part of the income distribution) and find an elasticity of zero for wage earners, which they interpret as an estimate of the *compensated* elasticity. At the same time, the authors point out that if individuals accept a utility loss of not optimizing at the cut-off point of on average one percent of disposable income, the compensated elasticity could

[14] See Kleven (2016) for an overview of bunching studies.

be substantially larger.[15]

That elasticities may be underestimated due to optimization frictions does not only apply to bunching studies, but to most empirical studies of how individuals react to taxation. In the labor market, there are several adjustment costs and frictions, for example regarding the possibilities to change one's working hours, change jobs, etc., combined with the fact that it takes time and energy for people to get to know how the tax system works and to understand which tax rates apply.[16] This usually means that: (i) changes in behavior only occur in the longer term, and, (ii) changes only occur if the benefits of changing one's behavior are sufficiently large.[17] However, the vast majority of empirical studies are only able to study responses in the relatively short term. The problem is compounded by the fact that there are responses to taxes that can in principle only be measured in the long run (such as educational choices) and responses that can hardly be measured at all, such as how much effort people put into their workplace in order to get a higher wage, and which are only reflected in labor income after a long time (and which are difficult to attribute to tax changes as income changes over time for many reasons unrelated to taxes).

Finally, while taxes can have a significant negative impact on tax revenues in the long run, *public investment* can also have a significant positive impact on tax revenues in the long run. Examples of this are investments in education that increase labor productivity or investments in health promotion that reduce sickness absence. It is therefore essential to consider the long-term effects of both taxes and public investment. The advantage of the $MCPF$-framework surveyed in this paper is that it is symmetric with respect to the revenue and expenditure sides of the government budget.

3.2 Studies of income effects

In the context of the taxable income model studied in section 2.1, the total response to a change in the net-of-tax rate $(1 - t)$ can be decomposed using the

[15] In their study, compensated elasticities above 0.39 can be ruled out based on the empirical estimates for 1998 and compensated elasticities beyond 0.7 can only be ruled out based on the estimates for 1999-2005.

[16] Bastani and Waldenström (2021) present recent bunching evidence showing that conditional on income, the responses are larger among those with high cognitive ability.

[17] This is discussed in Chetty (2012), Chetty et al. (2011), Bastani and Selin (2014), Kleven and Schultz (2014), Kostøl and Myhre (2021), and Labanca and Pozzoli (2022), among others

well-known Slutsky equation as follows:

$$\epsilon_{z,1-t} = \epsilon^c_{z,1-t} + \eta, \tag{10}$$

where $\epsilon^c_{z,1-t}$ is the compensated elasticity of taxable income that describes substitution effects and η is a parameter that captures income effects.[18] The parameter η is defined as:

$$\eta = (1-t)\frac{dz}{dy}, \tag{11}$$

where $\frac{dz}{dy}$ is the marginal propensity to increase one's labor income in response to a marginal increase in non-labor income y. If leisure is a normal good (i.e., the demand for leisure never decreases as income increases), then $\frac{dz}{dy} \leq 0$.

Income effects can be estimated in basically two ways. Either structural labor supply models estimated using data on labor income/hours (z/h), wages (w), taxes (t) and various "other" incomes (y) (such as partner income) are used. One problem with these studies is that they rely on strong assumptions and rarely have access to credible exogenous variation in y. For example, individuals with a strong preference for work relative to leisure will simultaneously work more hours and have more financial assets and therefore greater non-work income, creating a spurious correlation between non-work income and labor supply.

Another way is to use some natural experiment that offers exogenous variation in non-labor income. An important branch of these studies is that which has used lottery winnings. Using lottery winnings offers many advantages over other natural experiments, such as studies based on inheritance (where the question arises to what extent such inheritance is expected or unexpected, and inheritance coincides with the death of a parent which in itself may affect labor supply). One challenge with lottery studies is that they require assumptions about how individuals choose to distribute lottery winnings over the remaining part of the life cycle.

An early study of the effects of lottery winnings on labor supply is Imbens et al. (2001). These authors use data in the United States in the 1980s and find a marginal propensity to increase labor income in response to an income

[18] The compensated elasticity is derived from the compensated supply function that describes labor supply adjustments to taxes when individuals are compensated so that they always achieve the same utility level u, see for example Saez (2001) for details.

increase of about -0.11, which should be interpreted as an increase in income of 1000 dollars leads to a decrease in labor income of 110 dollars. Cesarini et al. (2017) use Swedish lottery winnings and find a marginal propensity to increase labor income in response to an income increase of between -0.036 (at age 60) to -0.168 (at age 20).[19] This could justify a η of about -0.1.[20]

Golosov et al. (2021) find larger income effects on US data. They find a marginal propensity to increase labor income in response to an income increase of as much as -0.52 (see their Table 4.1), which could easily justify a η of around -0.2. This means that with a value of the compensated elasticity of $\epsilon^c_{z,1-t} = 0.2$, equation (10) yields a value of the uncompensated elasticity that is around zero.[21] Of course, one should be cautious about extrapolating values between countries, as there could also be cross-country differences in compensated elasticities.

3.3 Implications for the $MCPF$

Let us now briefly summarize the implications of the discussion in the two previous subsections. For this purpose, suppose a government agrees on a given value of the elasticity of taxable income for small tax changes that involve broad groups of taxpayers, and let us assume that this value is 0.2. To which extent should it be interpreted as reflecting income effects?

It is useful to distinguish between two borderline cases. In the first limiting case, 0.2 is interpreted as the uncompensated elasticity of taxable income which implies that $\epsilon_{z,1-t} = 0.2$ and we obtain a value of the $MCPF$ (assuming that $t = 0.5$) of $\frac{1}{1-\epsilon_{z,1-t}} = 1.25$. In the second limiting case, 0.2 is interpreted as the compensated elasticity, which means that we need to add the income effect discussed in section 3.2 according to equation (10) to get the uncompensated elasticity. If we use the estimate $\eta = -0.1$ from Cesarini et al. (2017), we

[19]See Cesarini et al. (2017), Table 5, Panel C. The authors also report an uncompensated (Marshallian) elasticity of close to zero, 0.009, within their calibrated life-cycle model, see Cesarini et al. (2017), Table 5, Panel D.

[20]Similar results have been found on Dutch data by Picchio et al. (2018) who estimate an average marginal propensity to increase labor income in response to an income increase of -0.056 in the same year that the lottery winnings were received.

[21]This conclusion is consistent with the early studies of labor supply among men that were done in the 1960s, 1970s, and 1980s, see Pencavel (1986) for a review. Early studies found significantly higher elasticities for women (Killingsworth and Heckman 1986) but these elasticities have declined sharply as labor force participation among women has increased, see for example Heim (2007).

obtain $\epsilon_{z,1-t} = 0.1$, and the $MCPF$ becomes approximately 1.11. This just serves to illustrate how one can go about figuring our reasonable ranges for the $MCPF$ based on empirical estimates.

4 Extensions

The presentation so far has focused on proportional changes in income taxes that affect all taxpayers, has focused only on the intensive labor supply margin, and has ignored distributional considerations. We now discuss the implications of relaxing these assumptions. In section 4.1, we discuss the tax factor that is relevant when a public good is financed by a tax only on high-income earners, section 4.2 briefly discusses the extensive margin, and section 4.3 introduces distributional considerations.

4.1 MCPF for an increase in the top income tax rate

In section 2.1 we calculated $MCPF$ for a tax change covering all incomes (from $z = 0$ to $z = \infty$). Suppose that we now instead increase the marginal tax rate by dt only above a certain income level $\bar{z}$. We assume that in the initial situation everyone faces the same tax rate t so that the result of the reform is a piece-wise linear tax schedule where taxpayers face tax rate t up to the income level $\bar{z}$ and face tax rate $t + dt$ above that (for $z > \bar{z}$). Such a reform has exactly the same effects on individuals with incomes $z \geq z$ as a two-part reform with two components: (i) a marginal tax increase of dt on incomes from $z = 0$ to $z = \infty$, and, (ii) a lump-sum compensation with size $\bar{z}dt$. The second component is necessary because a tax increase that covers only a portion of income does not make individuals as much poorer as a tax increase that covers all income. Saez (2001) shows how the income change to this reform for an individual with income z can be written as

$$dz = \frac{\partial z}{\partial(1-t)}dt + \frac{\partial z}{\partial y}\bar{z}dt = -(\epsilon_{z,1-t}z - \eta\bar{z})\frac{dt}{1-t},$$

and that the total reduction in tax revenue can be written (where $\mathbf{E}_{z>\bar{z}}$ means that we take an average over all individuals with income higher than $\bar{z}$)

$$\mathbf{E}_{z>\bar{z}}[t \cdot dz] = -t \cdot (\bar{\epsilon}_{1-t} z_m - \bar{\eta}\bar{z})\frac{dt}{1-t},$$

where z_m is the average income, $\bar{\epsilon}_{1-t}$ is the average uncompensated elasticity, and $\bar{\eta}$ is the average income effect for individuals with incomes higher than $\bar{z}$. We can use this to derive an expression equivalent to (8) but which applies to a tax increase dt only for individuals with incomes above $\bar{z}$:

$$MCPF^{\text{top}} = \frac{(z_m - \bar{z}) \cdot dt}{(z_m - \bar{z}) \cdot dt - t \cdot (\bar{\epsilon}_{1-t} z_m - \bar{\eta}\bar{z})\frac{dt}{1-t}} = \frac{1}{1 - \frac{t}{1-t} \cdot (\bar{\epsilon}_{1-t} \cdot a - \bar{\eta} \cdot b)}, \tag{12}$$

where $a = \frac{z_m}{z_m - \bar{z}}$ is the so-called "Pareto parameter" which is a measure of how "thin" the distribution of high incomes is above a certain level $\bar{z}$ (which is the level of income above which the tax is raised) and $b = \frac{\bar{z}}{z_m - \bar{z}}$ reflects how much of the total income is not subject to the tax increase (how much of the income is infra-marginal to the tax increase). Note that if $\bar{z} = 0$ so that the tax reform covers all income, $a = 1$ and $b = 0$ which means that (12) becomes identical to (8).[22]

Bastani and Lundberg (2017) studies the distribution of income in Sweden locally over a limit $\bar{z} = 3 \cdot z_{avg}$ where z_{avg} is the average labor income in the economy. They find that a ranged between 3 and 4 over the period 1971-2012. If we set $a = 3$, it necessarily follows that $z_m = 4.5 \cdot z_{avg}$. This in turn implies that $b = \frac{3 \cdot z_{avg}}{4.5 \cdot z_{avg} - 3 \cdot z_{avg}} = 2$. If we assume $\bar{\epsilon}_{1-t} = 0.2$, $t = 0.5$ and $\eta = 0.2$, we obtain $MCPF^{\text{top}} = \frac{1}{1-(0.2 \cdot 3 - 0.2 \cdot 2)} = 1.25$.[23]

[22] Saez et al. (2012), page 8, calculate $MCPF$ for a tax increase on top incomes without taking into account income effects and finds that $MCPF^{\text{top}} = \frac{1}{1 - \frac{t}{1-t} \cdot a \cdot e}$ where e is the compensated elasticity of taxable income. We get exactly the same expression if we put $\eta = 0$ and $\bar{\epsilon}_{1-t} = e$ in equation (12).

[23] Miao et al. (2022) study the phasing out of the Swedish working tax credit that was implemented in Sweden in 2016 (an increase in the marginal tax rate on top income earners) and find elasticities of between 0.13 and 0.16 over a three-year period for individuals above the 95th percentile of labor income.

4.2 The extensive labor supply margin

The paper has focused on the $MCPF$ which takes into account the intensive margin of taxable income. This margin deals with how working individuals' incomes change in response to changes in marginal taxes. The presentation has not explicitly included extensive responses, that is, decisions to work or not to work. Admittedly, elasticities of taxable income reflect the extensive margin to some extent, but the link to $MCPF$ is more complicated because the value of working is controlled by the *average* tax and not the marginal tax.[24] With a positive extensive margin elasticity, the tax factor is greater than one even if the uncompensated elasticity of taxable income is zero. However, participation elasticities are highly context-dependent as they are determined by how many people in the labor force are indifferent on the margin between working and not working and whose decision to work is affected by a small change in the average tax rate induced by a small change in the marginal tax rate.[25] Another drawback with participation elasticities is that they only consider the voluntary part of the participation decision, neglecting the fact that many who would like to work cannot find work due to labor demand considerations such as minimum wages in combination with insufficient skills.

4.3 Distributional considerations

A limitation of the $MCPF$ as I have presented it above is that it focuses only on the distortionary costs of taxation without taking into account the distributional effects. This is of concern as the reason why the government uses *distortionary* taxation is because it wants to redistribute income. If the distribution of income did not matter, the government could use a non-distortionary lump sum tax which would mean that public investment could be financed without distortions and the $MCPF$ would be obsolete.

It is not clear how $MCPF$ should be generalized to take into account distributional aspects. In this section we use the most common variant, as used by

[24] Kleven and Kreiner (2006) develop $MCPF$ in a context of both intensive and extensive margins of labor supply.

[25] Bastani et al. (2021) is a recent study that presents quasi-experimental evidence on labor supply responses along the extensive margin in response to changes participation tax rates, exploiting a reform of the housing allowance in Sweden in the late 1990s. They find an average participation elasticity of around 0.13 for their study population of married women with relatively low income levels. They also show that the elasticities decline with income.

Gahvari (2006), for example.[26] Gahvari generalizes the definition in Slemrod and Yitzhaki (2001) as follows:

$$MCPF = \frac{\mu}{\sum \pi^i \lambda^i}. \tag{13}$$

This expression can be directly compared to (7). In the numerator we have the marginal social value of public funds as before, but in the denominator we now have the marginal benefits λ^i of the different individuals in the economy weighted by each individual's importance in the social welfare function, π^i. Note that the distributional weights in equation (13) should reasonably also be used on the expenditure side when evaluating the social value of public investment (in $MBPG$).

It is clear that the $MCPF$ now depends on the extent to which taxes and transfers redistribute between individuals (and what tax instruments are available) because the degree of redistribution affects λ^i. It is also clear that the measure depends on government preferences for redistribution π^i.[27] Only if the government has access to *individualized* lump-sum taxation does the $MCPF$ above collapse to the definition in (7).[28] Individualized lump sum taxation, however, requires the government to observe each individual's underlying ability to earn income, for which, not surprisingly, methods are lacking.

To avoid $MCPF$ reflecting arbitrary restrictions on tax instruments, one can assume that the government redistributes among individuals with different abilities to earn income using an optimal non-linear tax on income. This is the starting point of modern tax research which assumes that the fundamental constraint on tax policy is asymmetric information about individuals' abilities, see Mirrlees (1971). In this tradition, Christiansen (1981) and Boadway and Keen (1993) show that the policy rule for the public good is the same as in a first-best setting (the Samuelson rule) without any adjustment for the marginal cost of public funds. The result is based on a model where preferences for labor supply are separable from other goods, including the public good. One way to understand this result is that the non-linear income tax $T(z)$ contains a lump-

[26] See also Johansson-Stenman (2005).

[27] The problem of interpreting $MCPF$ in models with distributional aspects and non-linear taxation of income has been discussed by Christiansen (1999).

[28] To see this, note that with optimal individualized lump sum taxation, $\lambda^i = \lambda$ and if we set $\pi^i = \frac{1}{N}$ it follows that $\frac{\mu}{\sum \pi^i \lambda^i} = \frac{\mu}{\lambda}$.

sum transfer $T(0)$ that can be reduced to finance the public good at no efficiency cost. Such an adjustment has distributional effects, but these can be neutralized by adjustments in the non-linear income tax so that all individuals achieve the same welfare as before.[29]

If preferences are not separable, a "modified" Samuelson rule applies instead, which takes into account the impact of the public good on income redistribution (through the so-called self-selection constraints) as well as the tax revenue from commodity taxes (see for example Edwards et al. 1994 and Aronsson et al. 2022b). While these effects depend on the tax wedge, they are not very meaningful to relate to the $MCPF$.

It is tempting to interpret it as $MCPF = 1$ under optimal non-linear taxation. However, Gahvari (2006) shows that $MCPF$ in Boadway and Keen (1993), for example, is actually less than one.[30] In a more general model, Gahvari (2006) shows that $MCPF$ under optimal non-linear taxation can be both less than and greater than one. One conclusion is that $MCPF$ is not a particularly meaningful concept in models with distributional aspects and optimal nonlinear taxation.

Some research has studied $MCPF$ in the presence of distributional aspects under restricted tax systems. Sandmo (1998) studies the policy rule for public goods under an optimal *linear* income tax (proportional taxation of labor income combined with a uniform lump-sum transfer) and shows that the $MCPF$ in this case is less than one. The reason is that the public good can be financed at the margin without efficiency cost by reducing the lump-sum transfer. As this reduction makes people poorer, tax revenues increase through income effects while distributional effects are zero since the tax system is assumed to be optimal from the outset.[31]

[29] Kaplow (1996, 2004) argues that the first-best Samuelson rule is relevant even if the tax system is not optimal as long as the introduction of the public good and its financing can be done in a distributionally neutral way.

[30] We thus have that $MCPF < 1$ even though the public good in the optimum is provided neither "under" nor "above" the Samuelson rule. Note, however, that the level of the public good can be both higher and lower in second-best compared to first-best.

[31] Note that in an optimal linear tax system, $MCPF$ is the same whether the marginal financing is done through a reduction in lump sum transfer or through the distortionary income tax rate. However, the lack of flexibility in the income tax (due to the linear rather than non-linear nature of the income tax) gives rise to a distribution factor linked to the public good in the policy rule, but this is included on the "revenue" side and not on the cost side. With optimal non-linear taxation, this generally does not arise because distributional issues can be dealt with entirely by income taxation (under certain separability assumptions)

Jacobs (2018) builds on Sandmo (1998) and proposes a modified measure of $MCPF$ based on Diamond (1975). With this measure, the income effects of tax financing are included in the social value of private funds (see also Lundholm 2005). With this definition, $MCPF = 1$ under both the optimal linear tax system and under an optimal non-linear income tax. However, this modified definition has not yet gained traction in the research literature.[32]

Common to the studies of $MCPF$ in the presence of distributional effects is that the distributional effects of the tax financing are taken into account. The importance of these effects depends on policy makers' preferences for redistribution, the tax instruments available, and the extent to which tax instruments can be used to achieve redistributive goals (for example, there are political constraints that limit how taxes can be adjusted in practice). Three cases can be distinguished:

1. If the current tax system is optimal, the efficiency cost of a small tax increase will exactly match the distributional gains.
2. If the current tax system is less redistributive than what the policymaker considers optimal, a small tax increase to finance a public good will have a distributional gain that exceeds the efficiency cost.
3. If the current system is more redistributive than what the decision-maker considers optimal, a small tax increase will have a distributional cost (the redistributive efficiency of the tax system moves even further from the decision-maker's optimum), which is added on top of the efficiency cost of the financing tax change.

One conclusion is that distributional aspects introduce quite a lot of arbitrariness into the analysis of the $MCPF$, as it requires difficult to assess assumptions about the optimality of the tax system and policy makers' preferences for redistribution. Ignoring distributional effects may therefore be reasonable for conditions intended for researchers or officials in specific government agencies because judgments about the optimal level of redistribution are a matter of political priorities.

[32]See Bos et al. (2019) for a discussion.

5 Concluding remarks

This paper has discussed how to account for the welfare losses that arise when public investment is financed through distortionary taxes, incorporating some recent developments in the public finance literature. My presentation of these costs has been based mainly on the definition of the Marginal Cost of Public Funds ($MCPF$) introduced by Mayshar (1990), Ballard (1990), Slemrod and Yitzhaki (2001), and recently received new attention in the form of the Marginal Value of Public Funds ($MVPF$) by Hendren (2016), Hendren and Sprung-Keyser (2020), and Finkelstein and Hendren (2020).

For a small project financed by a small tax change, the $MCPF$ can be expressed in terms of elasticities estimated in the large empirical research literature that has studied how individuals respond to changes in taxes and transfers. Those interested in the size of the tax factor therefore need not limit themselves to studies that explicitly calculate the $MCPF$, but can learn from a wide range of studies that have used different strategies for identification and estimation.

The way in which the public investment is financed determines the relevant elasticity for calculating $MCPF$. If a project is financed by a proportional increase in the marginal tax rate on labor income that covers all income groups, a very simple expression can be derived. This expression is equal to $\frac{1}{1-\frac{t}{1-t}\epsilon_{z,1-t}}$ where $\epsilon_{z,1-t}$ is the *uncompensated* elasticity of taxable income with respect to the net-of-tax rate (one minus the tax rate) and t is the current tax rate level.

The reason why it is the uncompensated elasticity that is relevant in calculating the $MCPF$ is that public investment (e.g. tax-financed infrastructure) involves a loss of income for households. This income effect means that, although the tax increase at the margin makes it less profitable to work, people become poorer and therefore have incentives to work more to maintain their level of consumption. Thus, equipped with an elasticity of taxable, one has to make a judgment to which extent this elasticity captures these income effects. If it doesn't, an external estimate of income effects can be employed, for example, taken from recent studies that examine behavioral responses to lottery winnings.

Larger investments, or the combination of many small projects (e.g. in the context of an infrastructure bill), require larger tax increases and the $MCPF$ can be more significant in size. This is because labor market decisions (such as decisions to change jobs or reduce working hours) are often discrete, that is, they are only taken when the value of changing behavior is sufficiently large compared to the costs, and empirical studies find that taxpayers tend to respond more to large compared to small tax changes (see for example Kleven and Schultz 2014). There is also uncertainty about the magnitude of elasticities in the long run because most empirical studies have a fairly short-term perspective and some margins are difficult to measure at all, such as effects on educational choices and career aspirations.

An important message of the paper is that "tax factors" ($MCPF$-expressions) should be calculated on both the revenue and the expenditure side of the government budget. The tax factor on the *revenue* side captures how a tax change reduces individuals' disposable income, leads to a mechanical increase in tax revenues, and affects tax revenues through effects on individuals' behavior. The tax factor on the expenditure side captures individuals' private willingness to pay for a project, the mechanical cost of the project, and the impact of the project on tax revenues through effects on individual behavior.

Because individuals respond to taxation, the actual increase in tax revenue from a tax increase can be both lower and higher than the purely mechanical increase in revenue. Similarly, behavioral effects of a public investment may mean that the actual cost of a project differs from the mechanical cost. For example, an improved infrastructure may lead to new jobs, increased accessibility, reduced travel time, and reduced risk of accidents, air pollution and noise, leading to revenue changes that in the long run contribute to increased tax revenues that fully or partially offset the mechanical cost. These indirect social benefits are called fiscal externalities because they are not included in the private willingness to pay of individuals.[33]

Finally, there are other costs that should be taken into account in the context of public investment that may be at least as important as tax distortions. Examples of such other costs are crowding-out effects, distorted market competition, inefficient public procurement due to asymmetric information in key project dimensions, and administrative costs. It is therefore of perhaps even greater importance to correctly calculate and predict the "gross" costs to which the $MCPF$ is applied.

[33] An investment in public transport can, for example, reduce the risk of a key person in a workplace arriving late at work. This obviously has a value for the individual, but also additional positive effects for society (effects for the company, the employees, etc.) that the individual does not take into account in his own benefit calculation.

A Net Social Benefit and Benefit-Cost Ratios

It is instructive to briefly outline other ways of performing benefit-cost analysis and relate this to the $MCPF$. A classical way of evaluating projects, at least since Feldstein (1964), is to calculate the net benefits of a project. García and Heckman (2022a) define Net Social Benefit (NSB) in the following way (see also García and Heckman 2022b):

$$NSB = B - D(1 + \phi) + \Omega(1 + \phi), \tag{A1}$$

where B is the direct welfare effect, D is the direct cost, and Ω is the benefit to society at large and $\phi = MEB$. Here, Ω may capture, for example, that part of the project cost is recovered in the long run through cost savings. The multiplication by $1+MEB$ is justified by the fact that one dollar in the hands of the government is valued at $1+MEB$ because the marginal source of financing has a welfare loss amounting to MEB.[34]

An advantage of calculating net social benefits over benefit-cost ratios is that the former concept takes into account the scale of social benefits and avoids the arbitrariness of what to include in the denominator or numerator. One problem, however, is that large projects tend to be ranked highest and the measure is sensitive to project delineation (lumping together two projects with positive but low NSB results in a new project with higher NSB).

When calculating NSB, it is also common to calculate the net benefit *per dollar* (NBD):

$$NBD = \frac{NSB}{D} = \frac{B}{D} - (1 + \phi) + \frac{\Omega}{D}(1 + \phi). \tag{A2}$$

If not all profitable projects can be implemented, it is important to look at both NSB and NBD. To see this, assume that the project benefit can be described as $B = (1 + \phi)D + \gamma$ for $\gamma \geq 0$ and that $\Omega = 0$. This means that $NSB = \gamma$ and $NBD = \frac{\gamma}{D}$. Suppose we have two types of projects, a large project with $D = 100$ and $\gamma = 1000$, and a smaller project with $D = 8$ and $\gamma = 100$.

[34] Remember that MEB reflects a different thought experiment than $MCPF$ and that $1 + MEB = MCPF$ only if the financing tax increase has no income effects on individuals' behavior. For example, it is always true that $1 + MEB \geq 1$ but $MCPF$ can be less than one or even negative if the income effects are large enough.

The large project has $NSB = 1000$ and $NBD = 10$. The smaller project has $NSB = 100$ and $NBD = 12.5$. The smaller project thus has lower NSB but higher NBD. Since the smaller project has a higher NBD, it means that if we have a budget of 100, and can implement 12 projects of the smaller project type, we get a total NSB of 1200 which is higher NSB than the large project.

How does NSB relate to the classical benefit-cost ratio (BCR) defined in, for example, Boardman et al. (2018)? Using the notation above, BCR becomes the following:

$$BCR = \frac{B + \Omega(1+\phi)}{D(1+\phi)}. \tag{A3}$$

The BCR quotient is thus created by "moving" the cost $D(1+\phi)$ to the denominator. Note that $NSB > 0$ if and only if $BCR > 1$. Therefore, exactly the same projects are judged to be socially desirable under NSB and BCR. However, the choice of metric affects the distance between projects, which matters if not all projects with positive net benefits can be implemented.

If we also "move" $\Omega(1+\phi)$ to the denominator (in the form of a reduced cost), we get:

$$BCR' = \frac{B}{D(1+\phi) - \Omega(1+\phi)}. \tag{A4}$$

Again, this manipulation does not affect which projects are deemed profitable, but does affect the ranking. If we assume that we have D dollars to spend, and avoid making an assumption about how D is financed, we can set $\phi = 0$ and get:

$$BCR'' = \frac{B}{D - \Omega}. \tag{A5}$$

The above expression is equal to $MCPF$ if we restrict Ω to represent the long-term behavioral effects of the project on *tax revenue* (and allow other positive welfare effects to be included in B). For example, we see that if $\Omega \to D$ (the project almost pays for itself) then $BCR'' \to \infty$ holds regardless of the size of $B > 0$. In future studies, numerical calculations illustrating the ranking of projects under different definitions of benefit-cost criteria would be useful to understand the practical significance of different assumptions.

B Marginal Value of Public Funds (MVPF)

The $MCPF$ has received new attention through the contributions of Hendren (2016), Hendren and Sprung-Keyser (2020) and Finkelstein and Hendren (2020). The aim of these contributions is to offer a broader model perspective compared to previous studies and to encourage empirical researchers to use the concept in the context of reform evaluation.[35] Hendren and Sprung-Keyser (2022) use an expression that is conceptually identical to (3) and calls this the Marginal Value of Public Funds ($MVPF$). Renaming $MCPF$ to $MVPF$ is useful given that there are many different definitions of $MCPF$ in the research literature. The general definition of $MVPF$ that also takes into account distributional effects is as follows:

$$MVPF = \frac{\text{Change in welfare in monetary terms}}{\text{Change in government expenditure}} = \frac{\sum_i \eta^i WTP^i}{\Delta E - \Delta C}. \tag{B1}$$

In the numerator of (B1) we have the total private willingness to pay for an additional dollar of investment in the project. It is a sum of all affected individuals' private willingness to pay WTP^i for the project weighted by each individual's social welfare weight η^i. For a tax cut that gives 1 dollar to each individual h, $WTP^i = 1$ because each individual h is willing to pay exactly 1 dollar to get 1 dollar in tax cut. In the denominator, we have the net cost to government, which consists of the mechanical cost ΔE minus the long-run effect of the project on government tax revenues, ΔC. These fiscal externalities capture the impact of the project on tax revenues through effects on individual behavior. Note that if $\sum_i \eta^i WTP^i > 0$ but $\Delta E - \Delta C < 0$ then the project increases societal welfare but has a negative net cost. This should be interpreted as $MVPF$ for the project being infinite because it pays for itself.[36]

If we want to finance a public good G with a tax reform T, two values are calculated, $MVPF_G$ and $MVPF_T$, and the reform is implemented if $MVPF_G > MVPF_T$. If G and T affect the same group of people, the same welfare weights

[35] Hendren and Sprung-Keyser (2020) illustrate the usefulness of the $MVPF$ by calculating this measure for 133 historical policy changes in the United States.

[36] Note that (B1) is identical to (4) in the special case when all individuals are identical and have labor income wh. To see this, disregard the distribution weights and set $\eta^i = 1$ for all i. Then notice that an increase in the income tax rate by dt leads to $WTP^i = -wh \cdot dt$ and the direct cost to the government is $\Delta E = -wh \cdot dt$. The long-run cost saving is given by $\Delta C = tw\frac{dh}{dt}dt$. We thus have that $MVPF = \frac{-wh \cdot dt}{-wh \cdot dt - tw\frac{dh}{dt}dt} = \frac{1}{1+\epsilon_{h,t}}$.

are used on the income side as on the cost side. Note that G does not have to be financed by tax reform, but we can also finance G by cutting another public project. Spending a dollar less on project 1 and a dollar more on project 2 is profitable if $MVPF_{G_2} > MVPF_{G_1}$. If $\mathcal{T}$ is the set of all possible tax reforms and $\mathcal{G}$ is the set of all possible public projects, then in a social optimum:

$$MVPF_T = MVPF_{T'} = MVPF_G = MVPF_{G'}$$

for all $T, T' \in \mathcal{T}$ and $G, G' \in \mathcal{G}$.[37]

It is instructive to briefly describe how to proceed if there are different groups that benefit from a public good and pay for it.

Suppose we are interested in computing $MVPF$ for a public good G offered to a group of individuals $\mathbf{L}$ who all have the same willingness to pay for G, that is, $WTP_G^i = WTP_G$ for all $i \in \mathbf{L}$. Furthermore, we assume that $\Delta C = 0$ for the public good and that the mechanical direct cost is $\Delta E = 1$. Thus, if $\bar{\eta}_{\mathbf{L}}$ is the average welfare weight of the individuals benefiting from the project, we have $MVPF_G = \bar{\eta}_{\mathbf{L}} WTP_G$. This means that for every dollar of investment in the project G, $\bar{\eta}_{\mathbf{L}} WTP_G$ is generated in social benefits.

In the next step, we calculate $MVPF$ for the tax financing. We assume that the public good is financed by increasing the tax on all high-income earners by one dollar. Since individuals are willing to pay 1 dollar to avoid 1 dollar in tax increase, we have $WTP_\tau = -1$ while the mechanical cost (per person) is $\Delta E = -1$. We further assume that tax revenues are reduced by 25 cents for each dollar of tax increase on high incomes, which gives $\Delta C = -0.25$ and $MVPF_\tau = \frac{-\eta_{\mathbf{H}}}{-1+0.25} \approx \bar{\eta}_{\mathbf{H}} 1.33$ where $\bar{\eta}_{\mathbf{H}}$ is the average welfare weight of high-income individuals. This means that for every dollar of tax increase for high-income individuals, the welfare loss is $\eta_{\mathbf{H}} 1.33$. Thus, the combined reform is profitable if the following criterion is met:

$$MVPF_G > MVPF_\tau \Longleftrightarrow \bar{\eta}_{\mathbf{L}} WTP_G > \bar{\eta}_{\mathbf{H}} \cdot 1.33.$$

If it is the same group that benefits from G and that is affected by the financing tax reform, we have that $\bar{\eta}_{\mathbf{L}} = \bar{\eta}_{\mathbf{H}}$, and if taxes and public investment are optimal, it must hold that $\bar{\eta}_{\mathbf{L}} WTP_G = \bar{\eta}_{\mathbf{H}} \cdot 1.33$.

[37] Johansson-Stenman (2005), equation (10), presents an identical condition for optimal public investment.

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