The Policy Elasticity

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Abstract

This paper applies basic price theory to study the marginal welfare impact of government policy changes. In contrast to the canonical marginal excess burden framework, the framework does not require a decomposition of behavioral responses to the policy into income and substitution effects. The causal effects of the policy are sufficient. Moreover, in the broad class of models where the government is the only distortion, the causal impact of the behavioral response to the policy on the government budget is sufficient for all behavioral responses. Because these behavioral responses vary with the policy in question and are, in general, neither pure Hicksian nor Marshallian elasticities, I term them *policy elasticities*. The model provides formal justification for a simple benefit/cost ratio measure for non-budget neutral policies: the welfare impact on beneficiaries per dollar of government expenditure. I calculate this ratio using existing causal effects from five policy changes: the top marginal income tax rate, EITC generosity, food stamps, job training, and housing vouchers. Comparisons across beneficiaries of such policies is accomplished using social marginal utilities of income. For example, the mid-range of existing causal estimates suggest increasing EITC generosity financed by an increase in the top marginal income tax rate is desirable if and only if one prefers giving an additional \$0.44-0.66 to an EITC-eligible single mother (earning less than \$40,000) relative to an additional \$1 to a person subject to the top marginal tax rate (earning more than \$400,000).

1 Introduction

There is a long history in economics of estimating marginal deadweight loss or marginal excess burden (MEB) to study the normative implications of government policy changes. Done properly, calculation of MEB requires decomposition of the behavioral response to policy changes into income and substitution effects. Only the substitution effect is desired for such a welfare analysis.[1]

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[1] See, e.g., Harberger (1964); Mas-Colell et al. (1995); Feldstein (1999); Chetty (2009b). The resulting importance of the compensated elasticity for marginal welfare analysis is discussed in the recent JEL survey:

Graduate textbooks teach that the two central aspects of the public sector, optimal progressivity of the tax-

A large and growing literature in economics focuses on estimating the causal effects of government policy changes. This rise in experimental and quasi-experimental methods have made significant advances in addressing the positive question of what policy changes *do* to behavior. But, translating causal effects into a normative evaluation of the policy change runs into an immediate hurdle, expressed succinctly by Goolsbee (1999): "The theory largely relates to compensated elasticities, whereas the natural experiments[2] provide information primarily on the uncompensated effects". Rarely do policy changes hold everyone's utility constant. Thus, the prevailing wisdom is that the causal effects of a policy change are not the behavioral responses that are desired for a normative analysis of that same policy change.

This paper shows how causal effects can be directly used in welfare analysis of government policy changes. In contrast to calculating MEB[3], I characterize each agent's willingness to pay out of their own income for a given policy change. The main result is that the only behavioral response required for calculating this measure of welfare is the *causal impact* of the policy – a decomposition into income effects, substitution effects, or any other mechanism is not required. Real-world policy changes are often complex; therefore, these causal effects will in general be neither a pure Hicksian nor Marshallian elasticity.[4] Because these desired responses vary with the policies in question, I term them *policy elasticities*. These are simply the difference in behavior if the policy is undertaken relative to the counterfactual world in which the policy is not undertaken, precisely the textbook definition of the causal effect of the policy.

Moreover, in the broad class of models in which government taxation is the only pre-existing distortion, a *single* causal effect is sufficient: the causal impact of the behavioral response to the policy on the government's budget.[5] The causal effect of the policy on the government budget matters because of the envelope theorem, which implies that behavioral responses to marginal policy changes don't affect utility directly. However, to the extent to which the prices faced by individuals do not reflect their resource costs (e.g. if there are marginal tax rates on labor earnings), behavioral responses impose a resource cost on society that has no impact on the agent's utility. If the government is the only distortion between private prices and social (resource) costs, the impact of the behavioral response on

> *and-transfer system, as well as the optimal size of the public sector, depend (inversely) on the compensated elasticity of labor supply with respect to the marginal tax rate.* (Saez, Slemrod, and Giertz (2012))

And also in the JEL, Feldstein (2012) writes his critique of the Mirrlees review (Mirrlees et al. (2011)), an influential analysis of tax policy influenced heavily by optimal tax theory and empirical work:

> *While decisions on the appropriate size of government must be left to the political process, economists can assist that decision by indicating the magnitude of the total marginal cost of increased government spending. That cost depends on the structure of taxes, the distribution of income, and the compensated elasticity of the tax base with respect to a marginal change in tax rates.*

[2] In Goolsbee's case, the natural experiment was a change in top income marginal tax rates.

[3] MEB calculations compute the additional revenue the government could obtain under the policy if utility were held constant using individual-specific lump-sum transfers.

[4] Although causal effects are not, in general, a simple Marshallian price elasticity, the notion of defining "causal effects" to hold all else constant arguably follows from Marshall (1890)'s notion of *ceteris paribus*. See Heckman and Pinto (2013) for a recent discussion.

[5] To be precise, this causal effect is sufficient for all components of the second derivative of the utility function. See Footnote 32.

the government's budget is the only behavioral response required for welfare estimation.[6] Of course, this envelope theorem logic is not new – it underscores almost all previous literature in empirical welfare economics including Harberger (1964)'s triangle and the sufficiency of the taxable income elasticity in Feldstein (1999). The key difference is that the present framework uses the causal, not compensated, impact on the government budget.

With the causal effect on the government budget, welfare analysis follows straightforwardly. Only two other components are required to calculate an individuals' willingness to pay for the policy change, both of which are arguably well-known. First, if a policy changes the provision of publicly provided goods or services, one also needs to know the net willingness to pay for these goods. This is given by the difference between individuals' marginal rates of substitution and the marginal cost of production – an insight of Samuelson (1954). Indeed, this is a term that should be interpreted broadly as the relative advantage of the government over the private market (or vice-versa) in publicly provided goods. It is positive (negative) to the extent to which the value of the provision of public goods or services exceed (falls below) their resource costs. Second, one needs to know the change in net resource transfers to the individual, which are valued dollar-for-dollar by the individual. These three components – (1) the causal impact of the response to the policy change on the government's budget, (2) the net willingness to pay for the change in publicly provided goods and services, and (3) the net transfers – fully characterize the welfare impact of marginal policy changes to an individual.

While (1)-(3) characterize the welfare impact on a given individual, aggregating this welfare impact across individuals involves weighting by each person's social marginal utility of income. This is useful because ratios of social marginal utilities have a simple interpretation in terms of Okun's leaky bucket experiment (Okun (1975)): how much resources is society willing to lose to transfer from on person to another? In contrast, aggregation of MEB across individuals in a manner consistent with marginal social welfare measurement requires adding back in the income effects that were subtracted in calculating MEB.[7] In this sense, the aggregation of welfare across people is more easily accomplished when using the causal effects for conducting welfare as opposed to the MEB framework.

The framework can be applied to both budget-neutral and non-budget neutral policies alike. Indeed, many government policy changes are not budget neutral, at least in the short run. For dealing with non-budget neutral policies, straightforward differentiation shows that the welfare impact of two policies (e.g. tax and expenditure policies) can be added together to form a welfare analysis of a budget-neutral policy as long as the two policies sum to the policy of interest.[8] This motivates a simple measure of the marginal value of public funds (MVPF) suggested by (Mayshar (1990))[9]: the

[6] If the government is not the sole distortion in the market, one needs to estimate the causal impact on the other externalities as well as this fiscal externality. This includes not only traditional externalities such as pollution, but also externalities on one's self caused by imperfect optimization. Even in these more general models, the causal effects are sufficient for all behavioral responses; a decomposition into income and substitution effects is not required. See Section 2.7.

[7] This feature of MEB was initially derived by Diamond and Mirrlees (1971). See also Auerbach and Hines (2002) for a simple illustration of this on page 1370, equation 3.24.

[8] This might seem like an obvious condition, but it is violated if, for example, one used the MEB of a tax increase to adjust the standard Samuelson condition for the cost of raising revenue to finance the public good.

[9] See equation 9 on page 267 of Mayshar (1990); also, see Slemrod and Yitzhaki (1996, 2001) for similar definitions.

marginal social welfare impact of the policy per unit of government revenue expended.[10] With this benefit/cost ratio, one can compare the cost-effectiveness across policies: taking revenue from policies with low MVPF and spending on policies with high MVPF increases social welfare.[11]

I illustrate the framework to study the welfare impact of changes to five U.S. policies: the top marginal income tax rate, the generosity of the earned income tax credit (EITC), food stamps (SNAP), job training programs (JTPA), and housing vouchers (Section 8). To do so, I use existing causal effects to calculate the MVPF for these policies. For example, to study the impact of raising the top marginal income tax rate, I rely on the large literature studying the behavioral responses to such increases. Saez et al. (2012) and Giertz (2009) suggest mid-range estimates that 25-50% of the mechanical revenue that is raised from increasing the top marginal income tax rate is lost due to the behavioral response to the policy.[12] This suggests a MVPF of taxing top earners of \$1.33-\$2. For the EITC generosity, there is a large literature studying the impact of EITC expansions on labor earnings (Hotz and Scholz (2003)). Existing causal estimates suggest increasing EITC generosity leads to a cost that is ~14% above the mechanical cost due to behavioral responses. This suggests a MVPF of increasing EITC generosity of \$0.88.

Aggregating across policy beneficiaries using social marginal utilities of income[13], these existing causal estimates suggest additional redistribution is desired if and only if one prefers \$0.44-0.66 in the hands of an EITC beneficiary relative to \$1 in the hands of the rich (earnings $>$ \$400K). From a positive perspective, the existing causal estimates of the behavioral responses to taxation suggests the U.S. tax schedule implicitly values an additional \$0.44-0.66 to an EITC recipient as equivalent to \$1 to someone subject to the top marginal income tax rate.

Relation to Previous Literature This paper is of course not the first to study the types of behavioral elasticities required for normative analysis of government policies. As discussed above, previous literature has often highlighted the importance of the Hicksian (compensated) elasticity. However, Hicksian price elasticities are the causal effects of policies that are known to hold utility constant. So, they are insufficient in this framework for measuring the marginal welfare impact of policies that actually change utilities.[14]

[10] I use the term MVPF instead of MCPF because the policy need not be solely an expenditure or tax policy – it could be any non-budget neutral policy. Moreover, the MVPF is particularly useful for the analysis of tax policies in a dynamic setting. Individuals taxed today may expect lower taxes in the future (i.e. a classic Ricardian equivalence generally overlooked in the MCPF literature). If individuals borrow or save against these future tax changes, they may respond in a compensated manner (Barro (1974)). As discussed in footnote 47, the MVPF does not require knowledge of the degree to which Ricardian equivalence holds, provided one can estimate the causal effects.

[11] Although the model formalizes the use of the cost-effectiveness ratio, $\frac{\text{Benefits}}{\text{Cost}}$, it also shows that simple cost-benefit analysis of Benefits $-$ Cost does not lead to a coherent welfare ranking of policies. A standard adjustment to the Benefits $-$ Cost approach is to add a marginal cost of public funds adjustment to the Cost term by choosing a particular hypothetical financing policy; however, the present framework shows that no such "adjustment" is necessary if one simply considers the policy in question as a marginal value of public funds in and of itself.

[12] Saez et al. (2012) suggest a midpoint of around 20-25% while Giertz (2009) suggests a midpoint of around 50%

[13] MEB calculations such as those in Eissa et al. (2008) and Eissa and Hoynes (2011) for EITC expansions, cannot be aggregated using the social marginal utilities of income. One would first need to adjust the social marginal utilities with the income effects that were removed to calculate the MEB (see footnote 7).

[14] Interestingly, the logic that the pure Hicksian response is not required for the marginal welfare impact is arguably due to Hicks (1942), at the top of page 134. In discussing the relationship amongst non-marginal measures of price indices,

Hicksian elasticities arise in MEB calculations because it involves a different conceptual experiment. Instead of asking how much individuals are willing to pay for the policy change, MEB asks how much additional revenue the government could receive as a result of the policy change if utilities were held constant using individual-specific lump-sum transfers (Auerbach and Hines (2002)). Although MEB is a reasonable metric for evaluating marginal policy changes, it is not empirically tractable unless the empiricist can decompose the behavioral responses into income and substitution effects. In contrast, calculating individuals' marginal willingness to pay for the policy change relies on the causal, not compensated, effect of the policy change. Moreover, the resulting welfare measures can be aggregated using the social marginal utility of income, in contrast to MEB which requires adding back in the income effects to form the marginal social welfare impact of policy changes.[15]

This paper is also related to the "Stiglitz-Dasgupta-Atkinson-Stern"[16] approach to defining the marginal cost of public funds (see Ballard and Fullerton (1992) for a discussion). In the language of the present framework, this tradition defines the MCPF as a sub-component of a welfare analysis of a broader policy that increases taxes and exhausts the revenue on a public good – namely, the causal impact of the behavioral response to this policy on the government's budget. Such a MCPF does not depend on the causal effect of policies that raise revenue; rather they depend on the causal effect of budget neutral policies that raise revenue and exhaust it in public expenditure. In contrast, the MVPF presented here (which is based on the insights of Mayshar (1990) and Slemrod and Yitzhaki (1996, 2001)) is defined for any non-budget neutral policy and relies on the causal effects of that particular policy.

This paper is also related to the work studying the optimal design of tax and transfer systems (e.g. Mirrlees (1971), Diamond and Mirrlees (1971), Saez (2001) among others). This literature uses a first order condition to write the (constrained) optimal tax rates as functions of estimable elasticities. By construction, these elasticities measure the response to policy changes locally *around the optimum*. Hence, it is important that the elasticities are "structural" so that extrapolation of estimates using local variation provides an estimate around the optimum. In contrast, estimating the welfare impact of policy changes relies on causal effects defined locally around the status quo.

This paper is also related to the sufficiency of the taxable income elasticity (Feldstein (1999); Chetty (2009a)). It is well known that the taxable income elasticity is no longer sufficient in cases when there are responses to the policy on multiple tax bases with different marginal tax rates (e.g. capital and labor income (Saez et al. (2012)) or intensive versus extensive margin responses (Kleven

Hicks notes that the various measures are locally equivalent (for marginal price changes) and that the substitution effect enters only as a second order term in some of the various measures (I thank Jesse Shapiro for providing several useful references to Hicks in this vein).

[15] Hicksian elasticities also arise in the optimal commodity taxation program with a representative agent proposed by Ramsey (1927) and analyzed in detail by Diamond and Mirrlees (1971). In Appendix D, I illustrate how the present model can nest this result. At an optimum, the marginal welfare impact of a budget-neutral policy change is zero. So, in representative agent models, optimal taxes depend on Hicksian elasticities because utility is locally constant at the optimum. More generally, however, the social welfare impact of changing commodity tax rates depends not on the Hicksian elasticity but rather on the causal impact of such policy changes.

[16] See Ballard and Fullerton (1992). The label refers to the foundational papers by Atkinson and Stern (1974); Stiglitz and Dasgupta (1971) and Atkinson and Stern (1974). See Dahlby (2008) for a recent survey of the literature on the marginal cost of public funds.

and Kreiner (2006))). However, the present analysis shows that the causal impact of the behavioral response on the government budget (e.g. tax revenue) as opposed to the tax base (e.g. taxable income) remains sufficient even in cases where the behavioral response by individuals occurs on multiple tax margins. This suggests focusing on the tax revenue impacts, as opposed to taxable income, may be the most general empirical approach for welfare analysis.

The rest of this paper proceeds as follows. Section 2 presents the model and characterizes an individual's marginal willingness to pay for a policy change. Section 3 discusses the additivity condition and the marginal value of public funds. Section 4 uses existing causal estimates to study the desirability of changing the top marginal income tax rate, EITC generosity, food stamps, job training, and housing vouchers. Section 5 concludes.

2 Model

I consider a canonical price-theoretic model with heterogeneous agents and multiple goods, along with a government that sets taxes, transfers, and publicly provided goods and services. The generality captures many realistic issues faced in empirical applications and also allows the model to nest many models in previous literature. But, for simplified reading, Example 1 on page 12 illustrates the main concepts in a model with a representative agent, single taxable good, and single publicly provided good.

2.1 Setup

There exist a continuum of individuals of equal mass in the population, indexed by $i \in I$. These individuals make two choices: they choose a vector of J_X goods to consume, $\mathbf{x_i} = \{x_{ij}\}_{j=1}^{J_X}$, and a vector of labor supply activities, $\mathbf{l_i} = \{l_{ij}\}_{j=1}^{J_L}$.[17] There also exists a government that does three things: it provides a vector of J_G publicly provided goods and services to each individual, $\mathbf{G_i} = \{G_{ij}\}_{j=1}^{J_G}$, provides monetary transfers to each individual, T_i, and imposes linear taxes[18] on goods, $\tau_{\mathbf{i}}^{\mathbf{x}} = \left\{\tau_{ij}^{x}\right\}_{j=1}^{J_X}$ and labor supply activities, $\tau_{\mathbf{i}}^{\mathbf{l}} = \left\{\tau_{ij}^{l}\right\}_{j=1}^{J_L}$.

Individuals value their goods, labor supply activities, and publicly provided goods and services according to the utility function:

$$u_i\left(\mathbf{x}_i, \mathbf{l}_i, \mathbf{G}_i\right) \tag{1}$$

which is allowed to vary arbitrarily across people.[19]

To simplify the exposition, I assume a stylized model of production in which one unit of any type of labor supply produces 1 unit of any type of good under perfect competition. Thus, agents face a

[17] For example, j can index time so that l_{ij} is the labor supply of individual i in time j. Or, l_{i1} could be labor supplied in wage work and l_{i2} could be labor supplied in the informal (un-taxed) sector.

[18] Because I focus on marginal policy changes, the model can consider nonlinear tax settings by interpreting T_i as "virtual income" and τ_{ij}^{l} as the marginal tax on labor earnings.

[19] Note that these publicly provided goods could be market or non-market goods. For example, one can capture a setting where G is a market good by assuming the utility function has a form: $u_i\left(x_1, x_2, G\right) = \tilde{u}_i\left(x_1, x_2 + G\right)$, so that G and x_2 would be perfectly substitutable.

single linear budget constraint given by

$$\sum_{j=1}^{J_X}\left(1+\tau_{ij}^{x}\right)x_i \leq \sum_{j=1}^{J_L}\left(1-\tau_{ij}^{l}\right)l_{ij}+T_i+y_i \tag{2}$$

where y_i is non-labor income.[20] This simplified production structure rules out many interesting features that can easily be added to a more general model, including imperfect competition (i.e. producer surplus), production externalities (e.g. spillovers), and pecuniary externalities (in which case real prices would not always be 1).[21] I assume the marginal cost to the government of producing publicly-provided goods, G_{ij} is given by c_j^G for $j=1,..,J_G$.[22]

Each individual takes taxes, transfers, non-labor income, and the provision of publicly-provided goods as given and chooses goods and labor supply activities to maximize utility. This yields the standard indirect utility function of individual i,

$$\begin{aligned} V_i\left(\tau_{\mathbf{i}}^{\mathbf{l}},\tau_{\mathbf{i}}^{\mathbf{x}},T_i,\mathbf{G_i},y_i\right) &= \max_{\mathbf{x},\mathbf{l}} u_i\left(\mathbf{x},\mathbf{l},\mathbf{G_i}\right) \\ & \quad s.t. \quad \sum_{j=1}^{J_X}\left(1+\tau_{ij}^{x}\right)x_{ij} \leq \sum_{j=1}^{J_L}\left(1-\tau_{ij}^{l}\right)l_{ij}+T_i+y_i \end{aligned}$$

where V_i depends on taxes, transfers, income, and publicly provided goods. The Marshallian demand functions generated by the agent's problem are denoted $x_{ij}^m\left(\tau_{\mathbf{i}}^{\mathbf{x}},\tau_{\mathbf{i}}^{\mathbf{l}},T_i,\mathbf{G_i},y_i\right)$ and $l_{ij}^m\left(\tau_{\mathbf{i}}^{\mathbf{x}},\tau_{\mathbf{i}}^{\mathbf{l}},T_i,\mathbf{G_i},y_i\right)$. Because the utility function is allowed to vary arbitrarily across people, it will be helpful to normalize by the individual's marginal utility of income, λ_i,

$$\lambda_i = \frac{\partial V_i}{\partial y_i}$$

which is the Lagrange multiplier from the type i maximization program. For measuring welfare, it will also be helpful to define the expenditure function, $E_i\left(u;\tau_{\mathbf{i}}^{\mathbf{l}},\tau_{\mathbf{i}}^{\mathbf{x}},T_i,\mathbf{G_i}\right)$, of individual i to be the amount of income y_i required for individual i to obtain utility level u in a world with taxes, transfers, and publicly provided good $\left(\tau_{\mathbf{i}}^{\mathbf{l}},\tau_{\mathbf{i}}^{\mathbf{x}},T_i,\mathbf{G_i}\right)$. The standard duality result implies that

$$E_i\left(V_i\left(\tau_{\mathbf{i}}^{\mathbf{l}},\tau_{\mathbf{i}}^{\mathbf{x}},T_i,\mathbf{G_i},y_i\right);\tau_{\mathbf{i}}^{\mathbf{l}},\tau_{\mathbf{i}}^{\mathbf{x}},T_i,\mathbf{G_i}\right)=y_i$$

The indirect utility function provides a measure of individual i's utility; to move to social welfare, I assume there exists some vector of Pareto weights, $\{\psi_i\}$, for each individual i, so that social welfare is given by

$$W\left(\left\{\tau_{\mathbf{i}}^{\mathbf{l}},\tau_{\mathbf{i}}^{\mathbf{x}},T_i,\mathbf{G_i},y_i\right\}_i\right)=\int_{i\in I}\psi_i V_i\left(\tau_{\mathbf{i}}^{\mathbf{x}},\tau_{\mathbf{i}}^{\mathbf{l}},T_i,\mathbf{G_i},y_i\right)di \tag{3}$$

[20] I allow (but do not require) taxes and transfers to be individual-specific. This allows the model to next the standard MEB experiment.

[21] I discuss some of these extensions in Subsection 2.7 and provide a detailed discussion of externalities in Appendix C.

[22] Note this nests the case of a pure public good by assuming $c_j^G=\frac{1}{N}$ and G_{ij} is constant across i.

Note that this is an implicit function of the vector of taxes, transfers, and publicly provided goods to every type in the economy. In what follows, it will also be helpful to also consider the social marginal utility of income, $\eta_i = \psi_i \lambda_i$, which is the social welfare weight in units of the individual's own income.

2.2 Policy Paths and Potential Outcomes

The social welfare function, W, provides a theoretical metric for evaluating the desirability of government policy. In this subsection, I use this metric to evaluate the welfare impact of marginal changes to the status quo policy. To do so, I define a "policy path", $P(\theta)$. For any θ in a small region near 0, $\theta \in (-\epsilon, \epsilon)$, let $P(\theta)$ be a vector of taxes, transfers, and publicly provided goods to each individual,

$$P(\theta) = \left\{ \hat{\tau}_{\mathbf{i}}^{\mathbf{x}}(\theta), \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}(\theta), \hat{T}_i(\theta), \hat{\mathbf{G}}_{\mathbf{i}}(\theta) \right\}_{i \in I} \tag{4}$$

where the "^" indicates the policies are functions of θ. I make two assumptions about how the policy varies with θ. First, I normalize the value of the policy at $\theta = 0$ to be the status quo:

$$\left\{ \hat{\tau}_{\mathbf{i}}^{\mathbf{x}}(0), \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}(0), \hat{T}_i(0), \hat{\mathbf{G}}_{\mathbf{i}}(0) \right\}_{i \in I} = \left\{ \tau_{\mathbf{i}}^{\mathbf{x}}, \tau_{\mathbf{i}}^{\mathbf{l}}, T_i, \mathbf{G}_{\mathbf{i}} \right\}_{i \in I}$$

Second, I assume that the policy path is continuously differentiable in θ (i.e. $\frac{d\hat{\tau}_{ij}^{x}}{d\theta}$, $\frac{d\hat{\tau}_{ij}^{l}}{d\theta}$, $\frac{d\hat{T}_i}{d\theta}$, and $\frac{d\hat{G}_{ij}}{d\theta}$ exist and are continuous in θ).[23] Intuitively, $P(\theta)$ traces out a smooth path of government policies, centered around the status quo. By using this path, one can easily consider policies that vary multiple policy parameters at the same time. Given a path $P(\theta)$, I consider the welfare impact of following the path, parameterized by an increase in θ. This can be interpreted as following a policy path or evaluating a policy direction.[24]

Before asking the normative question of whether the government should follow the policy path, I first consider the positive question of what the policy change would do to behavior. Given a policy path, I assume individuals choose goods and labor supply activities, $\hat{\mathbf{x}}_i(\theta) = \{\hat{x}_{ij}(\theta)\}_i$ and $\hat{\mathbf{l}}_i(\theta) = \left\{\hat{l}_{ij}(\theta)\right\}_i$, that maximize their utility under policy $P(\theta)$.[25] In the now-standard language of Angrist and Pischke (2008), $\hat{x}(\theta)$ and $\hat{l}(\theta)$ are the "potential outcomes" of individual's choices of goods and labor supply activities if policy world θ is undertaken. As θ moves away from 0, $\hat{\mathbf{x}}(\theta)$ and $\hat{\mathbf{l}}(\theta)$ trace out the causal effect of the policy change on the individual's behavior..

[23] This does not require that the behavioral response to the policy be continuously differentiable. For notational convenience in the text, I will assume the behavioral responses are continuously differentiable. However, in the empirical application to the study of the EITC expansion in Section 4, I allow for extensive margin labor supply responses (which is a key feature of the behavioral response to EITC expansions, and is known to be an important factor in MEB estimation (Eissa et al. (2008), Eissa and Hoynes (2011))).

[24] I have not specified a scale/speed for the policy path. In practice, one can normalize the speed of the policy to one unit of a tax or one dollar of revenue raised, as illustrated in the application in Section 4.

[25] These can be calculated in theory by evaluating the Marshallian demands at the policy vector for each θ:

$$\begin{aligned} \hat{x}_{ij}(\theta) &= x_{ij}^{m}\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}(\theta), \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}(\theta), \hat{T}_i(\theta), \hat{\mathbf{G}}_{\mathbf{i}}(\theta)\right) \quad \forall j = 1..J_X \\ \hat{l}_{ij}(\theta) &= l_{ij}^{m}\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}(\theta), \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}(\theta), \hat{T}_i(\theta), \hat{\mathbf{G}}_{\mathbf{i}}(\theta)\right) \quad \forall j = 1..J_L \end{aligned}$$

In addition to the individual's behavior, the policy will also impact the government budget. To keep track of these effects, let $\hat{t}_i(\theta)$ denote the net government resources directed towards type i,

$$\underbrace{\hat{t}_i(\theta)}_{\text{Net Resources}} = \underbrace{\sum_{j=1}^{J_G} c_j^G \hat{G}_{ij}(\theta)}_{\text{Public-Provided Goods}} + \underbrace{\hat{T}_i(\theta)}_{\text{Transfers}} - \underbrace{\left(\sum_{j=1}^{J_X} \hat{\tau}_{ij}^x(\theta)\hat{x}_{ij}(\theta) + \sum_{j=1}^{J_L} \hat{\tau}_{ij}^l(\theta)\hat{l}_{ij}(\theta)\right)}_{\text{Tax Revenue}} \quad (5)$$

where $\sum_{j=1}^{J_G} c_j^G \hat{G}_{ij}(\theta)$ is the government expenditure on publicly provided goods to individual i, $\hat{T}_i(\theta)$ is the government transfers to type i, and $\sum_{j=1}^{J_X} \hat{\tau}_{ij}^x(\theta)\hat{x}_{ij}(\theta) + \sum_{j=1}^{J_L} \hat{\tau}_{ij}^l(\theta)\hat{l}_{ij}(\theta)$ is the tax revenue collected from individual i on goods and labor supply activities.

With this definition of $\hat{t}_i$, the total impact of a policy on the government's budget is given by $\int_{i\in I} \frac{d\hat{t}_i}{d\theta} di$. The analysis does not require policies to be budget-neutral[26], but budget-neutrality of a policy path could be imposed by assuming

$$\int_{i\in I} \frac{d\hat{t}_i}{d\theta} di = 0 \quad \forall\theta$$

where

$$\frac{d\hat{t}_i}{d\theta} = \sum_j c_j^G \frac{d\hat{G}_{ij}}{d\theta} + \frac{d\hat{T}_i}{d\theta} - \frac{d}{d\theta}\left[\sum_{j=1}^{J_X} \hat{\tau}_{ij}^x(\theta)\hat{x}_{ij}(\theta) + \sum_{j=1}^{J_L} \hat{\tau}_{ij}^l(\theta)\hat{l}_{ij}(\theta)\right]$$

The term $\sum_j c_j^G \frac{d\hat{G}_{ij}}{d\theta}$ is how much the policy changes spending on publicly provided goods; $\frac{d\hat{T}_i}{d\theta}$ is how much the policy increases direct transfers; and the last term is the impact of the policy on the net tax revenue from goods and labor supply activities.

As is well-known, the impact of the policy on individual behavior and on the government budget are related through the mechanical and behavioral impact of the policy on net tax revenue from goods and labor supply activities:

$$\frac{d}{d\theta}\left[\left(\sum_{j=1}^{J_X} \hat{\tau}_{ij}^x(\theta)\hat{x}_{ij}(\theta) + \sum_{j=1}^{J_L} \hat{\tau}_{ij}^l(\theta)\hat{l}_{ij}(\theta)\right)\right] = \underbrace{\left(\sum_j^{J_X} \hat{x}_{ij}\frac{d\hat{\tau}_{ij}^x}{d\theta} + \sum_j^{J_L} \hat{l}_{ij}\frac{d\hat{\tau}_{ij}^l}{d\theta}\right)}_{\substack{\text{Mechanical Impact} \\ \text{on Govt Revenue}}} + \underbrace{\left(\sum_j^{J_X} \hat{\tau}_{ij}^x \frac{d\hat{x}_{ij}}{d\theta} + \sum_j^{J_L} \hat{\tau}_{ij}^l \frac{d\hat{l}_{ij}}{d\theta}\right)}_{\substack{\text{Behavioral Impact} \\ \text{on Govt Revenue}}} \quad (6)$$

The mechanical effect is the change in revenue holding behavior constant. This would be the marginal budget impact of the policy if one did not account for any behavioral responses. The behavioral impact is the effect of the behavioral response to the policy on the government's budget.

[26] I do not model explicitly the source of non-budget neutrality, but one can extend the model to a world in which the government issues debt, B, and even allow B to affect behavior, $u(\mathbf{x}, \mathbf{l}, \mathbf{G}, B)$. I discuss this further in relation to the definition of the MCPF in footnote 47.

2.3 Definition of Welfare

Moving from positive to normative analysis requires a definition of welfare. The measure of individual welfare adopted here will be the individual's willingness to pay out of their own income to follow the policy path.[27] Social welfare is then a weighted sum of individual welfare, with weights given by the social marginal utilities of income.

To be more specific, let $\hat{V}_i(\theta)$ denote the utility obtained by type i under the policy $P(\theta)$. The marginal impact of the policy on the utility of individual i is given by $\frac{d\hat{V}_i}{d\theta}|_{\theta=0}$. Normalizing by the marginal utility of income, the individual's own willingness to pay (out of their own income) for a marginal policy change is given by $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$.[28]

With this definition of individual welfare, aggregation to social welfare is straightforward: one can take a weighted sum of individual willingness to pay, with the weights given by the social marginal utilities of income, $\frac{d\hat{W}}{d\theta}|_{\theta=0} = \int_{i\in I} \eta_i \frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i} di$.[29] Social marginal utilities η_i can be interpreted in terms of Okun's classic bucket experiment (Okun (1975)): Society is indifferent to transferring $\frac{\eta_1}{\eta_2}$ resources to individual 2 as opposed to \$1 to individual 1. If $\eta_1 < \eta_2$, society is willing to lose resources in order to make a transfer from individual 1 to individual 2. While $\frac{d\hat{W}}{d\theta}|_{\theta=0}$ is measured in units of social utility, it can be normalized by $\eta_{\hat{i}}$ so that it is measured in units of individual i's income. For this, I define $\frac{d\hat{W}^{\hat{i}}}{d\theta}|_{\theta=0} = \frac{\frac{d\hat{W}}{d\theta}|_{\theta=0}}{\eta_{\hat{i}}} = \int_{i\in I} \frac{\eta_i}{\eta_{\hat{i}}} \frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i} di$, where the superscript $\hat{i}$ denotes the fact that social welfare is measured in units of $\hat{i}$'s income.

2.4 The Components of Welfare

With these definitions, Proposition 1 characterizes the marginal welfare gain to individual i from pursuing the policy.

[27] Alternatively, one could evaluate the marginal excess burden of the policy change – this is discussed below in Section 2.6.

[28] It is well-known that $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$ is equivalent to two other canonical measures of welfare for marginal policy changes. First, the equivalent variation, $EV_i(\theta)$, of policy $P(\theta)$ for type i is the amount that the consumer would be indifferent to accepting in lieu of the policy change. $EV_i(\theta)$ solves

$$V_i\left(\tau_{\mathbf{i}}^{\mathbf{l}}, \tau_{\mathbf{i}}^{\mathbf{x}}, T_i, \mathbf{G}_{\mathbf{i}}, y_i + EV_i(\theta)\right) = \hat{V}_i(\theta)$$

Second, the compensating variation, $CV_i(\theta)$, of policy $P(\theta)$ for type i is the amount of money that must be compensated to the agent after the policy change to bring her back to her initial utility level. $CV_i(\theta)$ solves

$$V_i\left(\tau_{\mathbf{i}}^{\mathbf{l}}(\theta), \tau_{\mathbf{i}}^{\mathbf{x}}(\theta), T_i(\theta), \mathbf{G}_{\mathbf{i}}(\theta), y_i - CV_i(\theta)\right) = \hat{V}_i(0)$$

It is straightforward to verify (e.g. Schlee (2013)) that:

$$\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i} = \frac{d[EV_i]}{d\theta}|_{\theta=0} = \frac{d[CV_i]}{d\theta}|_{\theta=0}$$

[29] Note this remains true even if the welfare weights are not fixed and are functions of utility levels, since marginal policy changes do not change the welfare weights. For example, if $W = \int_{i\in I} G(V_i)\, di$ for a concave function G, then the social marginal utility of income would be $\eta_i = G'\left(\hat{V}_i(0)\right)\lambda_i$.

Proposition 1. *The marginal welfare impact to individual i of pursuing policy path $P(\theta)$ is given by:*

$$\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i} = \left(\underbrace{\frac{d\hat{t}_i}{d\theta}|_{\theta=0}}_{\textit{Net Resources}} + \underbrace{\sum_{j=1}^{J_G} \left(\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G \right) \frac{d\hat{G}_{ij}}{d\theta}|_{\theta=0}}_{\substack{\textit{Public Spending/} \\ \textit{Mkt Failure}}} + \underbrace{\left(\sum_j^{J_X} \tau_{ij}^x \frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0} + \sum_j^{J_L} \tau_{ij}^l \frac{d\hat{l}_{ij}}{d\theta}|_{\theta=0} \right)}_{\substack{\textit{Behavioral Impact} \\ \textit{on Govt Revenue}}} \right)$$

Proof. The proof is an application of the envelope theorem and is provided in Appendix B. □

The first term, $\frac{d\hat{t}_i}{d\theta}$, is straightforward: it is the change in net government resources provided to individual i from the government, which is the difference between the change in spending on publicly provided goods and transfers and the collection of taxes on goods and labor supply activities. For budget neutral policies, recall that $\int_i \frac{d\hat{t}_i}{d\theta} di = 0$; in this sense, $\frac{d\hat{t}_i}{d\theta}$ captures the redistributive impact of the policy. These transfers increase social welfare to the extent to which those receiving the net transfer have higher values of the social marginal utility of income than those who pay for the net transfer.

The second term captures the value of any changes to publicly provided goods, $\frac{d\hat{G}_{ij}}{d\theta}|_{\theta=0}$. This is given by the difference between the willingness to pay for the publicly provided goods and their costs of production, $\sum_{j=1}^{J_G} \left(\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G \right) \frac{d\hat{G}_{ij}}{d\theta}|_{\theta=0}$. This component is well-known and popularized in Samuelson (1954). One can interpret this number as the size of the market inefficiency being addressed by the publicly provided goods. If the private market can efficiently supply and allocate all goods, then agents would be able to pay c_g to obtain a unit of a good that is equivalent to the publicly provided good, so that $\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} = c_j^G$. If the private market does not provide such goods as efficiently as the government (or vice-versa), then one needs to know the difference between the costs and benefits of its provision.

The final term in Proposition 1 summarizes the importance of behavioral responses. It is the impact of the behavioral response to the policy on the government's budget. It is a weighted sum of the *causal effects* of the policy on behavior locally around the status quo, $\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0}$ and $\frac{d\hat{l}_{ij}}{d\theta}|_{\theta=0}$, with the weights given by the marginal tax rates.[30]

The causal effect matters because of a fiscal externality. The envelope theorem guarantees that behavioral responses do not affect utility directly; however, when prices do not reflect their resource costs (as is the case with taxation), behavioral responses impose a cost on those bearing the difference

[30] Although this causal effect is the impact of a marginal change in the policy, in practice causal effects are often measured using discrete changes in policies. Appendix E provides intuitive conditions under which the non-marginal causal effects (i.e. $\hat{x}_{ij}(1) - \hat{x}_{ij}(0)$ instead of $\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0}$) can be used to measure the individual's willingness to pay for the policy change.

between the prices faced by the individual and their resource costs.[31] Conditional on calculating this fiscal externality, behavioral responses are not required for welfare analysis.[32]

Example 1. *Assume there is one publicly-provided good, G, called roads. There is one untaxed consumption good, x, and there is one labor supply variable, l, which has a labor tax of τ^l. Assume there is only one type of agent (drop i subscripts). Also, assume there is no lump-sum taxation, $T = 0$.*

Normalize θ to parameterize an increase in spending on roads, so that $\hat{G}(\theta) = G + \theta$ and thus $\frac{d\hat{G}}{d\theta} = 1$. To impose budget neutrality, assume the marginal tax revenue (obtained from increasing the tax on labor supply) is spent on roads,

$$\tau^l \frac{d\hat{l}}{d\theta} + \hat{l}\frac{d\tau^l}{d\theta} = \frac{d\hat{G}}{d\theta} = 1 \quad \forall \theta$$

In this environment, Proposition 1 implies that the marginal welfare impact is positive if and only if

$$\left(\frac{\frac{\partial u}{\partial g}}{\lambda} - c_g\right) \geq -\hat{\tau}^l \frac{d\hat{l}}{d\theta}|_{\theta=0} \tag{7}$$

where the LHS is the net willingness-to-pay for additional roads, $\hat{\tau}^l$ is the marginal tax rate on labor supply, and $\frac{d\hat{l}}{d\theta}|_{\theta=0}$ is the causal impact of the policy on labor supply. It is the response that would be observed if the policy were undertaken to increase G financed by an increase in τ^l.[33]

The desirability of additional roads depends on how they affect government revenue. If roads increase labor supply because they make it easier to get to work, then the policy response is smaller; if roads increase the value of leisure and decrease taxable income, this makes roads less socially desirable (not because the planner doesn't value leisure, but because the government has a stake in the labor earnings).

[31] As discussed in Appendix C, if there are other externalities one also requires an estimate of the impact of the policy on those externalities as well. However, the causal effects remain the desired behavioral responses.

[32] For completeness, it is also important to note that a decomposition of causal effects into income and substitution effects do not generally help measure the size of market inefficiency, $\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G$. Income and price effects depend on the Hessian (2nd derivative) of the utility function, whereas the size of the market failure, $\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G$, depends on the first derivatives of the utility function (Mas-Colell et al. (1995)).

One exception is the model of Chetty (2008) who models unemployment durations with a separable effort function and a binary state. He shows that the size of the market failure (wedge between marginal utilities) is a function of the causal impact of assets on search (liquidity effect) and the causal impact of unemployment benefits on search (moral hazard). Of course, it is not a general feature of economic models that marginal utilities can be written as functions of elasticities. Generally, marginal utilities are equated to prices, and elasticities correspond to the impact of price changes.

[33] In general, $\frac{d\hat{l}}{d\theta}|_{\theta=0}$ is neither a Marshallian nor a Hicksian response. Indeed, one can write the RHS of equation (7) using a set of Marshallian elasticities and arrive at the optimality condition provided by Atkinson and Stern (1974). Let $l^*\left(\tau^l, G\right)$ denote the solution to the agent's maximization program given taxes on labor, τ^l, and government spending G. Also, following Atkinson and Stern (1974), assume that $\tau^l l = G$, so that the government has no other spending other than on G. Then, it is easy to show that

$$\hat{\tau}^l \frac{d\hat{l}}{d\theta}|_{\theta=0} = \frac{\epsilon^m_{l^*,\tau} + \epsilon^m_{l^*,G}}{1 + \epsilon^m_{l^*,\tau}}$$

where $\epsilon^m_{l^*,\tau}$ is the standard marshallian elasticity of labor supply with respect to the labor tax rate, holding G fixed; and $\epsilon^m_{l^*,G}$ is the elasticity of l^* with respect to G, holding τ^l fixed. So, the policy elasticity can be computed from these two marshallian elasticities. But, such a decomposition is not necessary; the policy elasticity is sufficient.

In practice, the intuition in equation (7) *can be useful for bounding the welfare gain of a policy. For example, Baird et al. (2012) estimate that a de-worming program in Kenya led to an increase in income tax revenue (from improved health and labor supply) that was sufficient to cover the program costs (i.e.* $\tau \frac{dl}{d\theta}|_{\theta=0} > c_g$*). Under the mild assumption that individuals preferred being offered the de-worming program,* $\frac{\partial u}{\partial g} > 0$*, one can conclude the program improved welfare.*

Proposition 1 shows that the type of behavioral responses required depends on the policy in question. If a policy increases marginal tax rates on individual i and provides no compensation, it is an uncompensated response; if it compensates agents for their tax increase, it is a compensated response; if a policy increases tax rates to finance increased education spending, one needs to incorporate not only the impact of the increased taxes on behavior, but also incorporate the impact of the simultaneous increase in education spending on behavior that affects the government's budget. To provide terminology to distinguish the desired responses from Hicksian or Marshallian price responses, I define the *policy response* of x_{ij} and l_{ij} to be the local causal effect of the policy on x_{ij} and l_{ij}. Similarly, I define the *policy elasticity* of x_{ij} and l_{ij} to be the local causal effect of the policy on $log\left(x_{ij}\right)$ and $log\left(l_{ij}\right)$.

Definition 1. The *policy response* of x_{ij} (or l_{ij}) with respect to policy $P(\theta)$ is given by $\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0}$ (or $\frac{d\hat{l}_{ij}}{d\theta}|_{\theta=0}$). The *policy elasticity* of x_{ij} (or l_{ij}) is given by $\hat{\epsilon}^x_{ij} = \frac{dlog(\hat{x}_{ij})}{d\theta}|_{\theta=0}$ (or $\hat{\epsilon}^l_{ij} = \frac{dlog(\hat{l}_{ij})}{d\theta}|_{\theta=0}$)

Given these definitions, the behavioral impact term of Proposition 1 has three representations:

$$\underbrace{\frac{d}{d\theta}\left(\sum_{j=1}^{J_X}\hat{\tau}^x_{ij}\hat{x}_{ij} + \sum_{j=1}^{J_L}\hat{\tau}^l_{ij}\hat{l}_{ij}\right) - \left(\sum_{j}^{J_X}\hat{x}_{ij}\frac{d\hat{\tau}^x_{ij}}{d\theta} + \sum_{j}^{J_L}\hat{l}_{ij}\frac{d\hat{\tau}^l_{ij}}{d\theta}\right)}_{\text{Total - Mechanical Impact on Govt Revenue}} = \underbrace{\left(\sum_{j}^{J_X}\tau^x_{ij}\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0} + \sum_{j}^{J_L}\tau^l_{ij}\frac{d\hat{l}_{ij}}{d\theta}|_{\theta=0}\right)}_{\substack{\text{Behavioral Impact}\\ \text{on Govt Revenue (levels)}}} = \underbrace{\left(\sum_{j}^{J_X}r^x_{ij}\hat{\epsilon}^x_{ij} + \sum_{j}^{J_L}r^l_{ij}\hat{\epsilon}^x_{ij}\right)}_{\substack{\text{Behavioral Impact}\\ \text{on Govt Revenue (logs)}}} \tag{8}$$

where the weights for the log responses, $\hat{r}^x_{ij} = \hat{\tau}^x_{ij}\hat{x}_{ij}$ (or $\hat{r}^x_{ij} = \hat{\tau}^l_{ij}\hat{l}^x_{ij}$), equal the government revenue on each good (or labor supply).

The representations in equation (8) suggest there are multiple potential empirical strategies one can use to estimate the impact of the behavioral response to the policy on the government's budget. First, one could attempt to estimate the fiscal externality directly. If one had a counterfactual budget forecast of what the government budget would be in the absence of any behavioral responses (the "mechanical impact on government revenue" in equation (6)), one could compare the difference in the realized budget and the mechanical revenue that would have been observed in the absence of behavioral responses.[34] Second, one could estimate the micro-level behavioral changes $\mathbf{x}_i$ and $\mathbf{l}_i$ resulting from the policy and multiply by the government's stake in the behavior. In this micro approach, one can either use policy responses and marginal tax rates (levels), or using policy elasticities and government revenues on each activity (logs).

[34] As discussed further in Section (4), this approach is taken by Chetty et al. (2013) who estimate the marginal incentives from the EITC schedule increase EITC expenditures by 5%.

2.5 Relation to Feldstein (1999)

If there is only one tax rate on aggregate taxable income and social marginal utilities of income are the same for all types, then the aggregate taxable income elasticity is sufficient for capturing the behavioral responses required for welfare analysis.[35] This insight was recently popularized in Feldstein (1999). I provide two clarifications to this result.[36] First, it is in general neither the Hicksian (compensated) nor the Marshallian (uncompensated) elasticity of taxable income that is desired for analyzing the welfare impact of government policy. Rather, it is the taxable income elasticity associated with the policy in question, which depends on how the revenue is spent.

Second, as is well known, the taxable income elasticity is not sufficient to the extent to which individuals face multiple tax rates. For example, if capital income is taxed at a different rate than labor income, the elasticity of the sum of these two incomes would not be sufficient (Saez et al. (2012)). If behavioral responses occur on both the participation and intensive margin, then the aggregate earnings elasticity is not sufficient (Kleven and Kreiner (2006)). Moreover, one also needs to know the extent to which policies affect consumption of subsidized goods or services (e.g. enrollment in government programs such as SSDI or unemployment insurance). While subsequent literature tends to suggest a need for adding additional elasticities to the analysis[37], the present analysis shows that if one switches the dependent variables in these analyses from the components of taxable income to aggregate tax *revenue*, such a decomposition of the mechanics of the behavioral response is not required.[38] Of course, there are many reasons to be interested in the mechanisms driving such a response; but calculating the marginal welfare impact of the policy change in question is not one of them.

2.6 Relation to MEB

Since Harberger (1964), the MEB framework is arguably the most common welfare framework for the evaluation of the welfare impact of changes to tax and transfer policies.[39] As discussed in the introduction, calculating welfare changes with this approach requires the compensated (Hicksian) elasticity. However, the compensated (Hicksian) elasticity is the causal effect of a policy that holds utility constant; under the present framework, it is therefore not sufficient for calculating the welfare impact of policies that actually change utilities.

[35] To see this, note that if $\tau_1 = \tau_2$, then

$$\tau_1 \frac{dx_1}{d\theta}|_{\theta=0} + \tau_2 \frac{dx_2}{d\theta}|_{\theta=0} = \tau_1 \left(\frac{d\left(x_1 + x_2\right)}{d\theta}|_{\theta=0} \right)$$

[36] These clarifications are distinct from the insight of Chetty (2009a) who shows that the aggregate taxable income elasticity is not sufficient if the private marginal cost of tax avoidance is not equal to its social marginal cost.

[37] For example, if there are both intensive and extensive labor supply responses, one can compute both a participation elasticity that is weighted by the average tax rates and an intensive elasticity weighted by marginal tax rates (Kleven and Kreiner (2006)). If there are switches between capital and labor income, one can compute the causal impacts on each of these and weight by their respective tax rates.

[38] Indeed, this is the approach taken in Chetty et al. (2013) who show the behavioral responses to the marginal incentives induced by the EITC lead to a 5% increase in government expenditures.

[39] For example, Eissa et al. (2008) and Eissa and Hoynes (2011) apply this framework to study the welfare impact of recent expansions of the earned income tax credit in the US.

This section outlines the difference between the present framework that relies on causal effects and the marginal excess burden framework that relies on compensated effects. Let $P(\theta)$ be a policy path. To compute the marginal excess burden to individual i from the policy $P(\theta)$, let $\mathbf{v} = (v_i)$ be a vector of pre-specified utilities. Most commonly, $\mathbf{v}$ is chosen to be the set of status quo utilities. This corresponds to the "equivalent variation" measure of MEB.[40] Now, define the *compensated* policy path, $P^{\mathbf{v}}(\theta)$, such that $P^v = \left\{\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}(\theta), \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}(\theta), \hat{T}_i(\theta) + \hat{C}_i(\theta; v), \hat{\mathbf{G}}_{\mathbf{i}}(\theta)\right\}_i$ where $\hat{C}_i(\theta; u)$ is a compensation provided to individual i such that $V_i\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}(\theta), \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}(\theta), \hat{T}_i(\theta) + \hat{C}_i(\theta; v), \hat{\mathbf{G}}_{\mathbf{i}}(\theta), y_i\right) = v_i$. Intuitively, $P^v(\theta)$ is the same as the proposed policy path, $P(\theta)$, with the addition of individual specific lump-sum transfers, $\hat{C}_i(\theta; v)$, that hold agent i's utility constant at v_i.

Now, let $\hat{t}_i^v$ denote the net government resources allocated to individual i under the compensated policy $P^v(\theta)$. Following the textbook definitions of Auerbach and Hines (2002), the class of marginal excess burden measures are defined as

$$MEB_i^{v_i} = \frac{d\hat{t}_i^v}{d\theta}|_{\theta=0} \tag{9}$$

This measures the amount of additional resources the government must give to individual i in order to maintain individual her utility constant at v_i while the policy change is implemented.[41] If the policy change is not desirable to individual i, she must be compensated to hold her utility constant (so MEB is positive); conversely if the policy change is good for individual i, the government must take away resources to hold her utility constant (so MEB is negative).

If $\mathbf{v}$ is the status quo vector of utilities (i.e. the EV measure), then MEB is related to $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$ through the income effects that were removed to construct the MEB policy experiment. Let $\hat{x}_{ij}^c$ and $\hat{l}_{ij}^c$ denote the compensated choices of goods and labor supply activities under policy path $P^v(\theta)$. Then, the income effect component of the response to the policy on x_{ij} is the difference between the causal and compensated response: $\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0} - \frac{d\hat{x}_{ij}^c}{d\theta}|_{\theta=0}$.[42] Then, MEB is related to $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$ through the

[40] See Auerbach and Hines (2002). Choosing $\mathbf{v}$ to be the utilities obtained in the hypothetical first-best world with no economic distortions yields the "compensating variation" measure of MEB. Of course, the distinction between CV and EV measures of MEB depend on whether one is starting from the perspective of the first best or from the status quo. Hence, some papers switch these two definitions around.

[41] An alternative definition of marginal excess burden is given in the handbook chapter of Auerbach (1985) that preceded Auerbach and Hines (2002). In this chapter, the equivalent variation MEB is defined as the marginal willingness to pay for a hypothetical policy that is the same as the original policy but for which the budget constraint is closed using individual-specific lump-sum taxation. To express this definition of MEB in the present framework, define an augmented policy path

$$P^{85} = \left\{\left\{\hat{\tau}_{ij}^l(\theta)\right\}_j, \left\{\hat{\tau}_{ij}^x(\theta)\right\}_j, \hat{T}_i(\theta) - \hat{t}(\theta), \hat{\mathbf{G}}_{\mathbf{i}}(\theta)\right\}_i$$

where individual is forced to pay for net resources, $\hat{t}_i(\theta)$, provided to her by the policy path. Given this, the equivalent variation MEB from Auerbach (1985) is

$$MEB_i^{85} = \frac{\frac{d\hat{V}_i^{P^{1985}}}{d\theta}|_{\theta=0}}{\lambda_i}$$

which depends on compensated elasticities (since the individual must pay for the resource cost), but it is straightforward to verify that these are not "fully compensated" Hicksian elasticities since the transfers are not guaranteed to hold utility constant.

[42] The Slutsky equation guarantees that $\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0} - \frac{d\hat{x}_{ij}^c}{d\theta}|_{\theta=0} = \frac{dx_{ij}^m}{dy_i}\frac{d\hat{C}_i}{d\theta}$ where x_{ij}^m is the marshallian demand, $\frac{dx_{ij}^m}{dy_i}$ is

impact of the behavioral response to the compensation on the government budget:

$$MEB_i^{v_i} = \frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i} - \underbrace{\left(\sum_j^{J_X} \tau_{ij}^x \left(\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0} - \frac{d\hat{x}_{ij}^c}{d\theta}|_{\theta=0}\right) + \sum_j^{J_L} \tau_{ij}^l \left(\frac{d\hat{l}_{ij}}{d\theta}|_{\theta=0} - \frac{d\hat{l}_{ij}^c}{d\theta}|_{\theta=0}\right)\right)}_{\text{Income Effects on Government Budget}}$$

Also, if $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i} = 0$, then no marginal compensation is provided to individual i, so that $\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0} - \frac{d\hat{x}_{ij}^c}{d\theta}|_{\theta=0} = 0$ and $MEB_i^{v_i} = 0$ (and vice-versa).[43]

One reason MEB is a mainstay in the welfare analysis toolkit is perhaps because it is a fundamental input into the optimal commodity taxation analysis initiated by Ramsey (1927) and studied in detail in Diamond and Mirrlees (1971). Their results show that, in a model with a representative agent, the marginal excess burdens across commodities are equated. This yields the classic "inverse elasticity" rule for commodity taxation: at the optimum, tax-weighted compensated price derivatives for each commodity are equated.

However, as shown in Appendix D, this optimality formula involves compensated responses because a necessary condition for taxes to be at an optimum is that small budget-neutral changes to taxes do not affect utility.[44] Hence, around the optimum, the causal effects are compensated responses (i.e. $\frac{d\hat{x}_{ij}}{d\theta}|_{\theta=0} = \frac{d\hat{x}_{ij}^c}{d\theta}|_{\theta=0}$ because utility is not changing at the optimum). Moreover, away from an optimum, the causal effects from policies that change commodity taxes continue to provide information on the desirability of changing commodity tax rates. In contrast, compensated elasticities defined not around the optimum will not necessarily provide information about the optimal commodity tax rate, as this would require an assumption that the compensated elasticities are constant.

2.7 Extensions: General Equilibrium Effects and Non-Pecuniary Externalities

By assuming one unit of goods are produced with one unit of labor supply, the model ruled out general equilibrium effects (i.e. that the policy change affects prices). However, such effects are easily incorporated into the model by adding the implied transfers to the net resources term, $\frac{d\hat{t}_i}{d\theta}$.[45]

the response to income, and $\frac{d\hat{C}_i}{d\theta}$ is the amount of compensation required to hold utility constant.

[43] If $\mathbf{v}$ is not the status quo utilities, no such relationship is guaranteed between MEB and $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$ because λ_i and $\frac{\partial u_i}{\partial G_{ij}}$ need to be computed in the alternative world for which V_i is the utility level specified in the MEB experiment.

[44] Diamond and Mirrlees (1971) also consider a model with heterogeneous agents and derive their tax rules in such settings. With heterogeneous agents, the formulae no longer depend on compensated responses (see Section VII, page 268). This is because small budget-neutral policy changes does not hold the agents' utilities constant at the optimum when there are heterogeneous agents. Some agents are better off; others are worse off. Their optimal formula incorporate income effects into the social marginal utility weightings (See Auerbach and Hines (2002) for a simple derivation of this on page 1370, equation 3.24). Intuitively, Diamond and Mirrlees (1971) are adding back in the income effects that were taken out of the causal effects of feasible budget neutral changes to the commodity tax structure.

[45] Note that the aggregate impact of the policy on the value of production (i.e. GDP) does not enter the welfare calculation. This is not because of the stylized model of production per se. At the optimum, individuals trade off their private benefit from production (their after-tax wage) with their private cost of production (their disutility of labor supply activities). If production increases because of the policy, this envelope condition suggests individuals were

For example, if the policy increases the price of i's labor supply activity j, then she will obtain a resource benefit of $l_{ij}\frac{dw_{ij}}{d\theta}|_{\theta=0}$, where $\frac{dw_{ij}}{d\theta}|_{\theta=0}$ is the causal impact of the policy on the after-tax wage faced by individual i on her jth labor supply activity. These additional impacts are valued dollar-for-dollar and can simply be added to the resource transfer term, $\frac{d\hat{t}_i}{d\theta}|_{\theta=0}$, in Proposition 1. Hence, when policies have general equilibrium effects, one also needs to track the causal impact of the policy on prices, and adjust the size of the resource transfers in Proposition 1 accordingly. The causal effects are still the desired responses, but one needs to also know the general equilibrium effects of government policies.

In addition to ruling out general equilibrium effects, the model also ruled out non-pecuniary externalities. Policy analysis becomes slightly more difficult in these settings because one must value the impact of the policy change on the externality. Appendix C provides an extension of the model to the case where there is a variable (e.g. pollution) affecting the individuals utility that is a function of other individuals' behavior. In these cases, one requires the causal effect of the policy on the level of pollution; but in addition, one requires an estimate of the individual's marginal rate of substitution between pollution and income, analogous to the net willingness to pay required to value the provision of publicly provided goods. Welfare analysis in these models is more complicated because of the difficulty in valuing the externality, but the policy elasticities continue to be the required behavioral responses.

3 Additivity and the Marginal Value of Public Funds

Many government policies are not budget neutral, at least in the short run. Naturally, one desires a coherent way of analyzing these non-budget neutral policies. This section provides a condition that allows the welfare impacts of policies to be added together. In doing so, it provides formal justification for the calculation of a simple benefit-cost ratio – namely, the social welfare impact of the policy per dollar of government revenue expended – as the marginal value of public funds.[46]

To begin, suppose one is interested in characterizing the marginal welfare impact of a policy path, $P(\theta)$. Suppose that two policy paths, $P_{Tax}(\theta)$ and $P_{Exp}(\theta)$, sum to the policy path of interest, $P(\theta)$:

$$(P(\theta) - P(0)) = (P_{Tax}(\theta) - P(0)) + (P_{Exp}(\theta) - P(0)) \tag{10}$$

Condition (10) requires that the movement from the initial policy position, $P(0)$ towards $P(\theta)$ can be written as the sum of two movements: first in the direction of $P_{Tax}(\theta)$ and second in the direction

privately indifferent to the change. Hence, such changes to production matters for welfare only through the impact on the government budget. However, if there are spillovers or externalities in the production process, one would need to account for the impact of the policies on these externalities in a manner analogous to the impact on the fiscal externality (see Appendix C).

[46] Although the model provides a formal justification for a benefit-cost *ratio*, $\frac{B}{C}$, it should be clear that the difference in *levels*, $B - C$, of benefits and costs are not comparable across policies and does not lead to a coherent welfare ranking of policies. Intuitively, calculating whether benefits exceed cost assume that the social cost of raising the revenue to fund the program is 1, which will not be true in general (see Slemrod and Yitzhaki (2001); also see Kaplow (1996, 2004, 2008)).

of $P_{Exp}(\theta)$ (or vice-versa). This equality must hold for all components of the policy (taxes, transfers, and public provision of goods). For example, $P_{Exp}(\theta)$ could be a policy path that spends money from the government budget on a public good; $P_{Tax}(\theta)$ could be a policy that raises government revenue through increasing the labor tax rate. In this case, $P(\theta)$ would be a policy that simultaneously increases the labor tax rate and spends the resources on the public good.[47]

If equation (10) is satisfied, it is straightforward to show[48] that the marginal welfare impact of the comprehensive policy on type i, denoted $\frac{\frac{\partial \hat{V}_i^P}{\partial \theta}|_{\theta=0}}{\lambda_i}$, is given by the sum of the two welfare impacts:

$$\frac{\frac{\partial \hat{V}_i^P}{\partial \theta}|_{\theta=0}}{\lambda_i} = \frac{\frac{\partial \hat{V}_i^{P_{Tax}}}{\partial \theta}|_{\theta=0}}{\lambda_i} + \frac{\frac{\partial \hat{V}_i^{P_{Exp}}}{\partial \theta}|_{\theta=0}}{\lambda_i} \tag{11}$$

where $\frac{\frac{\partial \hat{V}_i^{P_{Tax}}}{\partial \theta}|_{\theta=0}}{\lambda_i}$ and $\frac{\frac{\partial \hat{V}_i^{P_{Exp}}}{\partial \theta}|_{\theta=0}}{\lambda_i}$ denote the marginal welfare impact of the component policies, P_{Tax} and P_{Exp}.

Despite being straightforward in the present framework, equation (10) is not innocuous from the perspective of the MEB framework. For example, suppose one were to take a MEB calculation for a tax increase from existing literature as P_{Tax}.[49] This hypothetical policy involves the government collecting or providing individual-specific lump-sum transfers in a manner that holds utility constant. Hence, for the additivity condition to hold there are two options depending on whether one seeks a comprehensive MEB estimate or a $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$ estimate. First, to calculate the MEB of the comprehensive policy, the expenditure policy must also hold utility constant while raising taxes via individual-specific lump-sum to finance the expenditure. For a calculation of individuals' willingness to pay, $\frac{\frac{\partial \hat{V}_i^P}{\partial \theta}|_{\theta=0}}{\lambda_i}$,

[47] The non-budget neutral policies, P_{Tax} and P_{Exp}, implicitly change government debt obligations. Intuitively, when the government implements non-budget neutral policies, it is either borrowing resources from its own citizens or from abroad (in an open economy). I do not explicitly model such borrowing, but it is important to note that one can augment the model to allow the level of government debt or obligations, B, to affect the agents' behavior, $u_i(\mathbf{x_i}, \mathbf{l_i}, \mathbf{G_i}, B)$. In this case, non-budget neutral policies can increase B; but when considering the sum of two non-budget neutral policies that sum to a budget neutral policy, one can ignore the impact of each individual policy on B, since on aggregate B remains unchanged in any budget neutral policy experiment.

[48] Let ∇V_i denote the gradient of V_i, so that $\frac{\partial \hat{V}_i^P}{\partial \theta} = \nabla V_i^P \frac{dP}{d\theta}$, where $\frac{dP}{d\theta}$ is the vector of policy changes. Note that

$$\begin{aligned}
\frac{\partial V_i^P}{\partial \theta} &= \nabla V_i \frac{dP}{d\theta} \\
&= \nabla V_i \left(\frac{dP_{Tax}}{d\theta} + \frac{dP_{Exp}}{d\theta} \right) \\
&= \nabla V_i \frac{dP_{Tax}}{d\theta} + \nabla V_i \frac{dP_{Exp}}{d\theta} \\
&= \frac{\partial V_i^{P_{Tax}}}{\partial \theta} + \frac{\partial V_i^{P_{Exp}}}{\partial \theta}
\end{aligned}$$

where all derivatives are evaluated at $\theta = 0$.

[49] Equation (10) is often violated in practice. For example, Liebman (2002) studies the welfare impact of EITC reforms. In equation 2 of Liebman (2002), the budgetary cost of the EITC program is weighted by the MEB to adjust for the cost of raising revenue. For the additivity condition to hold, the EITC policy experiment must fund the EITC expansion using lump-sum taxation on the general population (or the affluent, depending on the policy). As a result, the income effects that were subtracted in constructing the MEB need to be added back in to construct a measure of the social welfare impact of expanding EITC financed by taxation on the rest of the economy.

one must consider an expenditure policy that not only provided the expenditure but also removed the lump-sum transfers that were provided in the tax policy. In both cases, the causal effects of the expenditure policy are not sufficient for the behavioral responses required to compute the welfare impact of the comprehensive policy, even conditional on knowing the MEB of the tax policy. In contrast, if one uses the measures of welfare in the present framework, $\frac{\frac{\partial \hat{V}_i^{P_{Tax}}}{\partial \theta}|_{\theta=0}}{\lambda_i}$ and $\frac{\frac{\partial \hat{V}_i^{P_{Exp}}}{\partial \theta}|_{\theta=0}}{\lambda_i}$, the causal effects of the tax and expenditure policies are sufficient.[50]

The additivity condition in equation (11) suggests a natural method for dealing with non-budget neutral policies. One can simply compute the welfare cost per dollar of government budget expended, which captures a measure of the marginal value of public funds (MVPF). Normalizing social welfare into units of individual $\hat{i}$'s income, the MVPF is given by:

$$MVPF_P^{\hat{i}} = \frac{\int_i \frac{\eta_i}{\eta_{\hat{i}}} \frac{\frac{d\hat{V}_i^P}{d\theta}|_{\theta=0}}{\lambda_i} di}{\int_{i \in I} \frac{d\hat{t}_i^P}{d\theta} di} \tag{12}$$

which is the sum of the welfare impact on each individual, $\frac{\frac{\partial \hat{V}_{\hat{i}}^P}{\partial \theta}|_{\theta=0}}{\lambda_{\hat{i}}}$, weighted by their social marginal utilities of income, η_i, and normalized in units of dollars to individual $\hat{i}$.[51] There is an extraordinary number of different definitions for the MCPF in previous literature (Fullerton (1991); Auerbach and Hines (2002); Dahlby (2008)). The particular definition in equation (12) was initially proposed by Mayshar (1990) and also by Slemrod and Yitzhaki (1996). The key advantage of this definition of the MVPF is that the behavioral responses depend solely on the causal, not compensated, effects of the non-budget neutral policies in question.

Given any two policies, P_{Tax} and P_{Exp}, satisfying equation (10), the additivity condition implies

$$\frac{d\hat{W}^P}{d\theta} = \eta^{\hat{i}} \left(MVPF_{P_{Exp}}^{\hat{i}} - MVPF_{P_{Tax}}^{\hat{i}} \right) \tag{13}$$

so that policy P_{Exp} provides a benefit of $MVPF_{P_{Exp}}^{\hat{i}}$ per dollar of government revenue and a cost of $MVPF_{P_{Tax}}^{\hat{i}}$ per dollar of government revenue. If $MVPF_{P_{Exp}}^{\hat{i}}$ is greater (less) than $MVPF_{P_{Tax}}^{\hat{i}}$, then taking resources from the tax (expenditure) policy and using it to finance the expenditure (tax)

[50]In the context of tax policies, it is interesting to note that causal effect of tax increases may be either a pure Hicksian response, an uncompensated response, or neither. If agents expect the increased revenue to be returned through future transfers or publicly provided goods and then borrow against these in capital markets (i.e. Ricardian equivalence holds), then the behavioral response may be similar to a compensated response. In contrast, the uncompensated approach may describe behavior if people do not expect future tax revenue or do not borrow against these future benefits. Indeed, whether or not the policy response is compensated or uncompensated arguably depends the degree to which Ricardian equivalence holds and how people respond to government debt. Of course, I do not explicitly model government debt. But, as eluded to in Footnote 47, comparisons of the values of MVPF are implicitly constructing budget neutral policies (e.g. $MCPF_{P_1}^{\hat{i}} - MCPF_{P_2}^{\hat{i}}$ is the welfare impact of taking \$1 along policy path P_2 and using it to increase spending along policy path P_1). Hence, the combined policy is budget neutral so that one need not isolate the particular impact of government debt on behavior and utility.

[51]Note that the $\hat{i}$ notation makes clear the units of income used in the definition; it is not the welfare impact on type $\hat{i}$. It is the welfare impact on all types measured in units of $\hat{i}$'s income.

policy will improve social welfare. Identifying heterogeneity in the MVPF across different policies is equivalent to identifying welfare-improving budget neutral policies.

I illustrate this definition using Example 1.

Example. *(Example 1 Continued) Consider the welfare cost a policy $P_{Tax}(\theta)$ that raises θ units of revenue through a tax on labor supply, $\hat{\tau}(\theta)$.*[52] *The marginal welfare impact of this policy is*

$$\frac{\frac{\partial \hat{V}^{P_{Tax}}}{\partial \theta}|_{\theta=0}}{\lambda} = -1 + \tau \frac{d\hat{l}_{P_{Tax}}}{d\theta}|_{\theta=0} \tag{14}$$

where the "-1" arises from the net negative transfer, and $\frac{d\hat{l}_{P_{Tax}}}{d\theta}|_{\theta=0}$ is the behavioral response to the tax policy that increases government revenue. Recall there is a single agent so that the MVPF does not depend on the choice of income units, $\hat{\imath}$. Moreover, $\frac{d\hat{t}}{d\theta} = -1$ because the policy raises θ units of revenue. So, the MVPF of the tax policy is given by

$$\begin{aligned} MVPF_{P_{Tax}} &= \frac{\frac{\frac{\partial \hat{V}^{P_{Tax}}}{\partial \theta}|_{\theta=0}}{\lambda}}{\frac{d\hat{t}}{d\theta}} \\ &= \frac{-1 + \tau \frac{d\hat{l}_{P_{Tax}}}{d\theta}|_{\theta=0}}{-1} \\ &= 1 - \tau \frac{d\hat{l}_{P_{Tax}}}{d\theta}|_{\theta=0} \end{aligned}$$

Intuitively, the marginal cost of public funds is given by one plus the causal impact of the response to taxation on the government's budget constraint.

Now, let $P_{Exp}(\theta)$ denote a policy that spends $\hat{G}(\theta) = G + \theta$ on additional roads. Then,

$$\frac{\frac{\partial \hat{V}^{P_{Exp}}}{\partial \theta}|_{\theta=0}}{\lambda} = \left(\frac{\frac{\partial u}{\partial g}}{\frac{\partial u}{\partial x}} - c_g \right) + 1 + \tau \frac{d\hat{l}_{P_{Exp}}}{d\theta}|_{\theta=0} \tag{15}$$

and, since $\frac{d\hat{t}}{d\theta} = 1$,

$$MCPF_{P_{Exp}} = \left(\frac{\frac{\partial u}{\partial g}}{\frac{\partial u}{\partial x}} - c_g \right) + 1 + \tau \frac{d\hat{l}_{P_{Exp}}}{d\theta}|_{\theta=0}$$

where $\left(\frac{\frac{\partial u}{\partial g}}{\frac{\partial u}{\partial x}} - c_g \right)$ is the net willingness to pay for the roads and "1" arises from the net positive transfer. The last term, $\tau \frac{d\hat{l}_{P_{Exp}}}{d\theta}$ is the impact of the behavioral response to the increased expenditure on roads on the government's budget. This term would be positive if roads increased labor supply; negative if it caused people to take more vacations and reduce labor earnings.

[52] For simplicity, I normalize the speed of the path so that $\frac{d\hat{t}}{d\theta} = -1$

Combining equations (14) *and* (15),

$$\begin{aligned}\frac{\frac{\partial \hat{V}^P}{\partial \theta}|_{\theta=0}}{\lambda} &= MVPF_{P_{Exp}} - MVPF_{P_{Tax}} \\ &= \left(\frac{\frac{\partial u}{\partial g}}{\frac{\partial u}{\partial x}} - c_g\right) + \tau\left(\frac{d\hat{l}_{P_{Tax}}}{d\theta}|_{\theta=0} + \frac{d\hat{l}_{P_{Exp}}}{d\theta}|_{\theta=0}\right) \\ &= \left(\frac{\frac{\partial u}{\partial g}}{\frac{\partial u}{\partial x}} - c_g\right) + \tau\frac{d\hat{l}_P}{d\theta}|_{\theta=0}\end{aligned}$$

where $\frac{d\hat{l}_P}{d\theta}|_{\theta=0}$ *is the joint effect of the expenditure and taxation policy on labor supply. Hence,* $\frac{\frac{\partial \hat{V}^P}{\partial \theta}|_{\theta=0}}{\lambda}$ *is precisely equal to the total welfare impact given in equation* (7)*. If* $MVPF_{P_{Exp}}$ *is greater (less) than* $MVPF_{P_{Tax}}$*, then increasing (decreasing) taxes through the tax policy* P_{Tax} *and decreasing (increasing) expenditures through the* P_{Exp} *policy will increase social welfare.*

Relation to previous definitions of the MCPF As mentioned, the definition of the MVPF is based on welfare measures of Mayshar (1990) and Slemrod and Yitzhaki (1996, 2001). However, it is conceptually distinct from the two main traditions in the MCPF literature (see Dahlby (2008) for a recent overview and Fullerton (1991) for evidence these conceptual differences lead to different numerical estimates). The so-called Pigou-Harberger-Browning tradition (Pigou (1947); Harberger (1964); Browning (1976, 1987)) uses the MEB as the measure of the MCPF. As mentioned above, this requires the expenditure policy to be financed using lump-sum taxation and that one incorporates these income effects. The so-called Stiglitz-Dasgupta-Atkinson-Stern tradition seeks a number that can be used to adjust the standard Samuelson (1954) condition for the welfare cost of raising the resources to finance the public expenditure (Ballard and Fullerton (1992)). This definition is the impact of the behavioral response to the policy on the government's budget of both increasing taxes and spending resources on the public good (i.e. the final term in Proposition 1 for a policy that raises taxes and increases spending on G). In practice, many papers estimating the marginal cost of public funds assume that the expenditure has a separable impact on utility and hence does not have an associated fiscal externality (Ballard and Fullerton (1992)). This is violated in many realistic policy settings, such as job training programs and education more generally, where perhaps a primary motivation for these expenditures is to capture fiscal externalities.

But a more general conceptual difference is that it is unclear why one desires a single measure of the cost of raising revenue to finance projects. In practice, revenue can be obtained not only from the tax schedule but also from a reduction in expenditure on alternative public goods and services. In contrast to the Stiglitz-Dasgupta-Atkinson-Stern definition of the MCPF, the MVPF proposed here is not a component of a broader welfare calculation but rather it is the total welfare impact of the policy per unit of government expenditure. By computing the MVPF for a range of policies, the government can improve social welfare by moving resources from policies with low to high MVPF policies, regardless of whether they are "tax" or "expenditure" policies, or combinations of both. Moreover, the behavioral responses required to answer such questions are precisely the causal effects of each of the policies in question.[53]

4 Applications

This section draws on the large literature estimating the causal effects of policy changes and places the in this normative framework by calculating their MVPF. In particular, I study changes involving the top marginal income tax rate, the generosity of the earned income tax credit (EITC), food stamps (SNAP), job training programs (JTPA), and housing vouchers (Section 8).

To simplify the analyses, throughout I assume that the social marginal utilities of income are constant within the set of beneficiaries for each policy change. For example, in considering the expansion of the EITC, I assume a dollar of welfare provided to someone earning $20K per year is valued equally to a dollar to someone earning $30K per year. This simplifies the calculation of the MVPF for each policy change, but could be relaxed with explicit assumptions on the distribution of social marginal utilities of income. Importantly, I do not require constant social marginal utilities of income across the entire population. Section 4.6 illustrates how one can make welfare comparisons across policies by considering the relative social marginal utilities of income between the beneficiaries.

The calculations are presented in Table 1.[54]

[53] An additional distinction relative to the MEB and MCPF is that these definitions are traditionally defined in static settings. In contrast, there is a large and growing literature emphasizing the importance of dynamic incentives and savings impacts of policy changes in generating different behavioral responses to taxation (e.g. see Blundell et al. (2011) and earlier summaries in Blundell et al. (2007)) and also that tax policies may affect the timing of taxable behavior (Goolsbee (2000)). The present definition of the MVPF naturally can be interpreted in a dynamic setting (let j index time). One needs to know the causal impact of the policy change on the government's budget, which may be a function not only of compensated or uncompensated static elasticities, but also Frisch elasticities, short-run income timing capabilities, and any other factor that affects the desire to engage in taxable behavior.

[54] The literature studying the causal effects of these policies focuses on a wide range of outcomes including many aspects of taxable behavior. However, in most cases, these studies do not construct a comprehensive measure of the revenue impact of the behavioral responses. Therefore, I construct such a measure using the causal effects on various components of taxable behavior. These details are discussed in Appendix A.

Table 1: MVPF for Various Policy Changes

Policy	Welfare Components Per Dollar of Net Resources: Public Spending	Welfare Components Per Dollar of Net Resources: Behavioral Impact on Govt Budget	MVPF	Source
Top Tax Rate	N/A	0.33 to 1	1.33 to 2	Saez, Slemrod, and Giertz (2012); Giertz (2009)
EITC Expansion	N/A	-0.12	0.88	Hotz and Scholz (2003), Chetty et al. (2013), Appendix A Calculations
Food Stamps	-0.13 to 0	-0.34[1]	0.53 to 0.66[1]	Whitmore (2002); Hoynes and Schanzenbach (2012), Appendix A Calculations
Job Training	-1.52 to 0.33	0.52	0 to 1.85	Bloom et al (1997), Appendix A Calculations
Housing Vouchers	-0.17	-0.05	0.78	Reeder (1985); Jacob and Ludwig (2012); Appendix A Calculations

[1]Estimate for labor supply response in Hoynes and Schanzenbach (2012) is not significantly different from zero, so that the MVPF is statistically indistinguishable from 0.8 to 1, depending on the valuation of the public spending.

4.1 Top Tax Rate Increase

There is a large literature estimating the causal effect of changes to the top marginal income tax rate and the impact of such behavioral responses on the government's budget (see Saez et al. (2012) for a recent review). Such estimates generally come from variation induced by two policy reforms: the Omnibus Budget Reconciliation Act of 1993 (a.k.a. OBRA-93 or the Clinton tax increases) and the Tax Reform Act of 1986 (a.k.a. TRA-86 or the Reagan tax cuts).

Translating the causal estimates from the literature into impacts on the government's budget requires a couple of assumptions. First, I assume that the policy has no spillover effects, so that the response to the top marginal income tax rate is zero amongst those whose earnings are below $\bar{l}$. This is commonly assumed in existing literature (e.g. Feldstein (1999)), as lower income groups are used as controls for macroeconomic effects argued to be unrelated to the tax policy. Of course, this assumption could be relaxed if one had an estimate of the causal effect of the policy on taxable behavior of those earning below the top income tax threshold.

Second, I assume that the rich have no income shifting across tax bases with different nonzero tax rates. This rules out the program having an impact on capital gains, for example. Again, this assumption could be relaxed with additional empirical work estimating the causal effect of raising the top income tax rate on tax revenue from capital gains.

With these assumptions, the MVPF of raising revenue from the rich through an increase in the top marginal tax rate is given by

$$MVPF_{PTax}^{Rich} = \frac{1}{1+r}$$

where r is the fraction of mechanical ordinary income tax revenue lost from behavioral responses to the tax increase,

$$r = \frac{\int_{i\in Rich} \tau_i^l \frac{d\hat{l}_i^{Tax}}{d\theta}|_{\theta=0} di}{\int_{i\in Rich} \frac{d\hat{\tau}_{Rich}^{Tax}}{d\theta}|_{\theta=0} \left(\hat{l}_i^{Tax} - \bar{l}\right) di} \tag{16}$$

Here, $\hat{l}_i$ is the taxable ordinary income of the rich and $\frac{d\hat{l}_i^{Tax}}{d\theta}|_{\theta=0}$ is the response of taxable ordinary income to a policy that raises the top marginal tax rate and uses the finances to raise government revenue.[55] Note $r < 0$ if behavioral responses lower tax revenue.

Fortunately, there is a large literature focused on estimating r in equation (16). Generally, this parameter is referred to as the "marginal excess burden" of the change in the top tax rate (Mirrlees et al. (2011); Saez et al. (2012)). However, as noted in earlier handbook chapters (Auerbach (1985); Auerbach and Hines (2002)), such an interpretation is technically incorrect in the presence of income effects. Such a point was raised by Feldstein (2012) in his critique of the ambitious and widely-celebrated Mirrlees Review (Mirrlees et al. (2011)) analyzing British tax policy:

> *Despite the centrality of the concept of excess burden, the Mirrlees Review fails to provide a clear explanation that the excess burden is the difference between the loss to taxpayers caused by the tax (e.g., the amount that taxpayers would have to receive as a lump sum to be as well off as they were before the imposition of the tax) and the revenue collected by the government. There are instead several alternative definitions at different points in the text, some of which are vague and some of which are simply wrong. For example, the Mirrlees Review states "it is the size of this revenue loss that determines the 'excess burden' of taxation" (61). That is not correct since the excess burden depends only on the substitution effects while revenue depends also on the income effects. (*Feldstein (2012))

Because this literature generally does not remove income effects, Feldstein (2012) is technically correct that it is not estimating the marginal excess burden. However, taking r to be the causal impact of the policy (without removing income effects), one obtains precisely the desired parameter for welfare analysis in the present framework.[56]

While there is a wide range of existing causal estimates, Saez et al. (2012) and Giertz (2009) suggest mid-points ranging from 25-50% – i.e., roughly 25-50% of the mechanical revenue that is raised from the tax is lost due to behavioral distortions. This implies $MVPF_{PTax}^{Rich}$ is between 1.33 and 2, as

[55] To see this, note that

$$\begin{aligned}
\frac{\frac{\frac{\partial \hat{V}_{PTax}^{Rich}}{\partial\theta}|_{\theta=0}}{\lambda^{Rich}}}{\int_i \frac{d\hat{t}^{PTax}}{d\theta} di} &= -\frac{\int_{i\in Rich} \frac{d\tau^{Rich}}{d\theta}|_{\theta=0}\left(\hat{l}_i - \bar{l}\right) di}{\int_{i\in Rich} \tau_i^l \frac{d\hat{l}_i^{Tax}}{d\theta}|_{\theta=0} di + \int_i \left(\sum_j \tau_{ij}^x \frac{d\hat{x}_{ij}^{Tax}}{d\theta}|_{\theta=0} + \tau_{ij}^l \frac{d\hat{l}_{ij}^{Tax}}{d\theta}|_{\theta=0}\right) di} \\
&= \frac{1}{1+r}
\end{aligned}$$

[56] Saez et al. (2012) show also how r can be incorporated into the calculation of the optimal top income tax rate. However, the optimal top tax rate depends on r defined locally *around the optimum*; hence one must assume that r is constant as the tax rate changes towards the optimum. In contrast, estimating $MVPF_{PTax}^{Rich}$ relies on local estimates of r for variation in taxes around the status quo.

reported in the first row of Table 1.[57]

4.2 EITC Expansion

There is also a large literature estimating the causal effects of EITC expansions, especially impacts on single mothers. Unfortunately, there is no study that estimates the impact of the behavioral response to EITC expansions on government expenditures directly. So, I construct such a causal estimate by taking the causal impacts on earnings and labor supply estimated in previous literature.

To do so, I make several assumptions commonly made in the empirical literature. First, I assume the policy has no effect on groups ineligible for the expansion. This assumes no response amongst (1) individuals above the income eligibility threshold and (2) low-income women choosing to become single mothers to become EITC eligible. Support for (1) is found in Chetty et al. (2013) who find minimal effects of behavioral responses in the so-called "phase-out" region of earnings above the refund-maximizing earnings level. Support for (2) is found in Hotz and Scholz (2003) who summarize the empirical literature as finding little or no effects on marriage and family formation.[58] Both of these assumptions could easily be relaxed with precise estimates of the impact of the behavioral responses of these groups to EITC expansions on its budgetary cost.

For EITC eligibles, I assume that the only behavioral impact of the program that affects tax revenue is through ordinary taxable (labor) income. Although capital income is less of an issue for EITC recipients, this assumption also rules out fiscal externalities of the EITC expansion on other social program take-up, such as SSDI or food stamps. Such impacts are likely to be present, as significant earnings generally disqualifies eligibility for such programs. To the extent to which an EITC expansion crowds out take-up other government services, the analysis will underestimate the social desirability of increasing funding of the EITC.

With these assumptions, one obtains an expression analogous to the change in the top income tax policy:

$$MVPF_{PEITC}^{Poor} = \frac{1}{1+p}$$

where p is the fraction of the mechanical revenue distributed that is increased due to behavioral distortions,

$$p = \frac{\int_{i\in Poor} \tau_i^l \frac{d\hat{l}_i^{EITC}}{d\theta}|_{\theta=0} di}{\int_{i\in Poor} \left(\frac{d\hat{T}_i^{EITC}}{d\theta}|_{\theta=0} + \frac{d\hat{\tau}_{ij}^{EITC}}{d\theta}|_{\theta=0} l_i \right) di}$$

[57] There are many caveats to this figure. For example, it assumes all of the reduction in taxable income is a social cost; in practice some avoidance behavior that reduces taxable income might be socially beneficial (e.g. if people increase charitable giving in response to higher tax rates) or even privately beneficial if individuals are not optimally choosing their degree of avoidance as in Chetty (2009a). If higher tax rates increase charitable giving or causes other positive spillovers, then the MVPF will be lower to the extent to which society values these induced transfers. Conversely, if tax rate increases cause negative spillovers or "trickle-down" general equilibrium effects as in the model of Scheuer and Rothschild (2013), the MVPF will be higher.

[58] A further defense of this assumption is found in the EITC papers using single women without children as a control group (e.g. Eissa and Liebman (1996); Chetty et al. (2013)).

There is a large literature focused on estimating the causal effects of EITC expansions on taxable behavior, such as labor supply. For my purposes, these studies would have ideally looked at the impact on tax revenue/expenditure in order to form an aggregate estimate of p. Short of this, I take estimates of the extensive and intensive margin labor supply response to the EITC to construct an estimate of the associated fiscal externality.

In appendix A, I generalize the model to allow for extensive margin (i.e. discontinuous) responses in labor supply. Estimates of causal effects summarized in Hotz and Scholz (2003) suggest that the cost of EITC expansions are ~9% larger than their mechanical cost due to extensive margin behavioral responses.

In addition to extensive margin responses, recent literature has also found evidence that the EITC induces distortions on the intensive margin as well but that these effects may take a while to fully be realized. Using variation in knowledge about the marginal tax rates induced by the EITC, Chetty et al. (2013) estimate that the cost of the EITC program is 5% higher due to behavioral responses. If responses to the marginal incentives primarily govern intensive margin responses and extensive margins are primarily about the average EITC rebate, this suggests these two estimates can be summed so that the total cost of EITC expansions are 14% higher due to behavioral responses. The estimate of $p = 14\%$ suggests that raising \$1 in general government revenue through a reduction in EITC spending would only require a reduction in benefits of 1/1.14=\$0.88. Hence, the marginal value of public funds of the EITC policy is roughly $MVPF_{PEITC}^{Poor} = 0.88$.[59]

4.3 Food Stamps (SNAP)

The Supplemental Nutrition Assistance Program (a.k.a. SNAP or "food stamps") provides financial assistance to low-income households for the purchase of food and is one of the largest transfer programs in the United States. Indeed, 1 in 4 children received benefits in July 2011 (Ganong and Liebman (2013)). Despite the program's size, there have been relatively few quasi-experimental studies analyzing its impact on behavior, perhaps due to the fact that it is a national program (Hoynes and Schanzenbach (2012)). A notable exception is the recent work of Hoynes and Schanzenbach (2012) who exploit county-level variation in the introduction of food stamps in the 1960s and 70s to estimate its impacts on labor supply. They find significant but noisy reductions in intensive labor supply and large but noisily estimated reductions in labor earnings (with a 95% confidence interval that includes zero impact). Appendix A.2 translates their point estimates into an estimate of the implied fiscal externality. The results suggest that although the program cost was roughly \$1,153.25 per household,

[59] The calculation of $MVPF_{PEITC}^{Poor}$ ignored the potential of general equilibrium effects of the policy expansion. This is easily incorporated if one has estimates of the causal impact of the policy on prices. For example, recent research suggests beneficiaries may only capture \$0.73 for every dollar of EITC spending (Rothstein (2010)). This suggests the marginal value of the program should be a weighted average of 0.73 for the beneficiaries and .27 for those who benefit from the reduced wages. To the extent to which the reduction in wages increases firm profits, one would then wish to add this fiscal externality into the benefit of the EITC expansion. But, to the extent to which those benefiting from the wage reduction have lower social marginal utilities of income, this will reduce the MVPF for the MVPF for the EITC expansion. For example, in the extreme case where society had zero value for the beneficiaries of the wage reduction and the wage change did not induce any additional fiscal externality, the MVPF would be 0.88 - 0.27 = 0.51.

the reductions in labor supply led to a reduced state and federal income tax receipt of \$588, which implies that the behavioral response is equal to 0.34 of the net resource cost of the program. However, one should be cautious in interpreting the magnitude of this coefficient since it is not statistically significantly different from zero.

Because the program benefits must be used to purchase food, these benefits may not be valued dollar-for-dollar by beneficiaries. However, many studies have shown that in general food stamp receipt does not significantly alter purchase decisions in the U.S. (Smeeding (1982)) and Puerto Rico (Moffitt (1989)). However, Whitmore (2002) uses a slightly different modeling approach and experimental data to arrive at an estimate of roughly. The former studies suggest the transfer of \$1,153.25 in food stamps is valued dollar-for-dollar by beneficiaries, whereas the latter suggests they are valued at only \$922.60 by beneficiaries. Appendix A.2 shows that this corresponds to a value of $\frac{\frac{\frac{\partial u}{\partial G}}{\lambda}-c_g}{\frac{dt}{d\theta}} = -.132$; 13% of the total cost of the program is lost due to the fact that the in-kind benefits were not valued as equivalent to cash. Combining the estimates together, the MVPF for food stamps is estimated at 0.53 to 0.64, depending on whether one takes the Smeeding (1982) estimate versus the Whitmore (2002) estimate for the cash-value of the food stamps to beneficiaries. Moreover, it is important to note that because the behavioral response is imprecisely estimated, one cannot rule out no behavioral response, which would imply a MVPF of 0.8 to 1.

There are a couple of important caveats to keep in mind in interpreting these results. First, the estimated behavioral responses correspond to a 1970s world with very different tax rates and extrapolation to present day may be problematic. Indeed, the presence of the EITC changes the government's stake in labor force participation and labor earnings. Second, food stamps may have significant benefits on children that are not perfectly incorporated into the utility function of the parents. For example, Almond et al. (2012) estimate that food stamps led to improvements in birth outcomes, such as increased birth weight. These potential externalities on newborn children are of course not captured in the current MVPF calculation. If one wished to add such effects, one could take the causal effects from Almond et al. (2012) and multiply by the valuation of the externality along the lines discussed in Appendix C.[60]

4.4 Job Training

While some transfer programs cause reductions in labor supply, others programs are known to increase labor supply and taxable earnings. For example, the Job Training Partnership Act (JTPA) of 1982 provided job training to economically disadvantaged youth and adults with the attempt of promoting entry into the labor force. Bloom et al. (1997) reports results from a randomized controlled trial of the program. Fortunately for the present purposes, their analyses focuses not only on earnings impacts but also on budget-relevant variables such as welfare and tax receipt.

The program reports results on adult women, adult men, children; for brevity and comparison to the EITC policy, I focus on their results for adult women presented at the top of Table 8 on p573 of

[60]For example, one could translate the increase in birth weight to an implied increase in quality-adjusted life years (QALY) and multiply by an assumed value of a QALY.

Bloom et al. (1997).

The program increased earnings on adult women by \$1,683, which led to an increased tax collection of \$236 per enrollee and also a \$235 reduction in welfare expenditures (AFDC). Assuming these capture the behavioral response impact on the budget, the total impact is \$471. The marginal cost of providing the program to an adult female enrollee is \$1,381.[61] Subtracting this from the \$471 positive impact on the budget from behavioral responses, the net resource transfer is \$910.[62]

One needs to calculate the extent to which the individual would be willing to pay for the job training program in excess of its marginal cost. In their cost-benefit analysis, Bloom et al. (1997) implicitly assume that the earnings increase of the beneficiaries is a welfare benefit. For this to be the case, one needs to assume that this earnings increase was the result of a positive externality imposed on the beneficiaries (e.g. an increase in their productivity that was incurred with no cost to the beneficiary) and not the result of their increased labor effort. Under this assumption, the individuals willingness to pay for the program in excess of its cost is \$1,683-\$1,381 = \$302 per enrollee. This implies a MVPF of \$1,683/\$910 = 1.85 on the job training beneficiaries.

However, the envelope theorem suggests caution in this calculation. In the canonical model with no distortions besides government intervention, people who are induced into the labor force were, to first order, indifferent to working. Hence, the increase in earnings provides no direct evidence on the willingness to pay for the program. One potential assumption one can make is that the government has no comparative advantage or disadvantage in the provision of job training (e.g. there's an equally good private training program that can also provide similar job training for \$1,381). In this case, the market failure term would be zero so that the MVPF would be MVPF of \$1,381/\$910=1.52. Note this is still well above 1 because of the positive fiscal externalities associated with the program.[63] However, deriving a more precise MVPF requires future work that quantifies the extent to which government job training programs are valued above or below their cost by beneficiaries.

[61] \$1,227 of this is the administrative cost; \$154 is the cost of a wage subsidy associated with the program.

[62] The report also indicates women reduced their spending on private training programs by \$56 and considers this a benefit of the program. But by the envelope theorem, such crowd-out estimates are not welfare relevant to first order.

[63] It may also be reasonable to argue that the government provides an inferior job training product relative to the private market; or, equivalently from a welfare perspective, the type of people who select into a government job training program versus a private market job training program may be those who did not have a sufficient welfare gain for the job training program to begin with. Indeed, revealed preference of the participants in the JTPA program only guarantees that the willingness to pay was nonnegative for beneficiaries: $\frac{u_G}{\lambda} \geq 0$. As a result, one technically cannot rule out the possibility that individuals received no value whatsoever from the program, and the MVPF is zero. This highlights the importance of attempting to estimate individuals' willingness to pay for government programs when conducting a cost-benefit analysis of such programs.

In addition to issues with valuing $\frac{\frac{\partial u}{\partial G}}{\lambda} - c^G$, one may also be concerned about general equilibrium effects of such policies. For example, Crepon et al. (2012) find evidence that a job placement program in France had an increase in employment among beneficiaries but was offset by a decrease in employment by non-beneficiaries. In this case, even if the beneficiaries had a willingness to pay for the program, it might be perfectly offset by negative impacts on those not enrolled in the program. Incorporating such general equilibrium effects would reduce the estimate of the MVPF. For example, if the program was simply causing sorting within a fixed labor market and non-beneficiaries have equal social marginal utilities of income to beneficiaries of the program, one would find a MVPF of zero.

4.5 Housing Vouchers (Section 8)

With roughly 2 million beneficiaries, Section 8 housing vouchers constitute the largest low-income housing program in the US (Rice and Sard (2006)). Such vouchers provide rent assistance to low-income households; however, vouchers are mean-tested, and therefore induce potentially significant labor earnings distortions. Often, voucher applications exceed supply, which leads to rationing. Jacob and Ludwig (2012) exploit the randomness in the allocation of vouchers to excess applications in Chicago. They analyze not only the impact of voucher receipt on labor supply, but also on other governmental program participation such as TANF (cash welfare), Medicaid, and SNAP. They find housing vouchers lead to a significant reductions in labor supply – on both the intensive and extensive margin – and an increase in participation in other welfare programs.

Appendix A.3 translates these calculations into the impact of the behavioral response to the policy on the government's budget. Although the paper estimates significant behavioral responses, they are arguably modest relative to the cost of the voucher and correspond to \$432 per \$8,400 voucher, so that the fiscal externality comprises roughly 5% of the total cost of the program.

There is little work studying the willingness to pay for the housing voucher. To my knowledge, the only known study is Reeder (1985) who estimates \$1 in Section 8 vouchers are valued at \$0.83 by the beneficiaries (see also the discussion in Jacob and Ludwig (2012)).[64] Taking this estimate, one arrives at (0.83-1)/1.05 = -0.17, which suggests beneficiaries value the section 8 vouchers less than their costs by an amount equal to 17% of the total resource costs (voucher cost + fiscal externality). Combining, this suggests a MVPF of 0.78 for the housing vouchers.[65]

4.6 Combining Policies Using Okun's Bucket Experiment

While the previous sections constructed estimates of the MVPF for each of these policies, the beneficiaries for each policy are different. Hence, the MVPF are not directly comparable across policies. To make such comparisons, one needs to aggregate using the social marginal utilities of income.

To illustrate this, consider a budget neutral policy of increasing EITC generosity financed by an increase in the top marginal income tax rate. Such a policy increases social welfare if and only if

$$MVPF^{Poor}_{PEITC} - \frac{\eta^{Rich}}{\eta^{Poor}} MVPF^{Rich}_{PTax} \geq 0 \tag{17}$$

where η^{Rich} and η^{Poor} are the social marginal utilities of income on the rich with incomes above \$400K

[64] Carlson et al. (2011) argue that individuals value the housing voucher greater than its face value, but they don't seem to address the issue that the housing market imposes a natural upper bound on the valuation.

[65] There are a couple of potential caveats to this estimate that are perhaps worth mentioning. First, Jacob and Ludwig (2012) provides novel identification of the impact of voucher receipt on labor supply and public program take-up; but, they do not estimate the impact of increased voucher generosity on ex-ante labor supply decisions. Indeed, people may decrease their labor supply to become eligible in the first place. Second, there is some recent evidence that suggests a portion of housing vouchers (~0.13) may be captured by landlords instead of tenants (Collinson and Ganong (2013)). If the social marginal utilities of landlords and tenants were the same, this would not affect the MVPF; but if landlords have lower social marginal utilities of income, one would need to adjust for the fact that 13% of the mechanical subsidy falls in the hands of landlords and weight the MVPF accordingly.

who are subject to the top tax rate under the status quo and the poor single mothers earning less than \$40K who are eligible for the EITC.[66]

If one takes the upper range estimate of $MVPF^{Rich}_{P_{Tax}} = 2$, additional redistribution is desirable iff

$$0.88 - 2\frac{\eta^{Rich}}{\eta^{Poor}} \geq 0$$

or

$$\eta^{Rich} \leq 0.44\eta^{Poor}$$

Additional redistribution is desirable if and only if one prefers \$0.44 in the pocket of an EITC recipient relative to \$1 in the pocket of an individual subject to the top marginal tax rate (i.e. with income above ~\$400K). Similarly, if one takes the lower estimate of $MVPF^{Rich}_{PTax} = 1.33$, additional redistribution is desirable if and only if one prefers \$0.66 in the pocket of an EITC recipient relative to \$1 to someone subject to the top marginal tax rate. In this sense, comparisons of welfare impacts across policies involve an Okun (1975) bucket experiment between the beneficiaries of each policy in question.

Ratios of the other MVPF reveal other implicit ratios of social marginal utilities of income. For example, the EITC MVPF of 0.88 and the housing voucher estimate of 0.78 suggest society values money in the hands of Section 8 voucher-holders more than EITC beneficiaries. From a more normative perspective, if housing voucher beneficiaries have equal social marginal utilities of income as EITC beneficiaries, then the estimates suggest social welfare would be improved by increasing EITC funding financed by a decrease in Section 8 housing vouchers.

5 Conclusion

This paper provides a general framework for evaluating the marginal welfare impact of government policy changes that values them using individuals' marginal willingness to pay out of their own income. The behavioral response required for such welfare measurement is the causal, not compensated, impact of the policy. Moreover, in the broad class of models in which the government is the only distortion, the causal impact of the behavioral response to the policy on the government budget is sufficient for all behavioral responses.

I hope the framework, and the clarification relative to alternative frameworks, is useful for papers conducting analysis of causal effects of policy changes and seeking a welfare framework to evaluate the normative aspects of the policy change. Translating such causal estimates into their implicit MVPF – or even just the behavioral response component if one does not have a measure of the market failure $\left(\frac{\frac{\partial u}{\partial G}}{\lambda} - c^G\right)$ – would seem particularly promising with the potential to create a volume of estimates for

[66] This is similar to Browning and Johnson (1984) who simulate the marginal reduction in resources from an increased demogrant at the bottom of the income distribution. For their baseline simulation, additional redistribution is desirable if one prefers \$0.29 to the poor relative to \$1 to the rich. Because Browning and Johnson (1984) simulate the causal impacts of the redistributive policy, the desirability of pursuing the policy depends on the social marginal utilities of income, and hence have an interpretation in terms of Okun's bucket (Okun (1975)). In contrast, if one were to take the MEB estimates for increasing tax rates from Browning (1987), one would need to add back in the income effects before interpreting the results using the social marginal utilities of income.

different policies and a more comprehensive analysis of the desirability of potential government policy changes.

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Online Appendix: Not for Publication

A Application Details

A.1 EITC

This section outlines the welfare analysis of an EITC expansion. To correspond with the causal effects analyzed in much previous literature, the marginal expansion of the EITC program can best be thought of as increasing the maximum benefit level in a manner that maintains current income eligibility thresholds and tax schedule kink points (but raises the phase-in and phase-out rates in order to reach the new maximum benefit). However, the results from Chetty et al. (2013) suggest the phase-out slope of the EITC has only a minor impact on labor supply (most of the response is from individuals below the EITC maximum benefit level choosing to increase their labor supply). This suggests the impact on the behavioral response on the government budget would not be too sensitive to the precise design of the phase-out of the program.

The effects documented in previous literature consist of both intensive and extensive labor supply responses. With extensive margin responses, $\frac{d\hat{l}_i^{EITC}}{d\theta}$ may not exist for all i, as individuals make discrete jumps in their choice of labor supply. However, this is easily accommodated into the model. To see this, normalize the index of the Poor to be the unit interval, $i \in Poor = [0, 1]$. Then, order the index of the poor population such that $\hat{l}_i(\theta) > 0$ implies $\hat{l}_j(\theta) > 0$ for $j < i$ and all $\theta \in (-\epsilon, \epsilon)$. With this ordering, there exists a threshold, $i^{LFP}(\theta)$, such that $i < i^{LFP}(\theta)$ indicates that i is in the labor force and $i > i^{LFP}(\theta)$ indicates that i is not in the labor force. Hence, $i^{LFP}(\theta)$ is the fraction of the poor single mothers that are in the labor force. With this notation, the impact of the behavioral response to the policy by the poor on the government's budget is given by:

$$-\int_{i \in Poor} \tau_i^l \frac{d\hat{l}_i^{EITC}}{d\theta}|_{\theta=0} di = \underbrace{\left(\tau^l_{i^{LFP}(0)} l_{i^{LFP}(0)}\right) \frac{di^{LFP}}{d\theta}|_{\theta=0}}_{\text{Extensive Margin}} - \underbrace{\int_{i<\hat{i}} \tau_i^l \frac{d\hat{l}_i^{EITC}}{d\theta}|_{\theta=0} di}_{\text{Intensive Margin}} \tag{18}$$

where $\tau^l_{i^{LFP}(0)} l_{i^{LFP}(0)}$ is the average taxable income (or loss) generated by the marginal type entering the labor force and $\frac{di^{LFP}}{d\theta}$ is the marginal rate at which the policy induces labor force entry.[67] The cost resulting from extensive margin responses is given by the impact of the program on the labor force participation rate, multiplied by the size of the average subsidy to those entering the labor force. [68]

There is a large literature analyzing the impact of the EITC expansion on labor force participation of single mothers, beginning with Eissa and Liebman (1996). These approaches generally estimate the causal effect of EITC receipt on behavior using various expansions in the generosity of the EITC

[67] This formula is conceptually similar to that of Eissa et al. (2008) who simulate the MEB of recent EITC expansions using estimates of compensated labor supply elasticities on both the extensive and intensive margin.

[68] Because my model assumed individuals face linear tax rates, the distinction between the average and marginal tax rate is not readily provided, but it is straightforward to verify that the fiscal externality imposed by those entering the labor force is given by the size of the subsidy they receive by entering the labor force, not by the marginal tax or subsidy they face if they were to provide an additional unit of labor supply.

program. Hotz and Scholz (2003) summarize this literature and find consistency across methodologies in estimates of the elasticity of the labor force participation rate of single mothers, $\hat{i}$, rate with respect to the average after-tax wage, $E\left[\left(1-\tau^l_{\hat{i}}\right)l_{\hat{l}}\right]$, with estimates ranging from 0.69-1.16.

I translate this elasticity into equation (18) by normalizing θ to parameterize an additional unit of the mechanical subsidy[69] and writing:

$$\left(\tau^l_{i^{LFP}(0)} l_{i^{LFP}(0)}\right)\frac{di^{LFP}}{d\theta}|_{\theta=0} = \frac{\left(\tau^l_{i^{LFP}(0)} l_{i^{LFP}(0)}\right)}{\left(\left(1-\tau^l_{i^{LFP}(0)}\right)l_{i^{LFP}(0)}\right)}\epsilon^{LFP}_{E\left[\left(1-\tau^l_{\hat{i}}\right)l_{\hat{i}}\right]}$$

where $\epsilon^{LFP}_{E\left[\left(1-\tau^l_{\hat{i}}\right)l_{\hat{i}}\right]}$ is the elasticity of the labor force participation rate with respect to the after tax wage rate and $\frac{E\left[\tau^l_{\hat{i}}l_{\hat{i}}\right]}{E\left[\left(1-\tau^l_{\hat{i}}\right)l_{\hat{i}}\right]}$ is the size of the subsidy as a fraction of after tax income for the marginal labor force entrant. For the elasticity of labor force participation, I choose an estimate of 0.9, equal to the midpoint of existing estimates (Hotz and Scholz (2003)). For $\frac{E\left[\tau^l_{\hat{i}}l_{\hat{i}}\right]}{E\left[\left(1-\tau^l_{\hat{i}}\right)l_{\hat{i}}\right]}$, one desires the after tax wages and subsidies for marginal entrants into the labor force. While such parameters could be identified using the same identification strategies previous papers have used to estimate the labor supply impact of the EITC, to my knowledge no such estimates of the marginal wages and subsidies exist. Using the 2004 SOI, Eissa and Hoynes (2011) report that the average subsidy is \$1,806 per beneficiary, which corresponds to 9.2% of a \$20,000 gross income for EITC beneficiaries. Athreya et al. (2010) report the average recipient obtains a subsidy equal to 11.7% of gross income in the 2008 CPS. I therefore take the approximate midpoint of 11%.

These calculations suggest the extensive margin impact on the government budget is given by:

$$\underbrace{E\left[\tau^l_{\hat{i}}l_{\hat{i}}\right]\frac{d\hat{i}}{d\theta}}_{\text{Extensive Margin}} = \frac{0.11}{1+0.11} * 0.9 = 0.09$$

so that the EITC is 9% more costly to the government because of extensive margin labor supply responses.[70]

Intensive margin responses Until recently, there was little evidence that the EITC had intensive margin impacts on labor supply. However, the recent paper by Chetty et al. (2013) exploits the geographic variation in knowledge about the marginal incentives induced by the EITC, as proxied by the local fraction of self-employed that bunch at the subsidy-maximizing kink rate. Using the universe of tax return data from EITC recipients, their estimates suggest that the behavioral responses induced by knowledge about the marginal incentives provided by the EITC increase refunds by approximately

[69] This normalizes $\int_{i\in Poor}\left(\frac{d\hat{T}^{EITC}_i}{d\theta}|_{\theta=0} + \frac{d\hat{\tau}^{EITC}_{ij}}{d\theta}|_{\theta=0}l_i\right)di = 1$

[70] Taking elasticity estimates in the 0.69-1.12 range reported by Hotz and Scholz (2003), yields estimates of the extensive margin impact ranging from 0.07 to 0.11. Hence, if one assumed only extensive margin responses were operating, the policy elasticity would be $p = 0.09$, ranging between 0.07 and 0.11.

5% relative to what they would be in the absence of behavioral responses, with most of these responses due to intensive margin adjustments. What is particularly useful about this study is that it uses tax expenditures as an outcome variable, and hence can compute the associated fiscal externality directly.

The downside of Chetty et al. (2013) is that the policy path in question is the degree of "knowledge about the shape of the EITC schedule". While this policy path provides guidance on the size of the distortions induced by these marginal incentives, one could imagine that even in places with no knowledge of the EITC schedules the existence of the EITC generates extensive margin responses.

To account for this, I make the baseline assumption that the knowledge of the average EITC subsidy generates extensive margin responses and knowledge of the shape of the EITC schedule generates intensive margin responses. With this assumption, the results of Chetty et al. (2013) should be added together with the extensive margin responses found in previous literature to arrive at the total impact of an EITC expansion. This yields an estimate of $p = 0.09 + 0.05 = 14\%$ with a range of 0.12-0.16 taking the range of extensive margin labor supply responses.[71]

A.2 Food Stamps

Using variation induced in the introduction of food stamps in the 1960s and 70s Hoynes and Schanzenbach (2012) estimate that food stamps led to a significant reduction in labor supply, especially among female headed households. They estimate a fairly imprecise and large reduction in labor hours (-658 hours per year, with a 95% CI of [-1186 , 130]; see Column (2) of Table 2 on page 157). They also estimate a large and imprecise change in annual earnings of -$2,943 (95% CI of [-10,169 , 4,284]). Corresponding to the tax rates operating around 1970, I assume a linear marginal tax rate of 20% on earnings, consistent with the absence of an EITC program during this time period. I arrive at 20% using the 14% bottom tax bracket for federal taxes and a 6% state tax assumption. With this assumption, the net change tax revenue collected due to behavioral responses to food stamps is $2,943*.2=$588.60. It is important to note that this estimate is not statistically significantly different from zero.

In contrast, the food stamp program provided an average monthly benefit of $26.77 per person in 1978[72], which corresponds to $321.24 per person per year. Hoynes and Schanzenbach (2009) estimate a mean household size of 3.59 in their sample, which implies a household-level transfer size of $1,153.25. Hence, the total cost to the government of providing the food stamps policy is $1,153.25+$588.60=$1,741.85.

For the net valuation of food stamps, Smeeding (1982) estimates that food stamps are valued dollar-for-dollar. In contrast, Whitmore (2002) estimates that every dollar of food stamps is valued at ~$0.80 by the beneficiaries. In the absence of behavioral responses this estimate suggests the

[71] This is potentially an overestimate of the net effect of behavioral responses because some of the responses found in Chetty et al. (2013) is along the extensive margin and is more amenable to the potential critique that the earlier literature could not effectively separate the impact of EITC expansions from the impact of the decrease in welfare generosity (see Meyer and Rosenbaum (2001) for this debate). Therefore, I also consider the case that the 0.05 figure in Chetty et al. (2013) captures all of the EITC response (so that $p = 0.05$). This arguably provides a lower bound of the impact of the policy. For an upper bound, I consider the upper range of extensive margin response can be added to Chetty et al. (2013), so that $p = 0.11 + 0.05 = 16\%$.

[72] www.fns.usda.gov/pd/SNAPsummary.htm+&cd=3&hl=en&ct=clnk&gl=us&client=safari

MVPF would be 0.8. Placing this into the context of the size of the transfers, the estimate suggests that the mechanical transfer of $1,153.25 is valued by beneficiaries at only $922.60. In other words, $\frac{\frac{\partial u}{\partial G}}{\lambda} - c^G = -\$230.65$; expressed as a fraction of the net resource transfer, this is -922.60/1,741.85 = -0.132. In turn, the impact of the behavioral response on the government budget is -$588.60; expressed as a fraction of the net resource transfer, this is -588.6/1,153.25 = -0.338. Putting these together, we have a MVPF of 1-.132-.338=0.53 for the Whitmore (2002) estimate of the cash-value of the food stamps. Assuming instead that food stamps are valued dollar-for-dollar, the MVPF is 1-0.338 = 0.642. Of course, because one cannot reject the null hypothesis that the revenue impact of the policy is zero, one cannot reject the null hypothesis of a MVPF of 0.80 to 1 (no behavioral responses) or even higher.

A.3 Section 8 Housing Vouchers

Jacob and Ludwig (2012) study the impact of obtaining a housing voucher on labor supply (intensive + extensive), Medicaid receipt, TANF receipt, and SNAP receipt. For the extensive margin labor supply response, I use the 11% tax rate assumption from the EITC section. For the intensive margin response, Jacob and Ludwig (2012) report a marginal tax rate of 24% for the treatment group that includes phase-out of government benefits in addition to marginal income tax rates. For the change in TANF and SNAP use, I use the Green Book (2004) and compute average costs per household in 2002, normalized to 2007 dollars using the CPI-U to be consistent with Jacob and Ludwig (2012). For the change in Medicare enrollment, I use costs compiled by Holahan and McMorrow (2012). Table A1 reports the calculations.

Table A1: Housing Voucher Calculation

Item	Value	Source
Voucher Cost	$8,400	Jacob and Ludwig (2012)
Extensive Margin		
Extensive Margin Change	0.036	
Mean earnings	22,232	Mean earnings of $5557 per quarter (Jacob and Ludwig (2012))
Assumed Avg Tax Rate	-11%	Avg EITC subsidy (see EITC section)
Fiscal Impact	-88.0	
Intensive Margin		
% Intensive	0.592	Jacob and Ludwig (2012)
Earnings change	910	Jacob and Ludwig (2012) report quarterly change of 227.54
Assumed Tax Rate	24%	Jacob and Ludwig estimate 18% tax rate in control group and 24% tax rate in treatment group that includes phase-out of services
Fiscal Impact	129.3	
TANF		
% Increase	0.017	Jacob and Ludwig (2012)
Avg Cost	254	Mean monthly TANF from Green Book (2007 dollars deflated using CPI-U as in Jacob and Ludwig (2012))
Fiscal Impact	4.3	
Medicaid		
% Increase	0.058	Jacob and Ludwig (2012)
Avg Cost per enrollee	6192	Halahan and McMorrow (2012) Appendix Table 1 reports costs for 2002
Fiscal Impact	359.1	
Food Stamps		
% Increase	0.076	
Avg Cost per family	364	Family of 4 assumption
Fiscal Impact	27.7	
Total Program Cost	$8,832.4	
Total Behavioral Impact	$432.4	
% of cost	0.05	
Valuation of $1 of Voucher	0.83	Reeder (1985)
Value of $8,400 Voucher	6,972	
Net Valuation	-1,428	
% of cost	-0.17	
MVPF	$0.781	

B Appendix: Proof of Proposition 1

I first characterize $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$. Taking the total derivative of V_i with respect to θ, I have

$$\frac{d\hat{V}_i}{d\theta} = \frac{dV_i\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{l}}, \hat{\tau}_{\mathbf{i}}^{\mathbf{x}}, \hat{T}_i, y_i, \hat{G}_i\right)}{d\theta} = \frac{\partial V_i}{\partial T_i}\frac{d\hat{T}_i}{d\theta} + \sum_{j=1}^{J_G}\frac{\partial V_i}{\partial G_i}\frac{d\hat{G}_i}{d\theta} + \sum_{j=1}^{J_X}\frac{\partial V_i}{\partial \tau_{ij}^x}\frac{d\hat{\tau}_{ij}^x}{d\theta} + \sum_{j=1}^{J_L}\frac{\partial V_i}{\partial \tau_{ij}^l}\frac{d\hat{\tau}_{ij}^l}{d\theta}$$

Applying the envelope theorem from the agent's maximization problem and evaluating at $\theta = 0$ implies

$$\begin{aligned}
\frac{\partial V_i}{\partial \tau_{ij}^x} &= -x_{ij}\lambda_i \\
\frac{\partial V_i}{\partial \tau_{ij}^l} &= -l_{ij}\lambda_i \\
\frac{\partial V_i}{\partial T_i} &= -\lambda_i \\
\frac{\partial V_i}{\partial G_i} &= \frac{\partial u_i}{\partial G_i}
\end{aligned}$$

Replacing terms, I have

$$\frac{d\hat{V}_i}{d\theta}|_{\theta=0} = \lambda_i \left(\frac{d\hat{T}_i}{d\theta} + \sum_{j=1}^{J_G} \frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} \frac{d\hat{G}_{ij}}{d\theta} - \sum_{j=1}^{J_X} x_{ij} \frac{d\hat{\tau}_{ij}^x}{d\theta} - \sum_{j=1}^{J_L} l_{ij} \frac{d\hat{\tau}_{ij}^l}{d\theta} \right)$$

Now, I use equation 5 to replace the total transfers, $\frac{d\hat{T}_i}{d\theta}$, with the net government budgetary position, $\frac{d\hat{t}_i}{d\theta}$, which yields

$$\frac{d\hat{V}_i}{d\theta}|_{\theta=0} = \lambda_i \left(\sum_{j=1}^{J_G} \left(\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G \right) \frac{d\hat{G}_{ij}}{d\theta} + \frac{d\hat{t}_i}{d\theta} + \frac{d}{d\theta} \left[R\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}, \hat{\mathbf{x}}_{\mathbf{i}}, \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}, \hat{\mathbf{l}}_{\mathbf{i}} \right) \right] - \sum_{j=1}^{J_X} x_{ij} \frac{d\hat{\tau}_{ij}^x}{d\theta} - \sum_{j=1}^{J_L} l_{ij} \frac{d\hat{\tau}_{ij}^l}{d\theta} \right)$$

Finally, note that equation 6 shows I can replace the difference between the total revenue impact, $\frac{d}{d\theta} \left[R\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}, \hat{\mathbf{x}}_{\mathbf{i}}, \tau_{\mathbf{i}}^{\mathbf{l}}, \hat{\mathbf{l}}_{\mathbf{i}} \right) \right]$, and the mechanical revenue effect, $\sum_{j=1}^{J_X} x_{ij} \frac{d\hat{\tau}_{ij}^x}{d\theta} + \sum_{j=1}^{J_L} l_{ij} \frac{d\hat{\tau}_{ij}^l}{d\theta}$, with the behavioral impact of the policy on the government budget constraint, yielding

$$\frac{dV_i}{d\theta}|_{\theta=0} = \lambda_i \left(\sum_{j=1}^{J_G} \left(\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G \right) \frac{d\hat{G}_{ij}}{d\theta} + \frac{d\hat{t}_i}{d\theta} + \left(\sum_j^{J_X} \tau_{ij}^x \frac{d\hat{x}_{ij}}{d\theta} + \sum_j^{J_L} \tau_{ij}^l \frac{d\hat{l}_{ij}}{d\theta} \right) \right)$$

Now, I show that $\frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$ is equal to the marginal equivalent variation and marginal compensating variation. Recall that $EV_i(\theta)$ solves

$$V_i\left(\tau_{\mathbf{i}}^{\mathbf{l}}, \tau_{\mathbf{i}}^{\mathbf{x}}, T_i, \mathbf{G}_{\mathbf{i}}, y_i + EV_i(\theta) \right) = \hat{V}_i(\theta)$$

Thus, differentiating with respect to θ and evaluating at $\theta = 0$ yields

$$\frac{\partial V_i}{\partial y_i} \frac{d\left[EV_i\right]}{d\theta}|_{\theta=0} = \frac{d\hat{V}_i}{d\theta}|_{\theta=0}$$

or

$$\frac{d\left[EV_i\right]}{d\theta}|_{\theta=0} = \frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$$

Similarly, recall $CV_i(\theta)$ solves

$$V_i\left(\tau_{\mathbf{i}}^{\mathbf{l}}(\theta), \tau_{\mathbf{i}}^{\mathbf{x}}(\theta), T_i(\theta), \mathbf{G_i}(\theta), y_i - CV_i(\theta)\right) = \hat{V}_i(0)$$

Differentiating with respect to θ and evaluating at $\theta = 0$ yields

$$\frac{d\hat{V}_i}{d\theta}|_{\theta=0} - \frac{d\left[CV_i\right]}{d\theta}|_{\theta=0}\frac{\partial V_i}{\partial y_i} = 0$$

or

$$\frac{d\left[CV_i\right]}{d\theta}|_{\theta=0} = \frac{\frac{d\hat{V}_i}{d\theta}|_{\theta=0}}{\lambda_i}$$

so that $\frac{\frac{dV_i}{d\theta}}{\lambda_i}$ is equal to the marginal equivalent variation and marginal compensating variation of the program.

C Appendix: Externalities (and Internalities)

The analysis assumes individuals maximize their welfare without imposing any externalities on others or internalities on themselves. While researchers may debate the extent of externalities or internalities, my result that the causal response to the policy is required for policy analysis readily extends to a world with internalities and externalities.

To see this, now suppose that the agents' utility function is given by

$$u_i\left(\mathbf{x_i}, \mathbf{l_i}, \mathbf{G_i}, E_i\right)$$

where the externality imposed on agent i, E_i, is produced in response to the consumption choices of all agents in the economy,

$$E_i = f_i^E(\mathbf{x})$$

where $\mathbf{x} = \{\mathbf{x_i}\}_{\mathbf{i}}$ is the vector of all consumption decisions made by the agent (one could generalize this easily to incorporate l). I assume that there is no market for E_i and that agents do not take E_i into account when conducting their optimization. Note that I allow E_i to interact arbitrarily with the utility function, but I assume it is taken as given in the agents' maximization problem. Thus, E_i could represent a classical externality (e.g. pollution) or a behavioral "internality". An internality could be welfare costs of smoking that are not incorporated into their maximization program, or could incorporate "optimization frictions" of the form used by Chetty (2009a) where taxpayers over-estimate the costs of tax sheltering so that the marginal utility of tax sheltered income is not equal to the marginal utility of taxable income.

The value function is now given by

$$
\begin{aligned}
V_i\left(\tau_{\mathbf{i}}^{\mathbf{l}},\tau_{\mathbf{i}}^{\mathbf{x}},T_i,y_i,\mathbf{G_i},E_i\right) &= \max_{\mathbf{x},\mathbf{l}} u_i\left(\mathbf{x},\mathbf{l},\mathbf{G_i},E_i\right) \\
& \quad s.t. \quad \sum_{j=1}^{J_X}\left(1+\tau_{ij}^x\right)x_{ij} \leq \sum_{j=1}^{J_L}\left(1-\tau_{ij}^l\right)l_{ij}+T_i+y_i
\end{aligned}
$$

Given each agent's solution to this program, $\mathbf{x_i}$, I construct $E_i = f_i^E\left(\mathbf{x}\right)$ and $\mathbf{x}$ is the vector of solutions to each agents optimization program.

All other definitions from Section 2 are maintained. In particular, policy paths are defined as in equation 4.[73] Proposition 2 presents the characterization of the marginal welfare impact of a policy evaluated at $\theta = 0$.

Proposition 2. *The welfare impact of the marginal policy change to type i is given by*

$$
\frac{\frac{dV_i}{d\theta}|_{\theta=0}}{\lambda_i} = \left(\underbrace{\sum_{j=1}^{J_G}\left(\frac{\frac{\partial u_i}{\partial G}}{\lambda_i}-c_j^G\right)\frac{d\hat{G}_{ij}}{d\theta}}_{\substack{\textit{Public Spending /}\\ \textit{Market Failure}}} + \underbrace{\frac{d\hat{t}_i}{d\theta}}_{\textit{Transfer}} + \underbrace{\left(\sum_j^{J_X}\tau_{ij}^x\frac{d\hat{x}_{ij}}{d\theta}+\sum_j^{J_L}\tau_{ij}^l\frac{d\hat{l}_{ij}}{d\theta}\right)}_{\textit{Impact on Govt}} + \underbrace{\frac{\frac{\partial u_i}{\partial E_i}}{\lambda_i}\frac{d\hat{E}_i}{d\theta}}_{\textit{Impact on Externality}}\right)
$$

where

$$
\frac{d\hat{E}_i}{d\theta} = \left(\sum_i\sum_j^{J_X}\frac{\partial f_i^E}{\partial x_{ij}}\frac{d\hat{x}_{ij}}{d\theta}\right)
$$

is the net marginal impact of the policy on the externality experienced by type i.

Proof. Taking the total derivative of V_i with respect to θ, I have

$$
\frac{dV_i\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{l}},\hat{\tau}_{\mathbf{i}}^{\mathbf{x}},\hat{T}_i,y_i,\hat{\mathbf{G}}_{\mathbf{i}},\hat{E}_i\right)}{d\theta} = \frac{\partial V_i}{\partial T_i}\frac{d\hat{T}_i}{d\theta}+\sum_{j=1}^{J_G}\frac{\partial V_i}{\partial G_{ij}}\frac{d\hat{G}_{ij}}{d\theta}+\sum_{j=1}^{J_X}\frac{\partial V_i}{\partial\tau_{ij}^x}\frac{d\hat{\tau}_{ij}^x}{d\theta}+\sum_{j=1}^{J_L}\frac{\partial V_i}{\partial\tau_{ij}^l}\frac{d\hat{\tau}_{ij}^l}{d\theta}+\frac{\partial V_i}{\partial E_i}\frac{d\hat{E}_i}{d\theta}
$$

[73] Note that I do not allow the government to directly affect the level of E. This would be duplicating the role of publicly provided goods, as I could specify G to be provision of goods which mitigate the externality (either directly or through their effect on agents' choices of x).

Applying the envelope theorem from the agent's maximization problem and evaluating at $\theta = 0$ implies

$$\begin{aligned}
\frac{\partial V_i}{\partial \tau_{ij}^x} &= -x_{ij}\lambda_i \\
\frac{\partial V_i}{\partial \tau_{ij}^l} &= -l_{ij}\lambda_i \\
\frac{\partial V_i}{\partial T_i} &= -\lambda_i \\
\frac{\partial V_i}{\partial G_{ij}} &= \frac{\partial u_i}{\partial G_{ij}} \\
\frac{\partial V_i}{\partial E_i} &= \frac{\partial u_i}{\partial E_i}
\end{aligned}$$

Replacing terms, I have

$$\frac{dV_i}{d\theta}|_{\theta=0} = \lambda_i \left(\frac{d\hat{T}_i}{d\theta} + \sum_{j=1}^{J_G} \frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} \frac{d\hat{G}_{ij}}{d\theta} - \sum_{j=1}^{J_X} x_{ij} \frac{d\hat{\tau}_{ij}^x}{d\theta} - \sum_{j=1}^{J_L} l_{ij} \frac{d\hat{\tau}_{ij}^l}{d\theta} + \frac{\partial u_i}{\partial E_i} \frac{d\hat{E}_i}{d\theta} \right)$$

Now, I use equation 5 to replace the total transfers, $\frac{d\hat{T}_i}{d\theta}$, with the net government budgetary position, $\frac{d\hat{t}_i}{d\theta}$, which yields

$$\frac{dV_i}{d\theta}|_{\theta=0} = \lambda_i \left(\sum_{j=1}^{J_G} \left(\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G \right) \frac{d\hat{G}_{ij}}{d\theta} + \frac{d\hat{t}_i}{d\theta} + \frac{d}{d\theta} \left[R\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}, \hat{\mathbf{x}}_{\mathbf{i}}, \hat{\tau}_{\mathbf{i}}^{\mathbf{l}}, \hat{\mathbf{l}}_{\mathbf{i}} \right) \right] - \sum_{j=1}^{J_X} x_{ij} \frac{d\hat{\tau}_{ij}^x}{d\theta} - \sum_{j=1}^{J_L} l_{ij} \frac{d\hat{\tau}_{ij}^l}{d\theta} + \frac{\partial u_i}{\partial E_i} \frac{d\hat{E}_i}{d\theta} \right)$$

Finally, note that equation 6 shows I can replace the difference between the total revenue impact, $\frac{d}{d\theta} \left[R\left(\hat{\tau}_{\mathbf{i}}^{\mathbf{x}}, \hat{\mathbf{x}}_{\mathbf{i}}, \tau_{\mathbf{i}}^{\mathbf{l}}, \hat{\mathbf{l}}_{\mathbf{i}} \right) \right]$, and the mechanical revenue effect, $\sum_{j=1}^{J_X} x_{ij} \frac{d\hat{\tau}_{ij}^x}{d\theta} + \sum_{j=1}^{J_L} l_{ij} \frac{d\hat{\tau}_{ij}^l}{d\theta}$, with the behavioral impact of the policy on the government budget constraint, yielding

$$\frac{dV_i}{d\theta}|_{\theta=0} = \lambda_i \left(\sum_{j=1}^{J_G} \left(\frac{\frac{\partial u_i}{\partial G_{ij}}}{\lambda_i} - c_j^G \right) \frac{d\hat{G}_{ij}}{d\theta} + \frac{d\hat{t}_i}{d\theta} + \left(\sum_{j}^{J_X} \tau_{ij}^x \frac{d\hat{x}_{ij}}{d\theta} + \sum_{j}^{J_L} \tau_{ij}^l \frac{d\hat{l}_{ij}}{d\theta} \right) + \frac{\partial u_i}{\partial E_i} \frac{d\hat{E}_i}{d\theta} \right)$$

And, note that I can expand $\frac{d\hat{E}_i}{d\theta}$ by taking a total derivative of $E_i = f_i^E(\mathbf{x})$ across all goods and types, yielding

$$\frac{d\hat{E}_i}{d\theta} = \sum_i \sum_{j=1}^{J_X} \frac{\partial f_i^E}{\partial x_{ij}} \frac{d\hat{x}_{ij}}{d\theta}$$

which concludes the proof. $\square$

With externalities, I must know the net causal effect of behavioral response to the policy on the externality, $\frac{dE_i}{d\theta} = \left(\sum_j^{J_X} \frac{\partial f_i^E}{\partial x_{ij}} \frac{d\hat{x}_{ij}}{d\theta} \right)$, along with the the marginal willingness to pay for the externality, $\frac{\frac{\partial u_i}{\partial E_i}}{\lambda_i}$. Therefore, the welfare loss from a behavioral response that reduces government revenue may be counteracted by the welfare gain from any reduction on the externality imposed on other individuals.

Thus, financing government revenue using so-called "green taxes" that also reduce externalities may deliver higher government welfare than policies whose financing schemes do not reduce externalities.[74] This is the so-called "double-dividend" highlighted in previous literature (Bovenberg and de Mooji (1994); Goulder (1995); Parry (1995)). My results show that even in this world, the causal effect of the policy on behavior, i.e. the policy elasticity, continue to be the behavioral elasticities that are relevant for estimating welfare impact of the policy.

D Optimal Commodity Taxation and the "Inverse Elasticity" Rule

Ramsey (1927) proposes the question of how commodities should be taxed in order to raise a fixed government expenditure, $R > 0$. Diamond and Mirrlees (1971) provide a formal modeling of this environment and show that, at the optimum, the tax-weighted Hicksian price derivatives for each good are equated. Here, I illustrate this result and relate it to the framework provided in this paper.

Assume there is a representative agent and drop i subscripts. A necessary conditions for tax policy to be at an optimum is given by

$$\frac{d\hat{V}_P}{d\theta} = 0$$

for all feasible policy paths, P. With a representative agent, the optimal tax would be lump-sum of size R. However, the optimal commodity tax program proposed by Ramsey (1927) makes the assumption that the government cannot conduct lump-sum taxation. Hence, the only feasible policies are those that raise and lower tax rates in a manner that preserves the budget constraint.

Consider a policy, $P(\theta)$, that lowers the tax on good 1 and raises the tax on good 2. The optimality condition is given by

$$\sum_k \hat{\tau}_k \frac{d\hat{x}_k}{d\theta} = 0 \tag{19}$$

Equation (19) suggests more responsive goods should be taxed at lower rates, thereby nesting the standard "inverse elasticity" argument (higher $\frac{d\hat{x}_k}{d\theta}$ should be associated with lower $\hat{\tau}_k$). The optimal tax attempts to replicate lump-sum taxes by taxing relatively inelastic goods.

Diamond and Mirrlees (1971) further note that, because $\frac{d\hat{V}_P}{d\theta} = 0$ at the optimum, one can expand the behavioral change using the Hicksian demands, x_k^h,

$$\frac{dx_k}{d\theta} = \frac{\partial x_k^h}{\partial \tau_1}\frac{d\tau_1}{d\theta} + \frac{\partial x_k^h}{\partial \tau_2}\frac{d\tau_2}{d\theta}$$

where, in general, there would be the additional term, $\frac{\partial x_k^h}{\partial u}\frac{dV_p}{d\theta}$, but this vanishes at the optimum. Hence, that the optimality condition is given by

$$\sum_k \tau_k \frac{\partial x_k^h}{\partial \tau_1}\frac{d\tau_1}{d\theta} = \sum_k \tau_k \frac{\partial x_k^h}{\partial \tau_2}\left(-\frac{d\tau_2}{d\theta}\right) \tag{20}$$

[74] As is well-known (e.g. Salanie (2003)), if taxes are initially near their optimal levels, then at the margin it is not clear that an additional green tax will be any more desirable than a tax on any other good.

so that the tax-weighted Hicksian responses are equated across the tax rates – precisely the classic result in Diamond and Mirrlees (1971) (see equation 38).[75]

However, note that one never relied on compensated elasticities to test the optimality condition in equation (19). Compensated elasticities arise only because of the assumption that policy is at the optimum. One could consider any budget-neutral policy that simultaneously adjusts two commodity taxes and test equation (19) directly. Conditional on knowing the causal effects of such a policy, one would not need to know whether income or substitution effects drive the behavioral response to commodity taxes. The policy elasticities would be sufficient.

E Non-Marginal Welfare Analysis

Equivalent variation, $EV(\theta)$, of the policy at point θ from the initial point $\theta = 0$ is given by the implicit equation:

$$V(P, y + EV(\theta)) = \hat{V}(\theta)$$

where $V(P, y)$ is the utility obtained under policy P with non-labor income $y + EV(\theta)$. Differentiating yields:

$$EV'(\theta) = \frac{\frac{d\hat{V}(\theta)}{d\theta}}{\lambda(P, y + EV(\theta))} = \underbrace{\frac{\lambda\left(\hat{P}(\theta), y\right)}{\lambda(P, y + EV(\theta))}}_{\text{MU of Income Adjustment}} \underbrace{\frac{\frac{d\hat{V}}{d\theta}}{\lambda\left(\hat{P}(\theta), y\right)}}_{\text{Std Measure}}$$

where $\frac{\frac{d\hat{V}}{d\theta}}{\lambda\left(\hat{P}(\theta), y\right)}$ relies on the local causal effects of the policy at $P(\theta)$. Expanding yields:

$$EV(1) = \int_0^1 \frac{\lambda\left(\hat{P}(\theta), y\right)}{\lambda(P, y + EV(\theta))} \left[\left(\frac{\frac{\partial \hat{u}}{\partial G}}{\lambda\left(\hat{P}(\theta), y\right)} - c_G\right)\frac{d\hat{G}}{d\theta} + \frac{d\hat{t}}{d\theta} + \sum_j \hat{\tau}_j \frac{d\hat{x}_j}{d\theta}\right] d\theta$$

Conditions for Global = Local If two conditions are satisfied, global and local conditions are equivalent. Suppose that:

(a) the marginal utility of income does not vary for the policy relative to the income effects: $\lambda\left(\hat{P}(\theta), y\right) = \lambda(P, y + EV(\theta))$

(b) the causal effects are linear in θ (i.e. $\frac{d\hat{x}_j}{d\theta} = \hat{x}_j(1) - \hat{x}_j(0)$ and $\frac{d\hat{l}_j}{d\theta} = \hat{l}_j(1) - \hat{l}_j(0)$ for all θ.

Note that (a) is implied by quasilinear utility, but is far less restrictive. Also, (b) is commonly imposed in empirical applications. To derive the total equivalent variation for the policy, let $D_j = \int_0^1 \left(\frac{\frac{\partial \hat{u}}{\partial G_j}}{\lambda\left(\hat{P}(\theta), y\right)} - c_j^G\right) d\theta$ denote the average willingness to pay above cost for the publicly provided

[75] Under the additional assumption that compensated cross-price elasticities are zero, one arrives at the classic inverse elasticity rule:

$$\frac{\tau_2}{\tau_1} = \frac{\frac{\partial x_1^h}{\partial \tau_1} \frac{d\tau_1}{d\theta}}{\frac{\partial x_2^h}{\partial \tau_2} \frac{d\tau_2}{d\theta}}$$

so that optimal tax rates are inversely proportional to their compensated (Hicksian) demands.

goods. Then, if (a) and (b) hold, one can show that:

$$EV(1) = \underbrace{\sum_j \Delta\hat{G}_j * D_j}_{\text{Public Goods}} + \underbrace{\Delta\hat{t}}_{\text{Net Transfer}} + \underbrace{\sum_j \bar{\tau}_j^x \Delta\hat{x}_j + \sum_j \bar{\tau}_j^l \Delta\hat{l}_j}_{\text{Behavioral Reponse}}$$

where $\Delta\hat{G}_j = \hat{G}_j(1) - \hat{G}_j(0)$ is the change in publicly provided good j, $\Delta\hat{t}$is the change in net resources, and $\Delta\hat{x}_j = \hat{x}_j(1) - \hat{x}_j(0)$ is the difference in potential outcomes in policy world $\theta = 1$ relative to $\theta = 0$ (i.e. $\Delta\hat{x}_j$ is the **non-marginal** causal effect of the policy on $\hat{x}_j$).