Ramsey, Pigou, and a Consumption Externality

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Abstract

This paper analyzes the effects of consumption externalities on optimal taxation and on the social cost and optimal levels of public good provision. If public and private goods are Hicksian complements and no lump sum taxes are available, the second-best level of public good provision can exceed the first-best level. In contrast to economies without externalities, this result even holds for Cobb-Douglas economies with homogeneous agents. Heterogeneity of agents raises the second-best commodity tax rate due to equity considerations, but lowers the tax rate due to the concern for externality-correction.

Keywords and Phrases: consumption externality, public good provision, Ramsey rule, Pigou.

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1 Introduction

This paper addresses the effects of a consumption externality on optimal commodity taxation (many person Ramsey rule), the social cost of public good provision (Pigovian rule property), and the optimal level of public good provision (Pigovian level property). The paper is motivated by the recent literature on consumption externalities and happiness.

Consumption externalities have attracted the attention of economists for centuries. Many classical economists, for instance, assumed that the quest for status — a consumption externality — is an important component of the pursuit of self-interest (Kern, 2001).[1] More recently, a rapidly growing body of literature addresses the paradoxical development of income and happiness. While real per capita disposable income has substantially increased over the last fifty years, there is no trend in subjective well-being. The fact that raising income of all does not increase happiness of all (Easterlin 1995) can be explained by a consumption externality: the average income or consumption level represents a point of reference (Brekke and Howarth 2002, Frank 1985 and 1999). A number of survey experimental studies confirm this explanation. Solnik and Hemenway (1998, 2005) present questions involving two states of the world. Both states are identical, except for one characteristic, e.g., income. In state A, an individual has a given income level that is lower than the average (others') income level. In state B, an individual has a *lower* absolute income level that exceeds the average income level. Nearly half of the respondents prefer state B over state A, which indicates the importance of a consumption reference level. Similar evidence is provided by survey experimental studies of Johansson-Stenman et al. (2002, 2006).[2]

Consumption externalities have shed light on the analysis of happiness (Easterlin 1995, Frank 1985, Frank 1999, Scitovsky 1992), economic growth (Brekke and

[1]In *The Theory of Moral Sentiments*, Adam Smith notes: "Though it is in order to supply the necessities and conveniences of the body that the advantages of external fortune are originally recommended to us, yet we cannot live long in the world without perceiving that the respect of our equals, our credit and rank in the society we live in, depend very much upon the degree in which we possess, or are supposed to possess those advantages. The desire of becoming the proper objects of this respect ... is perhaps the strongest of all our desires." (Smith 1759, pp. 348–349)

[2]A number of further studies offer strong evidence of the existence of consumption externalities. Important contributions include Alpizar et al. (2005), Carlsson et al. (2007), Ferrer-i-Carbonell (2005), Luttmer (2005), McBride (2001), and Neumark et al. (1998).

Howarth 2002, Carroll *et al.* 1997, Liu and Turnovsky 2005), asset pricing (Abel 1999, Campbell and Cochrane 1999, Dupor and Liu 2003), optimal tax policy over the business cycle (Ljungqvist and Uhlig 2000), optimal redistributive taxation (Aronsson and Johansson-Stenman forthcoming, Boskin and Sheshinski 1978, Layard 1980), and the excess burden (Wendner and Goulder 2008). Yet consumption externalities also have important implications for the optimal provision of public goods. Although other authors have raised this point[3], I know of no prior study that rigorously analyzes how consumption externalities influence the optimal first-best and second-best *levels* of public good provision. This is the focus of the present paper. I develop a theoretical model to examine a generalized Ramsey rule and optimal rules *and levels* of public good provision in the presence of a consumption externality.

In the prior literature, it has been argued that the second-best level of public good provision is lower than the first-best level as long as the government's expenditures are financed by distortionary taxes, as suggested by Pigou (1947). This argument, however, is not always true. First, the fact that — under distortionary taxation — the social cost of public good provision may exceed the private cost does not necessarily imply that the second-best *level* of public good provision is lower than the first-best level. Second, an extensive literature argues that distortionary taxation need not inevitably raise the social cost of public good provision for a variety of reasons. Distortionary taxation may have desirable consequences for the income distribution (see e.g., King 1986, Batina 1990b, Gaube 2000). Next, if the private and public goods are Hicksian complements, an increase in the provision of the public good raises demand for the private good and thereby commodity tax revenue, which lowers the social cost of public good provision (Diamond and Mirrlees 1971, Atkinson and Stern 1974, King 1986, Batina 1990b). Furthermore, in a dynamic framework, distortionary taxation may improve the dynamic efficiency of the economy (Batina 1990a).[4] All of these effects lower the social marginal cost of a public good, which, in turn, potentially gives rise to a higher level of public good provision in the second-best optimum than

[3]See Aronsson and Johansson-Stenman 2008, Wendner and Goulder 2008.

[4]Further important contributions to the discussion on the social cost and optimal levels of public goods include Chang (2000), Gaube (2005), Ng (1987), Stiglitz and Dasgupta (1971), Wildasin (1984), Wilson (1991a, 1991b).

in the first-best optimum.

This paper contributes to the prior literature in that it identifies consumption externalities as a further source for "Pigovian level reversal." That is, in the presence of a negative consumption externality, the second-best level of public good provision may be larger than the first-best level. To gain intuition, suppose lump-sum taxes or transfers are not available to the public sector. If the revenue raised by applying the first-best commodity tax rate exceeds the funds required to finance the first-best level of the public good, the second-best commodity tax rate is lower than the first-best rate. In this situation, a marginal increase of the commodity tax (in public good provision) lowers the distortion introduced by the negative consumption externality. As a result, the second-best level of public good provision exceeds the first-best level.[5]

This paper also illustrates the possibility of "Pigovian level reversal" by an economy populated with homogeneous agents with Cobb-Douglas preferences. For such an economy without consumption externalities, Wilson (1991a) demonstrates that the second-best level of public good provision is always lower than the first-best level. In the presence of a negative consumption externality, however, the paper shows that the second-best level of public good provision can exceed the first-best level.

In addition, the paper contributes to the prior literature in that it presents a generalized Ramsey rule. The Ramsey rule reveals that a consumption externality interacts with heterogeneity of agents in a nontrivial and interesting way. Suppose, in addition to a commodity tax, only a poll tax is available to the public sector. For reasons of equity (high consumption agents should be discouraged), heterogeneity tends to increase the optimal commodity tax rate. In the presence of a negative consumption externality, low consumption agents — who respond the most to transfers received — contribute the most to the negative externality at the margin. For this reason, heterogeneity tends to lower the optimal commodity tax rate (thereby transfers paid) due to the externality. That is, if agents are heterogeneous, distributional considerations and externality effects — in connection with heterogeneity — represent a tradeoff between equity and efficiency.

[5]A related argument is offered by Wendner and Goulder (2008). They show, in a more specialized framework, that the second-best level of public good provision exceeds the first-best level if and only if the marginal excess burden of a rise in the commodity tax rate is negative.

Section 2 of this paper presents the economy's private and public sectors, introduces the consumption externality, and discusses the government's instruments under several (second-best) restrictions. Section 3 develops a generalized many person Ramsey rule. Section 4 analyzes the effects of consumption externalities on the social cost and optimal levels of public good provision. Section 5 presents an example of "Pigovian level reversal" for an economy with homogeneous agents. Section 6 discusses the results and concludes the paper. The appendix contains proofs and mathematical results that support the analysis of the main text.

2 The Economy

We consider an economy with a continuum of agents $i \in I \equiv [0,1]$ with the distribution function $F(i)$. Agents may differ with respect to preferences or income. The aim of allowing for such differences is to motivate the inclusion of consumption externalities *based on the economy's mean level of consumption.*

2.1 The Private Sector

We extend King's (1986) framework by introducing a consumption externality. An agent has preferences over a consumption good, x, leisure, l, a pure public good, g, and a consumption reference level, $\bar{x}$, that is considered to be exogenous by an individual agent:[6]

$$u = u(i, x, l, g, \bar{x})\,. \tag{1}$$

An agent's indirect utility function is given by:

$$v = v(i, q, g, y, \bar{x})\,, \tag{2}$$

where q is the consumer price of the consumption good, and y is the agent's full income (i.e., the value of labor endowment).[7] Equation (2) defines the maximum level of utility that an agent can obtain, given the price of the consumption good, full income, the level of public good provision, *and* the consumption reference level.

[6]The framework can easily be extended to any number of consumption goods. The results presented below are not affected by consideration of many consumption goods.

[7]We choose l to represent the numeraire good and set the wage rate equal to unity.

The consumption reference level is given by the mean consumption level:[8]

$$\bar{x} = \int_{i \in I} x(i)\, \mathrm{d}F(i)\,. \tag{3}$$

It gives rise to a consumption externality. The consumption reference level, $\bar{x}$, may capture, for example, preferences related to conspicuous consumption or to a positive network externality. We characterize consumption externalities according to the impact of the consumption reference level on indirect utility:

Definition 1 *A consumption externality is said to be negative if* $v_{\bar{x}}(i, q, g, y, \bar{x}) < 0$*. A consumption externality is said to be positive if* $v_{\bar{x}}(i, q, g, y, \bar{x}) > 0$*.*

This definition leads us to:

Lemma 1 *Let* $\mu(i)$ *be agent* i*'s marginal rate of substitution of* x *for* l*. Suppose* $u(.)$ *is strictly quasiconcave in* (x, l)*. Then, individual consumption is related to the consumption reference level as follows:* $x_{\bar{x}}(i) \gtreqless 0 \Leftrightarrow \mu_{\bar{x}}(i) \gtreqless 0$*.*

Proof. See appendix. ||

Consider the canonical example of a negative consumption externality: keeping up with the Joneses preferences. A keeping up with the Joneses externality is defined by: $u_{x\bar{x}} > 0$ (see Dupor and Liu 2003). In this case, the consumption reference level, $\bar{x}$, raises the marginal utility of individual consumption. That is, for given (q, g, y), optimal individual consumption rises in $\bar{x}$. As one's consumption is subject to the keeping up with the Joneses externality, an additional unit of consumption not only satisfies one's direct benefit of consumption but also one's indirect benefit of keeping up with (or being better than) the Joneses. Consequently, an agent is willing to give up more units of leisure for an additional unit of consumption in the presence of a keeping up with the Joneses externality.

It is important to emphasize that a negative consumption externality does not generally imply $x_{\bar{x}} > 0$, and a positive consumption externality does not generally imply $x_{\bar{x}} < 0$. Consider, for example, a positive network externality (a high mean level of cell phone users in a given country). In this situation, the marginal rate of

[8] A bar is used to denote the mean level of a variable throughout. Subscripts are used to denote partial derivatives with respect to the subscripted variable(s).

substitution of consumption for leisure rises in $\bar{x}$, which, by Lemma 1, implies $x_{\bar{x}} > 0$. Similarly, in case of a negative congestion externality (e.g., a high mean level of car users in a given road network), $\bar{x}$, lowers the marginal utility of consumption for leisure. By Lemma 1, $x_{\bar{x}} < 0$. These examples suggest that a positive consumption externality is associated with $x_{\bar{x}} > 0$, while a negative consumption externality is associated with $x_{\bar{x}} < 0$. But a keeping up with the Joneses externality represents a prominent exception to this rule.

For a given level of utility, $\bar{v}$, the willingness to pay for a marginal unit of g is given by:

$$\omega(i, q, g, y, \bar{x}) \equiv -\frac{d\, y}{d\, g}|_{\bar{v}} = \frac{v_g(i, q, g, y, \bar{x})}{v_y(i, q, g, y, \bar{x})}\,,$$

where the latter term follows from differentiating the equation $v(.) = \bar{v}$ with respect to g.

We define an agent's money metric utility (equivalent income), $y_e(i)$, as the level of income which — at the reference values (q^R, g^R, $\bar{x}^R$) — yields the same level of utility as can be attained under $(q, g, \bar{x})$:

$$y_e(i) \equiv e(i, q^R, g^R, \bar{x}^R, v) = f(i, q^R, g^R, \bar{x}^R, q, g, y, \bar{x})\,, \tag{4}$$

where $f(.)$ is itself an indirect utility function for the agent under consideration. Following King (1986), we will employ $f(.)$ in the social welfare function below. Considering conditional demand of the consumption good and the willingness to pay, Roy's identities — for given $\bar{x}$ — yield:

$$x(i, q, g, y, \bar{x}) = -\frac{\partial\, v(.)/\partial\, q}{\partial\, v(.)/\partial\, y} = -\frac{\partial\, f(.)/\partial\, q}{\partial\, f(.)/\partial\, y}\,, \tag{5}$$

$$\omega(i, q, g, y, \bar{x}) = \frac{\partial\, v(.)/\partial\, g}{\partial\, v(.)/\partial\, y} = \frac{\partial\, f(.)/\partial\, g}{\partial\, f(.)/\partial\, y}\,. \tag{6}$$

Compensated demand (indexed by superscript c) is given by:

$$x^c(i, q, g, v, \bar{x}) = \frac{\partial\, e(.)}{\partial\, q}\,, \quad \omega^c(i, q, g, v, \bar{x}) = -\frac{\partial\, e(.)}{\partial\, g}\,. \tag{7}$$

We finally state the Slutsky equations (again for given $\bar{x}$):

$$s_{xx}(i) \equiv \frac{\partial\, x^c(.)}{\partial\, q} = \frac{\partial\, x(.)}{\partial\, q} + \frac{\partial\, x(.)}{\partial\, y}\, x(.)\,, \quad s_{xg}(i) \equiv \frac{\partial\, x^c(.)}{\partial\, g} = \frac{\partial\, x(.)}{\partial\, g} - \frac{\partial\, x(.)}{\partial\, y}\, \omega(.)\,. \tag{8}$$

While the own price effect of the private good is negative, the sign of the other Slutsky term is indeterminate. In the following, we assume x to be weakly normal: $\partial x/\partial y \geq 0$. In this case, if the private and public goods are Marshallian substitutes then they are Hicksian substitutes, $s_{xg}(i) < 0$. Moreover, (8) shows that Hicksian complementarity implies Marshallian complementarity. Young's theorem implies: $s_{xg}(i) = \partial^2 e(.)/[\partial q\, \partial g] = \partial^2 e(.)/[\partial g\, \partial q] = -\partial \omega^c/\partial q$. That is, Hicksian substitutability (complementarity) between x and g implies that the compensated willingness to pay for the public good rises (declines) in q.

2.2 The Public Sector

An individual agent considers the consumption reference level, $\bar{x}$, as given. The government, however, takes the impact of its policy instruments on the consumption reference level into account.

Before discussing the instruments of the public sector, a technical note of the effects of changes in $z \in \{y, q, g\}$ on the consumption reference level suggests itself. Let $\tilde{x}_z \equiv \int_{i\in I} \partial x(i, q, y, g, \bar{x})/\partial z \, \mathrm{d}F(i)$ denote the aggregate impact of a rise in all agents' $z \in \{y, q, g\}$ by a marginal unit on average consumption — *for a given level of* $\bar{x}$. That is, $\tilde{x}_z$ does *not* capture the effect of a change in $\bar{x}$.[9] Next, let $\eta \equiv \int_{i\in I} x_{\bar{x}}(i, q, g, y, \bar{x})\, \mathrm{d}F(i)$ capture the aggregate impact (via the consumption externality) of a change in the consumption reference level on consumption demand. Then:[10]

$$\bar{x}_z \equiv \frac{\mathrm{d}\bar{x}}{\mathrm{d}z} = \frac{\tilde{x}_z}{1-\eta}\,, \qquad \eta < 1\,. \tag{9}$$

Derivative (9) shows the effect of a rise in $z \in \{y, q, g\}$ on the consumption reference level. In the presence of a consumption externality, all agents respond to the change in the consumption reference level. This "indirect" effect is accounted for by the term $(1-\eta)^{-1}$. The regularity condition, $\eta < 1$, ensures that the indirect effect does not dominate the direct effect of the change in z.

Remark. A consumption externality may but need not imply that $\eta \neq 0$. Consider utility function (1). If (x, l) is weakly separable from $\bar{x}$, then $x_{\bar{x}} = 0$, according

[9] Throughout the paper, a tilde indicates the aggregate (average) change of a variable — for a given value of $\bar{x}$ (that is, not accounting for the externality effect via the change in $\bar{x}$).

[10] From (3) define: $G(i, \bar{x}, q, g, y) \equiv \bar{x} - \int_{i\in I} x(i, q, g, y, \bar{x})\, \mathrm{d}F(i) = 0$. If $\partial G/\partial \bar{x} \neq 0$, $G(i, \bar{x}, q, g, y)$ defines an implicit function in $\bar{x}$, and: $(\mathrm{d}\bar{x})/(\mathrm{d}z) = -(\partial G/\partial z)/(\partial G/\partial \bar{x})$.

to Lemma 1. Hence, $\eta = 0$ in spite of the consumption externality. That is, a consumption externality implies $v_{\bar{x}} \neq 0$, but it does *not* generally imply: $\eta \neq 0$. In any case, $\tilde{x}_z = \bar{x}_z\,(1-\eta)$.

The public sector. The public sector controls the following instruments: a commodity tax $\tau = q - p$, the level of a public good, g, and lump sum taxes (transfers), $t(i) > 0$ ($t(i) < 0$), where p represents the constant marginal production cost of x. Per capita revenue, r, is given by: $r = t + \tau\,\bar{x}$, where $t = \int_{i \in I} t(i)\,\mathrm{d}\,F(i)$. We assume a constant average production cost of the public good, c. The government budget constraint is given by:

$$r = c\,g\,. \tag{10}$$

The government chooses its instruments such as to maximize an additively separable social welfare function, defined over individual levels of equivalent income:

$$SW = \int_{i \in I} W(y_e(i))\,\mathrm{d}F(i)\,, \tag{11}$$

where $W(.)$ is concave and increasing in $y_e(i)$. The concavity of $W(.)$ describes the degree of aversion to inequality in money metric utility levels, $y_e(i)$.

Taking into consideration (3), the government's Lagrangian becomes:

$$\mathcal{L} = \int_{i \in I} W(y_e(i))\,\mathrm{d}F(i) + \lambda \left[\int_{i \in I} t(i)\,\mathrm{d}F(i) + \tau \int_{i \in I} x(i)\,\mathrm{d}F(i) - c\,g \right]\,, \tag{12}$$

where the Lagrange multiplier measures the social evaluation of an additional unit of government revenues. In the *first-best optimum*, the government chooses $(\tau, g, t(i))$ such as to maximize (12). In the *second-best optimum*, the government faces one of the following three constraints:

$$t(i) = t\,, \tag{C1}$$

$$t(i) = t \leq 0\,, \tag{C2}$$

$$t(i) = t = 0\,. \tag{C3}$$

All constraints prevent the government from introducing *personalized* lump sum taxes (transfers). A poll tax is available, however, under constraint C1. In addition, constraint C2 restrains the government from imposing lump-sum *taxes* on agents. Finally, constraint C3 precludes the government from imposing any lump-sum taxes or transfers.

We now derive the necessary first-order conditions for the (first-best) optimal levels of the government's instruments. We use (9) together with the facts that $\partial f/\partial q = \partial f/\partial \tau$, and $\partial f/\partial t = -\partial f/\partial y$.

$$\int_{i\in I} W(i)' \left[f_q(i) + f_{\bar{x}}(i)\,\bar{x}_q\right] \mathrm{d}F(i) + \lambda\left[\bar{x} + \tau\,\tilde{x}_q + \tau\,\eta\,\bar{x}_q\right] = 0\,, \tag{13}$$

$$\int_{i\in I} W(i)' \left[f_g(i) + f_{\bar{x}}(i)\,\bar{x}_g\right] \mathrm{d}F(i) + \lambda\left[-c + \tau\,\tilde{x}_g + \tau\,\eta\,\bar{x}_g\right] = 0\,, \tag{14}$$

$$\int_{i\in I} W(i)' \left[f_y(i) + f_{\bar{x}}(i)\,\bar{x}_y\right] \mathrm{d}F(i) + \lambda\left[-1 + \tau\,\tilde{x}_y + \tau\,\eta\,\bar{x}_y\right] = 0\,. \tag{15}$$

In the first-best optimum, a rise in agent i's transfer implies:

$$W'(i)\,f_y(i) + \int_{j\in I} W'(j)\,f_{\bar{x}}(j)\,\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,\mathrm{d}F(j) \;+ \lambda\left[-1 + \tau\,x_y(i)|_{\bar{x}} + \tau\,\eta\,\frac{x_y(i)|_{\bar{x}}}{1-\eta}\right] = 0\,, \tag{16}$$

which follows from $\mathrm{d}\mathcal{L}/\mathrm{d}t(i) = 0$, division by the density of i, and (9).[11] Equations (13) to (16) hold in a first-best optimum. In a second-best optimum, (13) and (14) are generally satisfied. Under all constraints, (16) does not hold (no individualized lump sum taxes or transfers are available). In addition, under constraint C2, first order condition (15) holds as a weak inequality ($\leq$). Under constraint C3, (15) is not applicable.

By defining both the *net social marginal utility of income*, $b(i)$, and an *externality term*, ϵ, we can conveniently derive the Ramsey- and Pigou rules:

$$b(i) = \frac{W'(i)}{\lambda}\,f_y(i) + \tau\,\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,, \tag{17}$$

$$\bar{b} \equiv \int_{i\in I} b(i)\mathrm{d}F(i) = \int_{i\in I} \frac{W'(i)}{\lambda}\,f_y(i)\mathrm{d}F(i) + \tau\,\bar{x}_y\,. \tag{18}$$

In (17), the first term on the right hand side shows the social evaluation of the change in agent i's utility due to a transfer of \$1. The second term on the right hand side shows the change in commodity tax payments to the government. The mean level of the net social marginal utility of income is given by $\bar{b}$.

[11] The term $x_y(i)|_{\bar{x}}/(1-\eta)$ reflects the change in the consumption reference level when (only) agent i's lump sum transfer is marginally increased. From (3), the implicit function rule yields: $d\,\bar{x}/[d\,y(i)] = x_y(i)|_{\bar{x}}/(1-\eta)$.

The externality term is given by:

$$\epsilon \equiv \int_{i\in I} \frac{W'(i)}{\lambda}\, f_{\bar{x}}(i)\,\mathrm{d}F(i)\,. \tag{19}$$

Without an externality, $\epsilon = 0$. According to Definition 1, $\epsilon < 0$ ($\epsilon > 0$) in the presence of a negative (positive) consumption externality.

By employing $\bar{b}$ and ϵ, first order condition (15) yields:

$$\bar{b} = 1 - \epsilon\,\bar{x}_y\,. \tag{20}$$

The (mean) net social marginal utility of income can be interpreted as the *marginal* benefit to cost ratio of increasing a uniform lump sum transfer by a marginal unit. In the presence of a negative consumption externality, this ratio exceeds unity. With the marginal benefit declining in income, the negative consumption externality *lowers* the (first-best) level of the lump sum transfer. Intuitively, in the presence of a negative consumption externality, raising the transfer incurs an additional cost to all agents in terms of a rise in the consumption reference level.

In a second-best optimum, when t is restricted to be non-positive, $\bar{b}^{**} \leq \bar{b}^{*}$.[12] Starting from $t = 0$, raising the lump sum transfer by a marginal unit would raise the mean marginal benefit by less than cost. The second-best restriction ($t \leq 0$), if binding, forces the government to set $t = 0$. Thereby, the net social marginal utility of income is lower in a second-best- than a first-best optimum.

3 Ramsey Rule

Let ϕ_{mn} denote the covariance between variables $m(i)$ and $n(i)$.[13] As shown in the appendix, first order condition (13) yields the generalized many person Ramsey rule:

$$\frac{-(\epsilon+\tau)\,\bar{s}_{xx}}{(1-\eta)\,\bar{x}} = \left[1 - \bar{b} - \epsilon\,\bar{x}_y\right] - \frac{\phi_{bx}}{\bar{x}} - \epsilon\,\phi_{x_y x}\,, \tag{21}$$

where $\bar{s}_{xx} \equiv \int_{i\in I} s_{xx}(i)\,\mathrm{d}F(i)$, and $\phi_{x_y x} \equiv \mathrm{Cov}\left(\frac{x_y(i)|_{\bar{x}}}{1-\eta}, \frac{x(i)}{\bar{x}}\right)$. The approximate proportionate change in compensated demand of the consumption good depends on $\bar{b}$, the covariances ϕ_{bx}, $\phi_{x_y x}$, and the externality. We will interpret the covariance term

[12] In what follows, an asterisk refers (two asterisks refer) to the first-best (second-best) allocation.

[13] E.g., $\phi_{bx} \equiv \mathrm{Cov}\,(b(i), x(i)) = \int_{i\in I} (b(i) - b)(x(i) - \bar{x})\,\mathrm{d}F(i) = \int_{i\in I} b(i)\,x(i)\,\mathrm{d}F(i) - \bar{b}\,\bar{x}$.

$\phi_{bx}/\bar{x}$ as concern for equity and the term $\epsilon\,\phi_{x_y x}$ as concern for externality-correction (as related to the heterogeneity of agents).

Lemma 2 *In a first-best optimum,* $\tau^* = -\epsilon$.

Proof. See appendix. ‖

The first-best (Pigovian) tax rate, τ^*, equals the negative of the externality term. That is, $\tau^* > 0$ ($\tau^* < 0$) in the presence of a negative (positive) consumption externality. Ramsey rule (21) reveals two important results, one for the case of homogeneous agents and the other for the case of heterogeneous agents.

Proposition 1 (Homogeneous Agents) *Consider a negative consumption externality* ($\epsilon < 0$)*.*
(i) Under constraint C2: If $t^* \leq 0$ *then* $\tau^{**} = \tau^* = -\epsilon$ *and* $t^{**} = t^* \leq 0$*. If* $t^* > 0$ *then* $\tau^{**} > \tau^*$ *and* $t^{**} = 0$*.*
(ii) Under constraint C3: If $t^* < 0$ ($t^* > 0$) *then* $\tau^{**} < \tau^*$ ($\tau^{**} > \tau^*$)*. If* $t^* = 0$ *then* $\tau^{**} = \tau^*$*.*

Proof. See appendix. ‖

In Proposition 1, the sign of t^* is exogenous. The sign clearly depends on both the revenue requirement for financing the optimal level of the public good and the revenue earned from applying the (corrective) first-best tax rate on consumption.[14] Statement (i) shows that, as long as the second-best constraint C2 is not binding — that is, as long as the optimal lump sum tax is negative — first-best and second-best optima coincide. If the revenue earned from applying the (corrective) first-best tax rate on consumption exceeds the revenue requirement for financing the optimal level of the public good, the excess revenue is rebated to all agents as a lump sum transfer. Once, however, the constraint becomes binding, first order condition (15) — equivalently (20) — holds as a strong inequality (<), implying that a rise in the lump sum tax in order to increase government revenues would be welfare improving. In the second-best optimum, no lump sum *tax* can be introduced. Instead, the tax on consumption good x is raised beyond its first-best rate.

[14] To determine the sign of t^*, we also need the Pigovian rule, which is derived below.

Statement (ii) considers a constraint in addition to C2: no lump sum transfers are available. If this constraint binds, first order condition (15) holds as a strong inequality (>), implying that a rise in the lump sum *transfer* would be welfare improving, as the "corrective revenue" exceeds the revenue requirement for financing the public good. As no lump sum *transfers* can be introduced, the tax on the consumption good is reduced to a rate below its first-best rate.

A corollary of Proposition 1 concerns the case of a positive consumption externality. If $\epsilon > 0$, $\tau^* < 0$, according to Lemma 2. Consequently, $t^* > 0$. In this case, both constraints C2 and C3 are binding, and $\tau^{**} > 0 > \tau^*$.

In the following, we consider heterogeneous agents. If the social marginal utility of income is decreasing in income and the consumption level is increasing in income, covariance ϕ_{bx} will be negative. This is the main case considered below.

Proposition 2 (Heterogeneous Agents) *Suppose $\phi_{bx} < 0$. Consider constraint C1, and a negative consumption externality.*
If $\phi_{x_y x} < 0$, heterogeneity raises the second-best commodity tax rate due to the concern for equity, while heterogeneity lowers the second-best commodity tax rate due to the concern for externality-correction.

Proof. Under constraint C1 a poll tax is available, thus, first order condition (20) holds as equality. Ramsey rule (21) becomes:

$$\frac{-(\epsilon + \tau)\, \bar{s}_{xx}}{(1 - \eta)\, \bar{x}} = -\frac{\phi_{bx}}{\bar{x}} - \epsilon\, \phi_{x_y x}\,. \tag{21'}$$

In the presence of a negative consumption externality, $\epsilon < 0$. ||

The proposition considers the case in which $\phi_{bx} < 0$. The more consumption is concentrated among high income agents (with a low social evaluation), the higher is the optimal reduction in compensated demand due to the introduction of the commodity tax. High income agents pay an above average share of the commodity tax revenue that is *uniformly* redistributed among *all* agents, benefiting agents with a high social evaluation the most. Thus, the concern for equity raises τ beyond its first-best level.

If $\phi_{x_y x} < 0$, the agents with the lowest consumption (income) levels respond the most to an increase in transfers. That is, the marginal contribution to the consumption externality is the largest for agents with the lowest income levels. A rise of the commodity tax rate beyond its first-best level — e.g., for equity reasons — raises the poll transfer (or lowers the poll tax). The commodity tax is paid mainly by high-income agents, but the transfers are proportionally received by all agents. Thus, a rise of the commodity tax rate generates a redistribution towards low-income agents, whose marginal contribution to the negative consumption externality is the strongest. For this reason, the concern for externality-correction lowers the second-best commodity tax rate.

The concerns for equity and externality-correction reveal a heterogeneity-related equity-efficiency tradeoff. A marginal increase in the commodity tax rate (beyond its first-best level) advances equity via redistribution. However, just because of redistribution towards low-income agents, the marginal rise in the commodity tax rate induces agents to raise consumption, thereby extending the consumption reference level beyond its optimal level. The second-best level of the commodity tax rate exceeds the first-best level only if the concern for equity is stronger than the concern for externality-correction. It is an empirical matter, whether or not this is the case.

We conclude this section with three brief remarks. First, if $\phi_{x_y x} > 0$, the concerns for equity and externality-correction reenforce each other. This seems to be an unlikely case, however, as it requires high-income agents to respond the strongest to a marginal rise in transfers. Second, if one of the constraints C2 or C3 bind in addition to C1, the second-best effects discussed in relation to Proposition 1 apply in addition to the second-best effects discussed in relation to Proposition 2. Third, in case of a positive consumption externality, the role of $\phi_{x_y x}$ is reversed. If $\phi_{x_y x} < 0$, both concerns contribute to raising the second-best commodity tax rate.

4 Pigovian Rule and Pigovian Level Property

The first order condition for the public good provision (14), combined with Roy's identity (6) and the Slutsky equation for the public good (8), yields the generalized many person Pigovian rule (the derivation is shown in the appendix):

$$\frac{(\epsilon + \tau)\, \bar{s}_{xg}}{(1-\eta)\, \bar{\omega}} = \left[\frac{c}{\bar{\omega}} - \bar{b} - \epsilon\, \bar{x}_y \right] - \frac{\phi_{b\omega}}{\bar{\omega}} - \epsilon\, \phi_{x_y \omega}\,, \tag{22}$$

where $\bar{s}_{xg} \equiv \int_{i\in I} s_{xg}(i)\,\mathrm{d}F(i)$, and $\phi_{b\omega} \equiv \mathrm{Cov}(b(i), \omega(i))$, $\omega_{x_y\omega} \equiv \mathrm{Cov}\left(\frac{x_y(i)|_{\bar{x}}}{1-\eta}, \frac{\omega(i)}{\bar{\omega}}\right)$. The Slutsky term $\bar{s}_{xg}$ is positive (negative) if the private and public goods are Hicksian complements (substitutes). The left hand side of the Pigovian rule represents the (negative of the) approximate proportionate change in the compensated willingness to pay due to the implementation of the commodity tax (see (7)). It is negatively related with ϕ_{bx}, and — in the presence of a negative consumption externality — positively related with $\phi_{x_y\omega}$.

If the willingness to pay rises in income, while the social valuation declines in income, $\phi_{b\omega} < 0$. In this case, the introduction of the public good raises social inequality, as those agents with the lowest social evaluation have the highest willingness to pay. As the Slutsky term (left hand side of (22)) rises in the covariance, $\bar{\omega}_q(.)$ declines in $\phi_{b\omega}$ (that is, the willingness becomes more negative or less positive). This effect tends to be associated with a lower optimal level of public good provision.

Similarly, $\phi_{x_y\omega} < 0$ lowers the social cost of public good provision, in case of a negative consumption externality. The argument parallels the one given in relation to Proposition 2. Agents with the lowest willingness to pay (income) respond the most to a reduction in transfers. The implementation of the commodity tax induces a redistribution from high-income to low-income agents, as argued above. However, a marginal rise in public good provision — by lowering lump sum transfers — reduces the extent of this redistribution. The induced marginal reduction in (externality generating) consumption is larger for low-income than for high-income agents, implying a decline in the consumption reference level. Resources are shifted from the private sector (that is subject to the consumption externality) to the public sector, which lowers the social cost of public good provision.

Combining (22) with the Ramsey rule (21) yields an expression relating the willingness to pay to the *social* cost of providing the public good:

$$\int_{i\in I} \omega(i)\,\mathrm{d}F(i) = c - \frac{(\epsilon+\tau)\,\bar{\omega}}{1-\eta}\,\left[\frac{\bar{s}_{xx}}{\bar{x}} + \frac{\bar{s}_{xg}}{\bar{\omega}}\right] + H\,, \tag{23}$$
$$\text{with } H \equiv \bar{\omega}\,\left[\left(\frac{\phi_{bx}}{\bar{x}} - \frac{\phi_{b\omega}}{\bar{\omega}}\right) + \epsilon\,(\phi_{x_y x} - \phi_{x_y\omega})\right]\,,$$

where c represents the private cost of public good provision. The term $-(\epsilon+\tau)\,\bar{\omega}\,\bar{s}_{xx}/[(1-\eta)\,\bar{x}]$ represents the Pigou effect. It shows the indirect cost of financing the public good in the absence of nondistortionary means of taxation. The term $-(\epsilon+\tau)\,\bar{\omega}\,\bar{s}_{xg}/[(1-\eta)\,\bar{\omega}]$ captures the compensated Diamond-Mirrlees provision effect. If the private and public goods are Hicksian complements, an increase in the provision of the public good raises demand for the private good, and thereby commodity tax revenue. In case of Hicksian complementarity, the provision effect lowers the social cost of public good provision.[15] The term H accounts for heterogeneity of agents.

Lemma 3 *In the first-best optimum,* $\int_{i\in I}\omega^*(i)\,\mathrm{d}F(i)=c$.

Proof. See appendix. ‖

The lemma shows the Samuelson rule, according to which the "sum" of the marginal rates of substitution of g for l equals the marginal rate of transformation between those goods.

In the following, we discuss Pigovian rule- and level properties in the presence of consumption externalities. To sharpen results, we focus on the case of homogeneous agents: $H=0$.

Definition 2

The Pigovian rule property is said to hold if $\int_{i\in I}\omega^{**}(i)\mathrm{d}F(i) > \int_{i\in I}\omega^{*}(i)\mathrm{d}F(i)$.

The Pigovian level property is said to hold if $g^{**}<g^*$.

The definition of the Pigovian rule property implies that the social cost of public good provision in the second-best exceeds the social cost in the first-best. It is important to recognize that it is mistaken to assume that a higher social cost of public good provision (in the second-best as compared to the first-best) generally lowers the optimal *level* of public good provision. That is, the Pigovian rule property does not generally imply the Pigovian level property. As demonstrated by Chang (2000), the linkage between the social cost of public good provision and its optimal level critically depends on the Hicksian complementarity (substitutability) between the public and private good.

[15] Hicksian complementarity and normality of private consumption imply Marshallian complementarity between x and g. Bradford and Hildebrandt (1977) argue that such complementarities exist between, e.g., air safety and air travel, traffic network and private cars, lighthouses and private boating, public tennis courts and tennis rackets, or national defense and ownership of private property.

We define $\hat{s}_{xg} \equiv -\bar{s}_{xx}\,\bar{\omega}/\bar{x} > 0$. In (23), if $\bar{s}_{xg} < \hat{s}_{xg}$, the term in square brackets is negative (dominated by the Pigou effect). If if $\bar{s}_{xg} > \hat{s}_{xg}$, there is strong Hicksian complementarity between the public and private good, and the term in square brackets is positive (dominated by the provision effect). If $\bar{s}_{xg} = \hat{s}_{xg}$ the provision effect counterbalances the Pigou effect, and the term in square brackets equals zero.

Proposition 3 *Suppose $H = 0$. The Pigovian rule holds in the following two cases:*
(i) $\bar{s}_{xg} < \hat{s}_{xg}$ and $\tau^{**} + \epsilon > 0$,
(ii) $\bar{s}_{xg} > \hat{s}_{xg}$ and $\tau^{**} + \epsilon < 0$.

The proposition follows directly from (23). In case (i), the public and private goods are either Hicksian substitutes or Hicksian complements with $\bar{s}_{xg} < \hat{s}_{xg}$. If they are Hicksian substitutes, the provision effect adds to the social cost of public good provision. A marginal increase in public good provision lowers the compensated demand for the private good — thereby it lowers the commodity tax revenue. If the private and public goods are Hicksian complements (with $\bar{s}_{xg} < \hat{s}_{xg}$), the provision effect lowers the social cost of public good provision, but it is dominated by the Pigou effect that raises the social cost. Case (i) is restricted to $\tau^{**} + \epsilon > 0$. According to Proposition 1, $\tau^{**} + \epsilon > 0$ holds under both second-best restrictions C2 and C3 when $t^* > 0$. That is, the first-best, corrective commodity tax revenue is lower than the revenue required to finance the optimal level of the public good. Therefore $\tau^{**} > \tau^* = -\epsilon$ introduces a distortion whose social cost is not fully compensated for by the provision effect.

In case (ii), $\tau^{**} < \tau^*$, which can only occur under second-best restriction C3 when $t^* < 0$. In this case, a marginal increase of the commodity tax lowers the distortion created by the consumption externality. That is, the Pigou effect *lowers* the social cost of public good provision. As $\tau^{**} < \tau^*$, the provision effect is negative — compared to the first-best optimum, the commodity tax rate is lowered. That is, the provision effect raises the social cost of public good provision. As Hicksian complementarity between the private and public goods is strong enough so that the provision effect dominates the Pigou effect, the social cost of public good provision exceeds the private cost. Case (ii) is restricted to $\tau^{**} + \epsilon < 0$. According to Proposition 1, this inequality holds under second-best restrictions C3 when $t^* < 0$. The first-best, corrective commodity tax revenue exceeds the revenue required to finance the optimal level of the public good. But the government has no lump sum taxes or transfers available to rebate the "excess revenue."

Corollary 1 *Suppose $H = 0$. The Pigovian rule is reversed in the following two cases:*
(i) $\bar{s}_{xg} > \hat{s}_{xg}$ and $\tau^{**} + \epsilon > 0$,
(ii) $\bar{s}_{xg} < \hat{s}_{xg}$ and $\tau^{**} + \epsilon < 0$.

The reasoning parallels the one given for Proposition 3. In case (i), the Pigou effect raises the cost of public good provision. It is, however, dominated by the provision effect, so that the social cost of public good provision is lower than the private cost. In case (ii), the Pigou effect lowers the social cost of public good provision. As it dominates the provision effect, the private cost is higher than the social cost of public good provision. Table 1 summarizes the Pigovian rule properties in the presence of a consumption externality.

TABLE 1

Pigovian Rule Property and Consumption Externalities

	$\tau^{**} + \epsilon > 0$ (C2, C3: $t^* > 0$)	$\tau^{**} + \epsilon = 0$ (C2: $t^* \leq 0$; C3: $t^* = 0$)	$\tau^{**} + \epsilon < 0$ (C3: $t^* < 0$)
$\bar{s}_{xg} < \hat{s}_{xg}$	$\bar{\omega}^{**} > \bar{\omega}^*$	$\bar{\omega}^{**} = \bar{\omega}^*$	$\bar{\omega}^{**} < \bar{\omega}^*$
$\bar{s}_{xg} = \hat{s}_{xg}$	$\bar{\omega}^{**} = \bar{\omega}^*$	$\bar{\omega}^{**} = \bar{\omega}^*$	$\bar{\omega}^{**} = \bar{\omega}^*$
$\bar{s}_{xg} > \hat{s}_{xg}$	$\bar{\omega}^{**} < \bar{\omega}^*$	$\bar{\omega}^{**} = \bar{\omega}^*$	$\bar{\omega}^{**} > \bar{\omega}^*$

In Table 1, $\bar{\omega}$ refers to the uncompensated willingness to pay: $\bar{\omega}(q, y, g, \bar{x})$. Let $\bar{x}(q, y, g)$ be the solution to $\bar{x} - \int_{i \in I} x(i, q, y, g, \bar{x})\, \mathrm{d}F(i) = 0$ with respect to $\bar{x}$. We can then define an "ex post"-version of the willingness to pay: $\bar{w}(q, y, g) \equiv \bar{\omega}(q, y, g, \bar{x}(q, y, g))$.

Pigovian level property. For determining the Pigovian level property, we employ the compensated willingness to pay for the public good. Let $\bar{x}^c(q, v, g)$ be the solution to: $\bar{x} - \int_{i \in I} x^c(i, q, g, v, \bar{x})\, \mathrm{d}F(i) = 0$ with respect to $\bar{x}$. Then: $\bar{w}^c(q, v, g) \equiv$

$\bar{\omega}^c(q, v, g, \bar{x}^c(q, v, g))$, where $\bar{w}^c(q, v, g)$ refers to the "ex post"-version of the compensated willingness to pay.[16]

The analysis of the Pigovian level property employs the following assumption:

Assumption 1

$$\text{sign}\left[\frac{\partial\ \bar{w}^c(q, v, g)}{\partial\ z}\right] = \text{sign}\left[\frac{\partial\ \bar{\omega}^c(q, v, g, \bar{x}^c)}{\partial\ z}\right], \quad z \in \{q, v, g\}\,. \tag{A1}$$

Assumption 1 is a regularity assumption. The right hand side of (A1) captures the partial effect of a change in $z \in \{q, v, g\}$, *for a given consumption reference level.* The left hand side of (A1) captures the total effect of a change in z, taking into account the implied change in the consumption reference level. The assumption requires the direct effect of a change in z — that is, $\bar{\omega}_z^c$ — to dominate the indirect externality effect — that is, $\bar{\omega}_{\bar{x}}^c\,\bar{x}_z^c$.

Proposition 4 (Pigovian Level Property) *Suppuse $H = 0$.*
Let the economy fulfill (A1), $\bar{w}_g^c < 0$, $\bar{w}_v^c \geq 0$, and $\bar{s}_{xg} \in [0, \hat{s}_{xg}]$.
If $\tau^{**} + \epsilon > 0$, then $g^{**} < g^*$.

Proof. See appendix. ‖

Proposition 4 provides sufficient conditions for the Pigovian level property to hold. Conditions $\bar{w}_v^c \geq 0$ and $\bar{w}_g^c < 0$ require the public good to be (weakly) normal with declining marginal benefit. As $\bar{s}_{xg} \in [0, \hat{s}_{xg}]$, the private and public goods are Hicksian complements, and the compensated willingness to pay for the public good does not increase in τ. Restriction $\tau^{**} + \epsilon > 0$ is satisfied under second-best conditions C2 and C3, when $t^* > 0$. That is, the first-best commodity tax revenue is lower than the revenue required to finance the optimal level of the public good. Therefore $\tau^{**} > \tau^*$.

If, in addition to the conditions of Proposition 4, $\bar{s}_{xg} \in [0, \hat{s}_{xg})$, both the Pigovian rule and level properties hold. In fact, in this case, the Pigovian rule property implies the Pigovian level property. This is a generalization of Chang's (2000, p.88) result. Under the conditions of Proposition 4, $g^{**} \geq g^*$ implies $\bar{w}^{c**} \leq \bar{w}^{c*}$, which Chang

[16]The following identities should be noted: $\bar{\omega}(q, y, g, \bar{x}) = \bar{\omega}^c(q, v, g, \bar{x})$, with $v = v(q, y, g, \bar{x})$; $\bar{w}(q, y, g) = \bar{w}^c(q, v, g)$, with $v = v(q, y, g, \bar{x}(q, y, g))$.

(2000) termed the *linkage property*. However, as in fact $\bar{w}^{c**} > \bar{w}^{c*}$, it follows: $g^{**} < g^{*}$.

In the presence of a negative consumption externality, under second-best restriction C3, the Pigovian level property fails to hold if the first-best commodity tax revenue exceeds the revenue required to finance the optimal level of the public good. In this case, the Pigovian level property is reversed, and the second-best level of public good provision exceeds the first-best level.

Proposition 5 (Reversal of Pigovian Level Property) *Suppose $H = 0$. Let the economy fulfill (A1), $\bar{w}_g^c < 0$, $\bar{w}_v^c = 0$, and and $\bar{s}_{xg} \in [0, \hat{s}_{xg}]$. If $\tau^{**} + \epsilon < 0$, then $g^{**} > g^{*}$.*

Proof. See appendix. ||

The proposition provides a counterexample to the Pigovian level property. The prior literature already identified a positive provision effect (Diamond and Mirrlees 1971), a dynamic efficiency effect (Batina 1990a), and heterogeneity (Gaube 2000) as possible sources for reversal of the Pigovian level property. The proposition adds a further source to the list: negative consumption externalities.

In the presence of a negative consumption externality, $\tau^{*} = -\epsilon > 0$. If the "corrective revenue" exceeds the funds required to finance the first-best level of the public good, $t^{*} < 0$. Under the second-best restriction C3, however, no lump sum taxes or transfers are available to the public sector. As a consequence, $\tau^{**} < \tau^{*}$, as shown by Proposition 1. In this situation, a marginal increase of the commodity tax lowers the distortion introduced by the negative consumption externality.

A related argument was introduced, in a more specialized framework, by Wendner and Goulder (2008). They show that the relationship between the first-best and second-best levels of public good provision depends on the sign of the marginal excess burden of a rise in τ. If the marginal excess burden is negative, the second-best level of public good provision exceeds the first-best level. Table 2 summarizes the results.

TABLE 2

PIGOVIAN LEVEL PROPERTY AND CONSUMPTION EXTERNALITIES

		$\tau^{**}+\epsilon>0$ (C2, C3: $t^*>0$)	$\tau^{**}+\epsilon=0$ (C2: $t^*\leq 0$; C3: $t^*=0$)	$\tau^{**}+\epsilon<0$ (C3: $t^*<0$)
$\bar{s}_{xg}<0$	$\bar{w}_v^c \geq 0$	indet.	$g^{**}=g^*$	indet.
$\bar{s}_{xg}\in[0,\hat{s}_{xg}]$	$\bar{w}_v^c=0$	$g^{**}<g^*$	$g^{**}=g^*$	$g^{**}>g^*$
	$\bar{\omega}_v^c>0$	$g^{**}<g^*$	$g^{**}=g^*$	indet.
$\bar{s}_{xg}>\hat{s}_{xg}$	$\bar{w}_v^c\geq 0$	indet.	$g^{**}=g^*$	indet.

Proposition 5 is illustrated by a Cobb-Douglas example below. In the context of an economy *without* consumption externalities, Wilson (1991a) demonstrates that the Pigovian level property holds if preferences can be represented by a Cobb-Douglas utility function and the public good is normal.[17] The example shown below demonstrates that — in the context of an economy *with a negative* consumption externality — the Pigovian level property can be reversed, even for preferences that can be represented by a Cobb-Douglas utility function.

5 An Example with Homogeneous Agents

Consider an economy with identical agents whose preferences are represented by:

$$u(x,l,g,\bar{x}) = \left[x\left(\frac{x}{\bar{x}}\right)^{\frac{\gamma}{1-\gamma}}\right]^{\alpha} l^{1-\alpha} + \beta\ln g\,, \quad 0<\alpha<1\,, \tag{24}$$

where $\beta>0$ represents the strength of the desire for the public good, and $0<\gamma<1$ introduces a consumption externality. The strength of the consumption externality increases in γ. As $\gamma>0$, a rise in the consumption reference level lowers utility. Thereby, (24) represents an example of a negative consumption externality.[18] The example is particularly simple, as $\mu_{\bar{x}}=x_{\bar{x}}=\eta=0$.

[17]Indeed, Wilson (1991a) demonstrates that the Pigovian level property holds in the case of CES utility, given that the ad valorem commodity tax rate does not exceed 100 per cent.

[18]In the context of a keeping up with the Joneses externality, γ represents the marginal degree of positionality (Johansson-Stenman et al., 2002). Formally, define $r(x,\bar{x})=x/\bar{x}$, and $\tilde{u}(x,l,g,r)\equiv u(x,l,g,\bar{x})$. Then $\gamma=[\partial\,\tilde{u}(.)/\partial\,r\;\partial\,r(.)/\partial\,x]/[(\partial\,\tilde{u}(.)/\partial\,x+(\partial\,\tilde{u}(.)/\partial\,r\;\partial\,r(.)/\partial\,x)]$.

Let $\hat{\alpha} \equiv \alpha/[1-(1-\alpha)\,\gamma]$. The indirect utility function becomes:

$$v(q,y,g,\bar{x}) = \left[\frac{(1-\alpha)(1-\gamma)\,\hat{\alpha}}{\alpha}\right]^{1-\alpha} \left[\frac{\hat{\alpha}}{q}\right]^{\alpha} \left[\frac{\hat{\alpha}\,y}{q\,\bar{x}}\right]^{\frac{\alpha\,\gamma}{1-\gamma}} y + \beta \ln g\,.$$

Roy's identity yields: $x(q,y,g,\bar{x}) = \hat{\alpha}\,y/q$, and $\bar{x} = x$, where strong separability implies independence of $x(.)$ from g.

Calculation of the Hicksian demands yields the following expenditure function: $e(q,v,g,\bar{x}) = \alpha^{-\hat{\alpha}}\,[(1-\alpha)(1-\gamma)]^{-(1-\hat{\alpha})}\,q^{\hat{\alpha}}\,\bar{x}^{\hat{\alpha}\,\gamma}\,[1-(1-\alpha)\gamma]\,[v-\beta\,\ln g]^{\hat{\alpha}(1-\gamma)/\alpha}$, and the compensated willingness to pay, $-\partial\,e(.)/\partial\,g$, becomes:

$$\begin{aligned}\bar{\omega}^c(q,v,g,\bar{x}) &= \alpha^{-\hat{\alpha}}\,(1-\alpha)^{-(1-\hat{\alpha})}\,(1-\gamma)^{\hat{\alpha}}\,q^{\hat{\alpha}}\,\bar{x}^{\hat{\alpha}\,\gamma}\,[v-\beta\,\ln g]^{-\hat{\alpha}\,\gamma}\,\beta\,g^{-1}\,,\\ \bar{w}^c(q,g,v) &= \frac{\beta\,(1-\gamma)^{\alpha}\,q^{\alpha}}{\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}\,g}\,.\end{aligned}$$

As required by Proposition 5, $\bar{w}^c_g < 0$, and $\bar{w}^c_v = 0$.[19]

Let second-best restriction C3 apply. From the Lagrangian:

$$\mathcal{L} = \frac{\hat{\alpha}}{\alpha}\,\frac{\alpha^{\alpha}\,[(1-\alpha)(1-\gamma)]^{1-\alpha}}{q^{\alpha}}\,y + \beta\,\ln g + \lambda\,\left[t + (q-1)\,\frac{\hat{\alpha}\,(y-t)}{q} - c\,g\right]\,,$$

the first- and second-best solutions can easily be derived. In the Lagrangian, it is taken into account that $\bar{x} = x$, and the constant marginal production cost of the consumption good is set equal to $p = 1$.

In the first-best optimum: $\tau^* = \gamma/(1-\gamma) \Leftrightarrow q^* = 1/(1-\gamma)$, and the optimal public good provision is given by:

$$g^* = \frac{\beta}{\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}\,c}\,.$$

In the second-best optimum:

$$g^{**} = \frac{1}{[q\,(1-\gamma)]^{1-\alpha}}\,\frac{\beta}{\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}\,c} = \frac{1}{[q\,(1-\gamma)]^{1-\alpha}}\,g^*\,,$$

with the implication that: $g^{**} \lesseqqgtr g^* \Leftrightarrow q^{**} \gtreqqless q^* = (1-\gamma)^{-1}$.

The reversal of the Pigovian level property occurs when $q^{**} < q^*$. Whether or not $q^{**} < q^*$ depends on the strength of the negative consumption externality, γ, as well as on the strength of the preference for the public good, β. Intuitively, the

[19] In the example, $\bar{\omega}^c_q > 0$. Thus $0 > \bar{s}_{xg} \notin [0, \hat{s}_{xg}]$. However, $\bar{s}_{xg} \in [0, \hat{s}_{xg}]$ is a sufficient, not a necessary condition to generate reversal of the Pigovian level property.

higher γ (thereby the corrective tax revenue) and the lower β (thereby the revenue requirement for financing the public good) the more likely is the reversal the Pigovian level property. Formally:

$$\beta \gtreqless \hat{\beta} \Leftrightarrow g^{**} \lesseqgtr g^{*}\,, \quad \hat{\beta} \equiv \gamma\,\hat{\alpha}\,\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}\,y\,.$$

In the absence of a consumption externality $\gamma = \hat{\beta} = 0$. If $\beta > 0$, $g^{**} < g^{*}$, as demonstrated by Wilson (1991a). In the presence of a negative consumption externality, however, if $\beta < \hat{\beta}$, the corrective first-best revenue exceeds the revenue requirement for financing the public good. As a consequence, $\tau^{**} < \tau^{*}$, and $g^{**} > g^{*}$.

6 Discussion and Conclusions

This paper addresses the effects of consumption externalities on optimal commodity taxation, the social cost of public good provision (Pigovian rule property), and the optimal level of public good provision (Pigovian level property). Several of the paper's results deserve comments.

First, not taking heterogeneity effects into account for the moment, the paper shows that in the presence of a negative consumption externality, it is mistaken to assume that the second-best level of provision of the public good necessarily *differs* from the first-best level. Once available policy instruments include a poll transfer (but not a poll tax), $g^{**} = g^{*}$ whenever the revenue raised by applying the first-best commodity tax rate does not fall short of the revenue requirement for financing the optimal level of the public good. This case is the more likely the stronger is the negative consumption externality.

If the revenue raised by applying the first-best commodity tax rate is lower than the revenue requirement for financing the optimal level of the public good, a negative consumption externality still lowers the social cost of public good provision and thereby tends to raise the optimal level of provision. Intuitively, the commodity tax not only serves a revenue raising purpose but also an externality correcting purpose. For this reason, the externality lowers the Pigou effect, thus, the social cost of public good provision.

Second, it is mistaken to assume that heterogeneity unambiguously raises the commodity tax for reasons of equity. In the presence of a negative consumption externality, the paper identifies two opposing heterogeneity-effects on the optimal commodity tax rate. The covariance between the social valuations of agents and their consumption levels tends to raise the optimal commodity tax rate. However, the covariance between the marginal propensity to consume (with respect to a rise in income) and consumption levels tends to lower the optimal commodity tax rate. The agents with the lowest consumption levels — that is, with highest social valuation — have the highest propensity to consume due to an increase in (redistributive) transfers. Thereby, at the margin, they contribute the most to the negative consumption externality. This externality effect requires a lowering of optimal transfers, thereby of the optimal commodity tax rate. It is essentially an empirical matter which one of those two opposing effects dominates. Therefore, it is not generally true that heterogeneity always raises the optimal commodity tax rate for equity considerations. This equity-efficiency tradeoff should be kept in mind for the design of redistributive tax programs.

Third, a negative consumption externality is a potential source for the reversal of the Pigovian level property. In the presence of a negative consumption externality, the second-best level of public good provision may exceed the first-best level, once lump sum taxes and transfers are not available to the public sector. If the preference for the public good is low relative to the strength of the consumption externality, the first-best corrective revenue may exceed the revenue requirement for financing the optimal public good level. In this case, the commodity tax lowers the distortion introduced by the consumption externality, and the second-best level of public good provision exceeds the first-best level. This result even holds true for an economy populated with homogeneous agents with Cobb-Douglas preferences.

Even under less restrictive policy restrictions, as noted above, a negative consumption externality will tend to raise the second-best level of public good provision by lowering its social cost. In the presence of a negative consumption externality, the transfer of resources from the private sector — that is subject to the negative consumption externality — to the public sector of the economy — that is not associated with a consumption externality — lowers the social cost. This effect should be kept in mind when accessing the social cost of public good provision.

Fourth, the following limitations in this analysis are noted. The conditions for both the Pigovian level property and its reversal are sufficient in nature. No conclusions regarding the necessity of those conditions can be drawn. The identification of necessary conditions is still an open research question. Moreover, the reversal of the Pigovian level property occurs when the preference for the public good is "weak" relative to the strength of the consumption externality. Whether or not this condition is satisfied is an empirical question. Empirical estimates of the parameters governing both the preference for the public good and the strength of the consumption externality — β and γ in the example presented in section 5 — are scarce and unreliable, at best. One question for future research then is to determine empirical estimates for those parameters.

Notwithstanding these limitations, I hope this study clarifies the theoretical effects of consumption externalities on the social cost and optimal levels of public good provision, and can contribute to future discussions of Pigovian rules and levels.

Appendix

A Impact of Average Consumption on Individual Consumption. Consider utility function $u(i, x, l, g, \bar{x})$ and the individual agent's budget constraint $y - q\,x - l = 0$, where the price for labor equals unity. Define the marginal rate of substitution of x for l by $\mu(i, x, l, g, \bar{x}) \equiv u_x(.)/u_l(.)$. We need to prove the following:

Suppose $u(.)$ is strictly quasiconcave in (x, l). Then, individual consumption is related to the consumption reference level as follows:

$$x_{\bar{x}}(i) \gtrless 0 \Leftrightarrow \mu_{\bar{x}}(i) \gtrless 0\,.$$

Proof. The necessary first order conditions of the utility maximization problem are:

$$\begin{aligned} F^1 &= \mu(i, x, l, g, \bar{x}) - q = 0\,, \\ F^2 &= y - q\,x - l = 0\,. \end{aligned}$$

It follows:

$$\begin{bmatrix} \frac{\partial F^1}{\partial x} & \frac{\partial F^1}{\partial l} \\ \frac{\partial F^2}{\partial x} & \frac{\partial F^2}{\partial l} \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial x}{\partial \bar{x}} \\ \frac{\partial l}{\partial \bar{x}} \end{bmatrix} = \begin{bmatrix} \frac{-\partial F^1}{\partial \bar{x}} \\ \frac{-\partial F^2}{\partial \bar{x}} \end{bmatrix} \Leftrightarrow \begin{bmatrix} \mu_x(i) & \mu_l(i) \\ -q & -1 \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial x}{\partial \bar{x}} \\ \frac{\partial l}{\partial \bar{x}} \end{bmatrix} = \begin{bmatrix} -\mu_{\bar{x}}(i) \\ 0 \end{bmatrix}.$$

By applying Cramer's rule:

$$\frac{\partial x}{\partial \bar{x}} = \frac{\mu_{\bar{x}}(i)}{-\mu_x(i) + q\,\mu_l(i)}\,,$$

where the denominator is positive by strict quasiconcavity of the utility function. ‖

B Generalized Many Person Ramsey Rule. We define two covariances: $\phi_{bx} \equiv \mathrm{Cov}\,(b(i), x(i)) = \int_{i\in I} \left(b(i) - \bar{b}\right)(x(i) - \bar{x})\,\mathrm{d}F(i) = \int_{i\in I} b(i)\,x(i)\,\mathrm{d}F(i) - \bar{b}\,\bar{x}$, and $\phi_{x_y x} \equiv \mathrm{Cov}\left(\frac{x_y(i)|_{\bar{x}}}{1-\eta}, \frac{x(i)}{\bar{x}}\right) = \int_{i\in I} \left(\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,\frac{x(i)}{\bar{x}}\right)\mathrm{d}F(i) - \bar{x}_y$. Furthermore:

$$\bar{s}_{xx} \equiv \int_{i\in I} s_{xx}(i)\,\mathrm{d}F(i) = \int_{i\in I} x_q(i)|_{\bar{x}} + x_y(i)|_{\bar{x}}\,x(i)\,\mathrm{d}F(i)\,.$$

In first order condition (13), consider Roy's identity (5), and the definitions of the externality term (19) and the social marginal utility of income (17):

$$\begin{aligned}
&-\int_{i\in I} b(i)\,x(i)\,\mathrm{d}F(i) + \int_{i\in I} \tau\,\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,x(i)\,\mathrm{d}F(i) + \epsilon\,\bar{x}_q + \tau\,\bar{x}_q + \bar{x} = 0 \quad\Leftrightarrow \qquad \text{(B.1)}\\
&-\bar{b}\,\bar{x} - \phi_{bx} + \frac{\epsilon+\tau}{1-\eta}\int_{i\in I} x_y(i)|_{\bar{x}}\,x(i)\,\mathrm{d}F(i) - \frac{\epsilon}{1-\eta}\int_{i\in I} x_y(i)|_{\bar{x}}\,x(i)\,\mathrm{d}F(i)\\
&+(\epsilon+\tau)\int_{i\in I}\frac{x_q(i)|_{\bar{x}}}{1-\eta}\,\mathrm{d}F(i) + \bar{x} = 0 \quad\Leftrightarrow\\
&-\bar{b}\,\bar{x} - \phi_{bx} + \frac{\epsilon+\tau}{1-\eta}\,\bar{s}_{xx} - \frac{\epsilon}{1-\eta}\int_{i\in I} x_y(i)|_{\bar{x}}\,x(i)\,\mathrm{d}F(i) + \bar{x} = 0\,.
\end{aligned}$$

Rearranging terms implies:

$$-\frac{(\epsilon+\tau)\,\bar{s}_{xx}}{(1-\eta)\,\bar{x}} = 1 - \bar{b} - \frac{\phi_{bx}}{\bar{x}} - \epsilon\int_{i\in I}\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,\frac{x(i)}{\bar{x}}\,\mathrm{d}F(i)\,.$$

Considering the definition of covariance $\phi_{x_y x}$ yields Ramsey rule (21). ‖

C Proof of Lemma 2.

(i) Homogeneous agents. The right hand side of Ramsey equation (21) equals $1-\epsilon\,\bar{x}_y$. By first order equation (20), this expression equals zero. For the left hand side of (21) to be zero, $\tau = -\epsilon$. |

(ii) Heterogeneous agents. Employing the definition of $b(i) \equiv 1 - \epsilon\,\frac{x_y(i)|_{\bar{x}}}{1-\eta}$ in (B.1) yields: $\bar{s}_{xx}\,(\epsilon+\tau)/(1-\eta) = 0$, which, again, implies: $\tau = -\epsilon$. ‖

D Proof of Proposition 1.

(i) If $t^* \leq 0$, constraint C2 is not binding. Hence, first-best and second-best allocations coincide. If $t^* > 0$, constraint C2 binds, and first order condition (20) becomes:

$1-\bar{b}-\epsilon\,\bar{x}_y>0$. Considering this inequality, Ramsey rule (21) implies: $\epsilon+\tau^{**}>0$. |
(ii) If constraint C3 binds, then either $t^*>0$ or $t^*<0$. In the former case, argument (i) applies. In the latter case, first order condition (20) becomes: $1-\bar{b}-\epsilon\,\bar{x}_y<0$. Considering this inequality, Ramsey rule (21) implies: $\epsilon+\tau^{**}<0$. ‖

E Generalized Many Person Pigovian rule. In first order condition (14), consider Roy's identity for the public good (6), Slutsky term (8), and the definitions of the externality term (19) and the social marginal utility of income (17):

$$\begin{aligned}
&\int_{i\in I} b(i)\,\omega(i)\,\mathrm{d}F(i)-(\epsilon+\tau)\int_{i\in I}\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,\omega(i)\,\mathrm{d}F(i)+\epsilon\int_{i\in I}\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,\omega(i)\,\mathrm{d}F(i) \quad \text{(E.1)}\\
&+(\epsilon+\tau)\,\bar{x}_g=c \quad\Leftrightarrow\\
&\bar{b}\,\bar{\omega}+\phi_{b\omega}+\frac{\epsilon+\tau}{1-\eta}\int_{i\in I}x_g(i)|_{\bar{x}}-x_y(i)|_{\bar{x}}\,\omega(i)\,\mathrm{d}F(i)+\epsilon\int_{i\in I}\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,\omega(i)\,\mathrm{d}F(i)=c \quad\Leftrightarrow\\
&\bar{b}\,\bar{\omega}+\phi_{b\omega}+\frac{\epsilon+\tau}{1-\eta}\,\bar{s}_{xg}+\epsilon\int_{i\in I}\frac{x_y(i)|_{\bar{x}}}{1-\eta}\,\omega(i)\,\mathrm{d}F(i)=c\,.
\end{aligned}$$

Considering the definition of covariance $\phi_{x_y\omega}$ and rearranging terms yields Pigovian rule (22). ‖

F Proof of Lemma 3. Employing the definition of $b(i)\equiv 1-\epsilon\,\frac{x_y(i)|_{\bar{x}}}{1-\eta}$ in (E.1) yields: $\int_{i\in I}\omega(i)\mathrm{d}F(i)+\bar{s}_{xg}\,(\epsilon+\tau)/(1-\eta)=c$. By Lemma 2, $\tau^*=-\epsilon$. Thus: $\int_{i\in I}\omega^*(i)\mathrm{d}F(i)=c$. ‖

G Proof of Proposition 4. Assumption $\bar{s}_{xg}\in[0,\hat{s}_{xg}]$ implies: $\bar{\omega}^{**}\geq\bar{\omega}^*$ (see Table 1). We distinguish two cases: Case A with $\bar{s}_{xg}\in[0,\hat{s}_{xg})$; Case B with $\bar{s}_{xg}=\hat{s}_{xg}$.
Notice that $\bar{\omega}(q,y,g,\bar{x}(q,y,g))=\bar{\omega}^c(q,v,g,\bar{x}^c(q,v,g))=\bar{w}^c(q,v,g)$, with $v=v(q,y,g,\bar{x}(q,y,g))$.
Thus, $\bar{\omega}^{**}\geq\bar{\omega}^*\Leftrightarrow\bar{w}^{c**}\geq\bar{w}^{c*}\Leftrightarrow\bar{w}^c(q^{**},v^{**},g^{**})\geq\bar{w}^c(q^*,v^*,g^*)$.

Case A.

(i) As $0\leq\bar{s}_{xg}<\hat{s}_{xg}$, $\bar{w}^c(q^{**},v^{**},g^{**})>\bar{w}^c(q^*,v^*,g^*)$.
(ii) $\bar{\omega}^c_q(q,v,g,\bar{x})\leq 0$. By assumption (A1), $\bar{w}^c_q(q,v,g)\leq 0$. Moreover, $\bar{w}^c_v(q,v,g)\geq 0$.
(iii) $\tau^{**}+\epsilon>0\Rightarrow q^{**}>q^*$. $\tau^{**}>\tau^*$ and $v^{**}\leq v^*$ imply: $\bar{w}^c(q^{**},v^{**},g^*)\leq\bar{w}^c(q^*,v^*,g^*)$, for the *same* level of the public good (g^*).
(iv) From step (i), however, we know: $\bar{w}^{c**}>\bar{w}^{c*}$. Given $\bar{w}^c_g<0$, this inequality can only be satisfied if: $g^{**}<g^*$. |

Case B.

(i) As $\bar{s}_{xg}=\hat{s}_{xg}$, $\bar{w}^c(q^{**},v^{**},g^{**})=\bar{w}^c(q^*,v^*,g^*)$.

(ii) $\bar{\omega}^c_q(q, v, g, \bar{x}) < 0$. By assumption (A1), $\bar{w}^c_q(q, v, g) < 0$. Moreover, $\bar{w}^c_v(q, v, g) \geq 0$.
(iii) $q^{**} > q^*$ and $v^{**} \leq v^*$ imply: $\bar{w}^c(q^{**}, v^{**}, g^*) < \bar{w}^c(q^*, v^*, g^*)$, for the *same* level of the public good (g^*).
(iv) From step (i), however, we know: $\bar{w}^{c**} = \bar{w}^{c*}$. Given $\bar{w}^c_g < 0$, this inequality can only be satisfied if: $g^{**} < g^*$. $\|$

H Proof of Proposition 5. We distinguish two cases, A and B.
Case A: $\bar{s}_{xg} \in [0, \hat{s}_{xg})$.
(i) As $0 \leq \bar{s}_{xg} < \hat{s}_{xg}$, $\bar{w}^c(q^{**}, v^{**}, g^{**}) < \bar{w}^c(q^*, v^*, g^*)$, see Table 1.
(ii) $\bar{\omega}^c_q(q, v, g, \bar{x}) \leq 0$. By assumption (A1), $\bar{w}^c_q(q, v, g) \leq 0$.
(iii) $\tau^{**} + \epsilon < 0 \Rightarrow q^{**} < q^* \Rightarrow \bar{w}^c(q^{**}, v^{**}, g^*) \geq \bar{w}^c(q^*, v^*, g^*)$, for the *same* level of the public good, g^* (notice that $\bar{w}^c_v = 0$).
(iv) From step (i), however, we know: $\bar{w}^{c**} < \bar{w}^{c*}$. Given $\bar{w}^c_g < 0$, this inequality can only be satisfied if: $g^{**} > g^*$. $|$

Case B: $\bar{s}_{xg} = \hat{s}_{xg}$.
(i) As $\bar{s}_{xg} = \hat{s}_{xg}$, $\bar{w}^c(q^{**}, v^{**}, g^{**}) = \bar{w}^c(q^*, v^*, g^*)$.
(ii) $\bar{\omega}^c_q(q, v, g, \bar{x}) < 0$. By assumption (A1), $\bar{w}^c_q(q, v, g) < 0$.
(iii) $q^{**} < q^* \Rightarrow \bar{w}^c(q^{**}, v^{**}, g^*) > \bar{w}^c(q^*, v^*, g^*)$, for the *same* level of the public good (g^*).
(iv) From step (i), however, we know: $\bar{w}^{c**} = \bar{w}^{c*}$. Given $\bar{w}^c_g < 0$, this inequality can only be satisfied if: $g^{**} > g^*$. $\|$

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