Journal of Public Economics 96 (2012) 331–340

Contents lists available at SciVerse ScienceDirect

Journal of Public Economics

journal homepage: www.elsevier.com/locate/jpube

Signaling and indirect taxation ☆

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ARTICLE INFO

Article history:
Received 6 July 2010
Received in revised form 4 November 2011
Accepted 16 November 2011
Available online 1 December 2011

JEL classification:
C720
H210

Keywords:
Optimal taxation
Indirect taxation
Costly signaling
Identity
D1 criterion
Monotonic signaling

ABSTRACT

Commodities communicate. We investigate optimal indirect taxation when both the intrinsic qualities of goods and signaling motivate consumption choices. Optimal indirect taxes are introduced into a monotonic signaling game. We provide sufficient conditions for the uniqueness of the D1 sequential equilibrium strategies. In the case of pure costly signaling, signaling goods can in equilibrium be taxed without burden. When commodities serve both intrinsic consumption and signaling, optimal taxes are characterized by a Ramsey rule, which deals with distortions resulting from signaling.

1. Introduction

Commodities communicate. In consumption choices, consumers care about the intrinsic qualities of goods and about what a choice reveals about their identity to spectators. Intrinsic qualities are the mostly physical qualities of goods and remain unchanged if a good is consumed in social isolation. What a good communicates, its social meaning, is located, rather, in the head of spectators and depends on the choices of all consumers in society. Meaning thus introduces an interpersonal interdependency in the consumer problem, which entails an interesting opportunity for indirect taxation. If taxation changes the choices of all, it also changes the meaning of goods. Building on words of Richard Layard (1980) "In a poor society a man proves to his wife that he loves her by giving her a rose, but in a rich society he must give a dozen roses", the reasoning of this article is summarized: if one taxes roses sufficiently, one rose suffices to do the same job again in rich societies. If roses serve communication only and taxes do not break up the signaling equilibrium, then husband and wife are equally happy before and after taxation and tax revenues are a pure gain. If roses are also consumed for intrinsic reasons and the signaling equilibrium is not broken, then the husband still communicates the same after taxation, and policy makers should only consider intrinsic utility. If consumers use a complete visible consumption pattern to communicate, then some goods are consumed relatively more for signaling and less for intrinsic reasons, and the intrinsic utility cost of taxing these goods is lower. The communicative use of consumption thus provides a new motivation for differential indirect taxes, which is argued distinct from Pigovian arguments.

While status signaling is an old theme in economic theory,[1] the exact importance of signaling for consumption is more obscure. Because true motivations for consumption are notoriously hard to disentangle empirically, extreme examples of conspicuous but intrinsically useless purchases have caught much attention.[2] Yet, signaling motives also matter for everyday consumption. Solnick and Hemenway (1998) and Johansson-Stenman et al. (2002) let respondents choose between two hypothetical worlds: a 'relative case' (one is worse off in absolute terms, but better than peers) and

☆ I thank Erik Schokkaert, André Decoster, Pierre Pestieau, Jan Eeckhout, Frans Spinnewyn, Paul De Grauwe, Dirk Van de gaer, Martin Hellwig, Christian Traxler, seminar and conference participants in Budapest, Leuven, Marseille, Maastricht, Alba di Canazei, Bonn, Modena, Berlin, Louvain-la-Neuve, Steyr and Stockholm and two anonymous referees of this journal. Financial support by the Flemish Science Foundation (project G.0522.09N) and Belgian Program on Interuniversity Poles of Attraction is gratefully acknowledged.

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[1] See Mason (1998) for a history of ideas, Frank (1985, 1999) for a broad introduction or Truyts (2010) for a survey of the recent literature.

[2] Gell (1986, pp.113–114, cited in Van Kempen, 2005) documents a poor village in Sri Lanka without electricity, roads or piped water, where fishermen are observed "to buy unusable television sets, to build garages onto houses to which no automobiles had access, and to install rooftop cisterns into which water never flows."

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doi:10.1016/j.jpubeco.2011.11.004

an 'absolute case' (better off in absolute terms, but worse than peers).[3] Solnick and Hemenway (1998) find up to 80% of respondents preferring the relative case for some goods. Alpizar et al. (2005) conclude that social comparison matters far more for houses and cars than for e.g. vacation and insurance, and that absolute and relative consumption matter for all goods. Haan and Kooreman (2006) find consumers on the Dutch second hand car market, aware of the true car age, paying a premium for a new license plate format, which presumably signals a newer car to spectators. Basmann et al. (1988) find postwar commodity expenditures in the U.S. in very good agreement with a theory of conspicuous consumption. Status signaling is not confined to the rich. Van Kempen (2004) finds the Bolivian poor willing to pay a premium for a designer label on intrinsically identical clothing. Aryee (1984) finds Ghanese lower income consumers buying footwear primarily for fashion qualities and good finish, while higher income consumers indicate durability and price as more important. Finally, the whole visible consumption pattern matters. Spectators have no reason to disregard some parts of observed behavior, and are documented to care about 'mismatches'.[4]

This article characterizes optimal indirect taxation by a generalized many-person Ramsey rule if consumers use their consumption pattern for signaling. Consumer choices are understood as equilibrium strategies in a monotonic signaling game, with consumption patterns as multidimensional signals, chosen from a continuous consumption space, about only one dimension of heterogeneity: income. Our model builds on two literatures: costly signaling (e.g. Spence, 1973; Riley, 2001; Cho and Sobel, 1990) and optimal indirect taxation (e.g. Atkinson and Stiglitz, 1980). The taxation of goods only used for signaling relates to Ng's (1987) work on pure 'diamond goods' (cfr. infra). If goods serve both signaling and intrinsic consumption, optimal indirect taxation formally resembles indirect taxation with externalities (e.g. Sandmo, 1975; Cremer et al., 1998) or merit goods (Besley, 1988; Blomquist and Micheletto, 2006). More generally, our reasoning relates to taxes on relative consumption. Frank (1985, 1999) calls for a progressive tax on overall consumption, as consumption is deemed largely driven by relative concerns and thus self-defeating in welfare terms. Our analysis characterizes the extent to which consumption is self-defeating and establishes differential indirect taxation of visible goods. Ireland (1994) studies commodity taxes in a unidimensional signaling model and shows how a small tax on a signaling good can be Pareto improving. Ireland (1998, 2001) examines optimal direct taxation if consumption is characterized by a signaling equilibrium (cfr. infra).

The second section sets out the formal model and introduces a unique signaling equilibrium. The third section analyzes the benchmark case of pure costly signaling and demonstrates that such signaling goods can be taxed without burden. In the fourth section, visible goods serve both intrinsic consumption and communication, and optimal taxes are characterized by a many-person Ramsey rule. The fifth section discusses the robustness of our results with respect to preference heterogeneity, different signaling equilibria and nonlinear direct taxes. The last section discusses a number of critiques of indirect taxes to remedy status signaling as well as the limitations of our analysis.

2. Setting

Imagine a finite population of N consumers. Nature draws for each consumer a type t out of a finite typeset T with probabilities π_t. A consumer's type is private information and types differ ex ante only in income m_t. Let, without loss of generality, types be indexed in ascending order of incomes. Consumers spend their income on K different (categories of) goods, indexed k, represented by a consumption vector $c\equiv(c_1,\ldots,c_K)$. This consumption vector consists of one invisible good c_1 and a visible consumption bundle $\bar{c}\equiv(c_2,\ldots,c_K)$. The visible consumption pattern will signal the consumer's type to spectators (the other consumers), while invisible good c_1 is the opportunity cost of visible consumption. Producer prices are by assumption fixed and normalized to 1. Consumer prices are denoted $p\equiv(p_1,\bar{p})=(p_1,\ldots,p_K)$.

Upon observing visible consumption $\bar{c}$, spectators form beliefs $\beta(\bar{c})$ about a consumer's type. Beliefs $\beta(\bar{c})$ are a probability distribution over the typeset, such that $\beta_t(\bar{c})$ represents the believed probability that a consumer with visible consumption $\bar{c}$ is a type t. Consumer preferences are represented by a utility function

$$u(c,\hat{m}(\bar{c})), \tag{1}$$

in which $\hat{m}(\bar{c})$ is the spectators' estimate of the income of a consumer with visible consumption $\bar{c}$: $\hat{m}(\bar{c})\equiv\sum_t\beta_t(\bar{c})m_t$. The utility function in 1 either represents a problem in which consumers enjoy esteem for its own sake, with $\hat{m}$ a good on itself, or is a shorthand representation of a Spence signaling game. In the latter case, spectators interpret signal $\bar{c}$ and choose an action as a best reply. If this best reply is unique and strictly increasing with $\hat{m}(\bar{c})$ and if the sender's utility strictly increases with the spectators' action, then 1 can be understood as representing preferences with the spectators' best reply already substituted in the consumption problem, omitting an analysis of the spectators' choice of action.

Assume that this utility function satisfies the following regularity conditions.

Condition 1. *Assume that u is*

i) *twice continuously differentiable with* $u_1>0$, $u_k\geq 0$, $u_{K+1}>0$ *and* $u_{11}<0$, *and*
ii) *such that* u_1 *is bounded and* u_{K+1} *is bounded away from zero.*

Substitute the budget constraint into the utility function to obtain[5]

$$u\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},\hat{m}\right). \tag{2}$$

The utility function is also assumed such that 2 satisfies a Spence–Mirrlees single crossing condition for each dimension of $\bar{c}$, such that the slope of the indifference curve in the $(c_k,\hat{m})-$ plane is everywhere strictly decreasing with income. This slope equals

$$-\frac{-\frac{p_k}{p_1}u_1\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},\hat{m}\right)+u_k\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},\hat{m}\right)}{u_{K+1}\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},\hat{m}\right)}, \tag{3}$$

in which the numerator is the marginal utility of consuming more good k at the expense of invisible consumption. The single crossing condition requires that higher types always need strictly less compensation in terms of $\hat{m}$ for a marginal increase of c_k at the expense of c_1.

Condition 2. *Let Eq.(3) be strictly decreasing with* m_t *for all* $2\leq k\leq K$ *at all* $(\bar{c},\hat{m})$.

Note that the main ingredient of this single crossing condition is the strict concavity of utility with respect to invisible consumption, such that a marginal increase in visible consumption implies

[3] E.g. Relative: Your current yearly income is \$50,000; others earn \$25,000 or Absolute: Your current yearly income is \$100,000; others earn \$200,000. Prices are kept constant. Similar questions are asked for a range of goods. Although relative consumption is different from signaling, signaling provides a prime explanation for such a taste for relative consumption.

[4] Gambetta and Hamill (2005) investigate how taxi drivers in New York and Belfast distinguish trustworthy customers from robbers and runners (running off without paying) and find taxi drivers particularly vigilant for mismatches in clients' looks and behavior, i.e. different signs with too different meanings.

[5] Because $u_1>0$, we only consider consumption bundles which fully exhaust income. We slightly abuse notation for the sake of simplicity, replacing the K-dimensional column vector c by $(c_1,\bar{c})$, with the second component a $(K-1)$-dimensional column vector. Prices p and $\bar{p}$ are row vectors.

everywhere a smaller opportunity cost of in terms of foregone utility from invisible consumption for higher types. If u is strongly separable in c_1, then condition 2 is implied by condition 1. For more general utility specifications, condition 2 requires the marginal utility of visible good k and of impression made on spectators $\hat{m}$ not to decrease too much with invisible consumption. Thus, higher income types should not care too much less about making an impression and about visible consumption than lower types.

Consumer behavior is understood as equilibrium strategies in the signaling game. A mixed strategy $\mu(t,p)$ of type t at prices p is a probability distribution over her set of feasible visible consumption bundles $\{\bar{c}|\bar{p}\bar{c}\leq m_t\}$. A sequential equilibrium (S.E.) is a combination of strategy profile and beliefs, such that each type's strategy maximizes utility given these beliefs and that beliefs are Bayesian consistent with the equilibrium strategies.[6] A problem with sequential equilibrium as a solution concept is the lack of restrictions it imposes on the interpretation of signals not sent in equilibrium (other than 'supporting' the S.E.). This typically allows for a multitude of often counterintuitive equilibria and motivates a number of equilibrium refinements which restrict these out-of-equilibrium-beliefs. Although our results are more general, we first focus on the most commonly used D1 criterion[7] and the selected "Pareto Dominant Separating Equilibrium" or Riley outcome, after Riley (1979). Alternative criteria and equilibria are discussed in Section 5. The Riley outcome is generated by a fully separating equilibrium in which all types maximize utility under the constraint that no other type can benefit from imitating their visible consumption, while spectators concentrate all probability mass on their true type. If conditions 1 and 2 are satisfied, such S.E. strategy profile is constructed by letting the lowest type, with no lower types to distinguish herself from, choose visible consumption $\bar{c}^1$ to maximize utility without signaling concerns:

$$\bar{c}^1 \in \arg\max_{\bar{c}} \left\{ u\left(p_1^{-1}(m_1 - \bar{p}\bar{c}), \bar{c}, m_1\right)\right\}. \tag{4}$$

Higher types t choose visible consumption $\bar{c}^t$ to maximize utility under the constraint that type $t-1$ has no incentive to imitate her (and be seen as type t) rather than choosing her own equilibrium consumption bundle[8]:

$$\bar{c}^t \in \arg\max_{\bar{c}} \left\{ u\left(p_1^{-1}(m_t - \bar{p}\bar{c}), \bar{c}, m_t\right)\right\} \tag{5}$$

subject to

$$u\left(p_1^{-1}(m_{t-1} - \bar{p}\bar{c}), \bar{c}, m_t\right) \leq u^{t-1}, \tag{6}$$

with $u^{t-1} \equiv u\left(p_1^{-1}\left(m_{t-1} - \bar{p}\bar{c}^{t-1}\right), \bar{c}^{t-1}, m_{t-1}\right)$ the equilibrium utility of type $t-1$. Cho and Sobel (1990) demonstrate the existence of a D1 S.E. for monotonic signaling games with a finite typespace and demonstrate that any D1 S.E. outcome coincides with the Riley outcome. The following theorem summarizes their result.

Theorem 1. *If u satisfies conditions 1 and 2, then a D1 sequential equilibrium exists and the D1 equilibrium outcome is the Riley outcome, as defined by Eqs.(4)–(6).*

Proof. In appendix. □

Two issues complicate characterizing consumer behavior by Eqs. (4)–(6). First, Cho and Sobel (1990) demonstrate a unique D1 equilibrium outcome, but not uniqueness in strategies, which hinders a characterization of optimal taxes. Second, the maximization under constraints problem in Eqs. (4)–(6) is typically nonconvex, maximizing a function on a nonconvex set. We provide sufficient conditions for the problem in Eqs. (4)–(6) to have a unique solution $\bar{c}^t$ for all types, and show that under these conditions, an interior maximum can be obtained by Lagrange maximization. If the constraint in Eq. (6) is not binding, then strict concavity of u with respect to c suffices. Otherwise, we need that type t's utility function (with $\hat{m}=m_t$) is strictly concave on the set of consumption bundles which satisfy constraint (6) with equality. For a $\tilde{c}\equiv(c_3,\ldots,c_K)$, we denote by $f(\tilde{c})$ the maximal c_2 which satisfies Eq. (6) with equality[9]

$$u\left(p_1^{-1}(m_{t-1} - p_2 f(\tilde{c}) - \tilde{p}\tilde{c}), f(\tilde{c}), \tilde{c}, m_t\right) = u^{t-1}, \tag{7}$$

and we define

$$s_{k2}^t(\bar{c},\hat{m}) \equiv -\frac{\hat{u}_k^t(\hat{m}) - \frac{p_k}{p_1}\hat{u}_1^t(\hat{m})}{\hat{u}_2^t(\hat{m}) - \frac{p_2}{p_1}\hat{u}_1^t(\hat{m})},$$

with $\hat{u}_k^t(\hat{m}) \equiv u_k\left(p_1^{-1}(m_t - p_2 f(\tilde{c}) - \tilde{p}\tilde{c}), f(\tilde{c}), \tilde{c}, \hat{m}\right)$, as type t's marginal rate of substitution of visible good k for 2 at $\bar{c}$ (while respecting the budget constraint and keeping $\hat{m}$ fixed). The numerator is the marginal utility of more good k at the expense of less invisible consumption, the denominator is the same for good 2. Let then $\Delta s_{k2}^t(\bar{c},\hat{m}) \equiv s_{k2}^t(\bar{c},\hat{m}) - s_{k2}^{t-1}(\bar{c},\hat{m})$ be the difference in these marginal rates of substitution between type t and $t-1$. Then we impose either of the following conditions.

Condition 3. *Let $K=2$ and $u_2(.)=0$.*

Condition 4. *Let u be strictly increasing and strictly concave in c and if $K\geq 3$, then either*

a) *u is strongly separable in all dimensions of c, or*
b) *the symmetric matrix*

$$\left(\frac{\partial}{\partial c_{k'}}\left(\left(\hat{u}_1^t(m_t)\frac{p_2}{p_1} - \hat{u}_2^t(m_t)\right)\Delta s_{k,2}^t(\bar{c}, m_t)\right)\right)_{k,k'=3,\ldots,K} \tag{8}$$

is negative definite.

In Eq. (8), $\hat{u}_1^t(m_t)\frac{p_2}{p_1} - \hat{u}_2^t(m_t)$ is the marginal utility of one unit c_2 less in favor of invisible consumption, while the second factor is the difference in marginal rates of substitution of good k for good 2. Their product is type t's marginal utility of moving on type $t-1$'s indifference surface towards more good k, such that the negative definiteness of Eq. (8) states that type t's utility function is strictly concave on type $t-1$'s indifference surface.

Fig. 1 illustrates this for two visible goods ($K=3$). Type t's choice set is the gray area, constrained by her budget constraint, positivity constraints and type $t-1$'s indifference curve at her equilibrium utility level. This set is typically nonconvex and $t-1$'s indifference curve can

[6] Technically, a tuple $(\mu(t,p),\beta)$ is a Sequential Equilibrium (S.E.) if i) each type t chooses a strategy given β s.t.

$$\mu(t,p) \in \arg\max_{\mu} \left\{ \int_{\bar{c}\in\{\bar{c}'|\bar{p}\bar{c}'\leq m_t\}} u\left(p_1^{-1}(m_t - \bar{p}\bar{c}), \bar{c}, \hat{m}(\bar{c})\right)\mu(\bar{c}|t,p)d\bar{c}\right\}$$

ii) beliefs are updated according to Bayes' rule for $\bar{c}\in\text{supp}(\mu)$: $\beta_t(\bar{c}) = \frac{\pi_t\mu(\bar{c}|t,p)}{\sum_{t'}\pi_{t'}\mu(\bar{c}|t',p)}$.

[7] Divinity (D1) eliminates a consumer type t out of the support of the beliefs $\beta(\bar{c}^\diamond)$ following an out-of-equilibrium consumption pattern $\bar{c}^\diamond$, if a second type t' has a strict incentive to deviate to $\bar{c}^\diamond$ whenever the first type t under investigation has a weak incentive to deviate. Formally, fix a S.E. and equilibrium utility levels u^t for each type t. Let $M^+(\bar{c}^\diamond,t) = \{\tilde{m}|u(p_1^{-1}(m_t - \bar{p}\bar{c}^\diamond), \bar{c}^\diamond, \tilde{m}) > u^t\}$ be the set of beliefs (only $\hat{m}$ matters) which make type t strictly better off with $\bar{c}^\diamond$ than in the S.E. Similarly, let $M^o(\bar{c}^\diamond,t) = \{\tilde{m}|u(p_1^{-1}(m_t - \bar{p}\bar{c}^\diamond), \bar{c}^\diamond, \tilde{m}) = u^t\}$ be the set of beliefs which make type t indifferent between consumption pattern $\bar{c}^\diamond$ and the S.E. payoffs. Then Divinity requires that all types t for whom there is a type t' for which $M^+(\bar{c}^\diamond,t)\cup M^o(\bar{c}^\diamond,t)\subseteq M^+(\bar{c}^\diamond,t')$, are eliminated from the support of the out-of-equilibrium beliefs.

[8] As shown in the proof of Theorem 1, condition 2 ensures that no other type wishes to imitate t if $t-1$ does not. Since such a S.E. is separating, equilibrium beliefs satisfy $\beta_t(\bar{c}^t) = 1$ such that $\hat{m}(\bar{c}^t) = m_t$ in Eqs. (4)–(6).

[9] This selects the c_2 at which $\frac{u_1(c,m_t)}{u_2(c,m_t)} > \frac{p_1}{p_2}$. A second, smaller level of c_2 satisfies Eq. (7) but has $\frac{u_1(c,m_t)}{u_2(c,m_t)} < \frac{p_1}{p_2}$ and is easily shown inconsistent with the S.E. (see Appendix A).

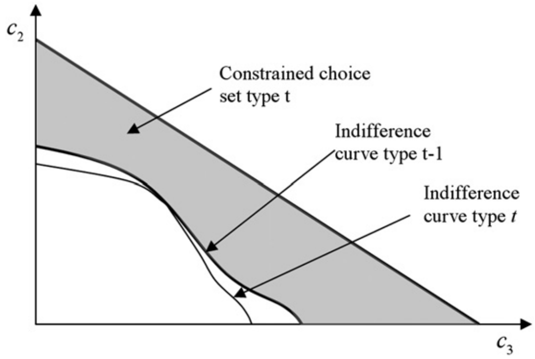

Fig. 1. Graphical illustration of part b) in condition 4.

be both convex and concave, even for u strictly concave, because of the substitution of the budget constraint into u. If constraint (6) is binding, then condition 4 ensures that the intrinsic marginal rate of substitution of the invisible good for good 2 exceeds their relative price on the constraint: $\frac{u_1\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},m_t\right)}{u_2\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},m_t\right)}>\frac{p_1}{p_2}$. If at $\bar{c}$ on the constraint, type t has a flatter indifference curve than type $t-1$, marginally moving over $t-1$'s indifference curve to more c_3 increases type t's utility, as it implies a greater reduction in c_2 (and greater increase or smaller decrease in c_1) than needed to keep type t indifferent. Similarly, a steeper indifference curve of type t compared to $t-1$ means that moving over $t-1$'s indifference curve to more c_3 decreases t's utility. Thus, an interior maximum is found where both marginal rates of substitution are equal, and a sufficient condition for a unique utility maximum of type t on $t-1$'s indifference curve is that the difference in marginal rates of substitution of c_3 for c_2 (while respecting the budget constraint) strictly decreases when moving over $t-1$'s indifference curve to more c_3.

Is condition 4 restrictive? If u is strongly separable in all dimensions of c (condition 4a), no more than strict concavity with respect to c is needed. A given budget for visible consumption is by all types intrinsically most efficiently allocated at the same $\bar{c}$ where $\frac{u_2}{u_3}=\frac{p_2}{p_3}$. The utility loss of a deviation further away from this point is compensated by an increase in invisible consumption, and type t needs more compensation in invisible consumption than type $t-1$, because utility is strictly concave in invisible consumption. Hence, type t's indifference curve is necessarily steeper than $t-1$'s if $\frac{u_2}{u_3}>\frac{p_2}{p_3}$ and flatter if $\frac{u_2}{u_3}<\frac{p_2}{p_3}$. In the general case, condition 4b ensures that type t's marginal utility strictly decreases when moving over type $t-1$'s indifference curve by requiring that the marginal utility of visible goods cannot decrease too much more with increased consumption for lower types.[10]

Proposition 1. *The problem in Eqs. (4)–(6) has a unique solution $\bar{c}^t$ for all types if u satisfies conditions 1, 2 and either condition 3 or 4. If this unique solution is interior ($\bar{c}^t \gg 0$), then it can be obtained by Lagrange optimization.*

Proof. In appendix. □

If consumer behavior is uniquely characterized by Eqs. (4)–(6), then let $W(\mathbf{v}(p))$ be a Bergson–Samuelson social welfare function, with $\mathbf{v}(p)$ a vector of consumers' equilibrium indirect utility functions at prices p. Tax revenue for prices p is

$$R(p)\equiv N\sum_t \pi_t\left((p_1-1)\frac{m_t-\bar{p}\bar{c}^t}{p_1}+(\bar{p}-\mathbf{1})\bar{c}^t\right),$$

with $\mathbf{1}$ a vector of ones. For required tax revenue $\bar{R}$, the optimal tax problem is[11]

$$\max_p W(\mathbf{v}(p)) \ \text{ s.t. } \ R(p)\geq\bar{R}. \tag{9}$$

The main information issue is consumers signaling to other consumers. The government knows preferences and the distribution of types, but not the actual type and consumption. The assumption of unobserved individual consumption excludes nonlinear indirect taxes. Nonlinear direct taxes, excluded for now, are discussed in Section 5.

3. Pure costly signaling

In the baseline case of pure costly signaling, visible consumption serves a single purpose: distinction. In this case, all visible goods are equivalent ways of conspicuously 'burning' purchasing power. Therefore, we set $K=2$ for this section, without loss of generality, to avoid multiplicity in equilibrium strategies, and assume that u satisfies condition 3. If $\bar{c}$ does not affect utility directly, the utility function can be written:

$$u^{\mathcal{P}}\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\hat{m}(\bar{c})\right). \tag{10}$$

If we write the problem in Eqs. (4)–(6) in terms of Eq. (10), visible consumption only appears multiplied by its own price. Type t spends exactly enough on signaling to make a lower type indifferent between wasting $\bar{p}\bar{c}^t$ to be deemed a t type and wasting $\bar{p}\bar{c}^{t-1}$ to appear a type $t-1$. Hence, the Riley outcome is for each type $t>1$ characterized by a unique expenditure on visible consumption $e(t,p)\equiv\bar{p}\bar{c}^t$, solving

$$\max_e u^{\mathcal{P}}\left(p_1^{-1}(m_t-e),m_t\right) \tag{11}$$

$$u^{\mathcal{P}}\left(p_1^{-1}(m_{t-1}-e),m_t\right)\leq u^{\mathcal{P}}\left(p_1^{-1}[m_{t-1}-e(t-1,p)],m_{t-1}\right). \tag{12}$$

The lowest income type does not waste means on visible consumption. Note that the solution to Eqs. (11) and (12) is independent of the price of visible goods, such that we write $e(t,p_1)$. Consumers only waste enough in terms of opportunity costs to keep worse types from mimicking, and the optimal amount of foregone invisible consumption does not depend on $\bar{p}$.

Lemma 1. *If u satisfies conditions 1, 2 and 3, then:*

1. *all D1 sequential equilibria are characterized by $\bar{p}\bar{c}_t=e(t,p_1)$, with $e(t,p_1)$ solving problem (11) and (12) for each type t.*
2. *equilibrium expenditures on visible goods are independent of $\bar{p}$.*

Equilibrium demand for visible consumption is then $\bar{c}^t=\frac{e(t,p_1)}{\bar{p}}$, such that the own price elasticity of demand for the visible good is -1 everywhere and the demand functions for pure costly signals of all types $t>1$ are rectangular hyperbola as a function of their price. This implies that visible goods can be taxed without burden in equilibrium.

Lemma 2. *If $u^{\mathcal{P}}(.)$ satisfies conditions 1, 2 and 3, then consumers' utility is in equilibrium unaffected by taxes on pure costly signals:*

$$\frac{\partial v^{\mathcal{P}}(t,p)}{\partial\bar{p}}=0,$$

$$\text{with } v^{\mathcal{P}}(t,p)\equiv u^{\mathcal{P}}\left(p_1^{-1}[m_t-e(t,p_1)],m_t\right).$$

[10] If utility were sufficiently more concave in visible consumption for consumers with a low invisible consumption (i.e. lower types), then the utility loss due to a less efficient allocation of visible consumption can be sufficiently greater for type $t-1$ to require more compensation in terms of c_1 than type t (despite the concavity of utility w.r.t. invisible consumption). This can then give rise to multiple local utility maxima of type t on the indifference curve of $t-1$.

[11] The possibility of nonconcavities in $W(\mathbf{v}(p))$ or nonconvexities in its domain and the justification of the first order approach is a known problem, but not discussed further here (see e.g. Mirrlees (1986)).

Both arguments of the utility function are unaffected by taxes on $\bar{c}$ (keeping p_1 constant), if the signaling equilibrium is maintained. Expenditures on visible goods, and thus invisible consumption, are independent of $\bar{p}$. And increasing $\bar{p}$ does not break up conditions 1, 2 and 3 needed to maintain the separating equilibrium, such that the second argument is unaffected by increases in $\bar{p}$. Optimal taxes maximally exploit this potential for burden free taxation.

Proposition 2. *In the D1 equilibrium of the pure costly signaling game, with u satisfying conditions 1, 2 and 3, optimal indirect taxes satisfy*

$$\frac{p_1-1}{p_1}=\frac{\bar{R}-\frac{\bar{p}-1}{\bar{p}}N\sum_{t\in T}\pi_t e(t,p_1)}{N\sum_{t\in T}\pi_t(m_t-e(t,p_1))}, \qquad (13)$$
$$\frac{\bar{p}-1}{\bar{p}}\to 1.$$

Proof. In appendix. □

The optimal tax on pure costly signals is infinite, $\bar{p}\to+\infty$. In Eq. (13), $\frac{\bar{p}-1}{\bar{p}}N\sum_{t\in T}\pi_t e(t,p_1)$ represents the revenues from taxing visible consumption, such that the tax on invisible goods is the ratio of the difference between required and burden free revenue over total expenditure on invisible goods. One subsidizes invisible consumption if burden-free revenues exceed the required revenues.

Thus, the policy maker collects almost all means wasted for social distinction. As such, the optimal tax scheme shifts the consumption of real resources almost completely from visible waste towards intrinsically valuable goods. This result underpins the burden free taxes on pure diamond goods of Ng (1987) for the case of pure costly signaling.[12] Clearly, this result crucially hinges, as a limit case, on the perfect divisibility and observability of the visible good. Very high taxes on visible goods only leave utility unaffected if very small quantities of visible consumption can be distinguished by spectators. However, the basic intuition of this section remains valid under much broader assumptions.

4. Mixed signaling

Few – if any – goods serve only signaling. Most consumers use ordinary consumption goods, often with luxurious characteristics, to distinguish themselves. Signaling then induces consumption choices which do not maximize intrinsic utility, but which communicate the same meaning before and after taxation if the separating equilibrium is not broken. This entails opportunities for indirect taxation. Formally, assume preferences such that all goods generate intrinsic utility and u satisfies conditions 1, 2 and 4.

The lowest type chooses her 'intrinsic utility maximum' c^1, characterized by the equality of intrinsic marginal rate of substitution to relative prices in Eq. (15). The equilibrium consumption c^t of higher types t, given c^{t-1}, satisfies first order conditions

$$\begin{aligned} &u_1\left(c^t,m_t\right)-\lambda_t p_1=0\\ \forall k>1: u_k\left(c^t,m_t\right)-\lambda_t p_k-\psi_t &\begin{bmatrix}-\frac{p_k}{p_1}u_1(p_1^{-1}\left(m_{t-1}-\bar{p}\bar{c}^t\right),\bar{c}^t,m_t+\\ u_k\left(p_1^{-1}\left(m_{t-1}-\bar{p}\bar{c}^t,\bar{c}^t,m_t\right.\right.\end{bmatrix}=0 \end{aligned} \qquad (14)$$

with $\lambda_t\geq 0$ and $\psi_t\geq 0$ the Lagrange multipliers associated with respectively the budget constraint and Riley constraint in Eq. (6). Optimal choices are summarized in the following lemma.

Lemma 3. *If u satisfies conditions 1, 2 and 4, the unique interior D1 equilibrium consumption is characterized for type* 1 *and* $k,k'=1,\ldots,K$ *by*

$$\frac{u_k\left(c^1,m_1\right)}{u_{k'}\left(c^1,m_1\right)}=\frac{p_k}{p_{k'}} \qquad (15)$$

and for higher types t and $k=2,\ldots,K$ *by*

$$\frac{u_k\left(c^t,m_t\right)+B_{t,k}}{u_1\left(c^t,m_t\right)}=\frac{p_k}{p_1} \qquad (16)$$

with

$$B_{t,k}\equiv\psi_t\begin{bmatrix}\frac{p_k}{p_1}u_1\left(p_1^{-1}\left(m_{t-1}-\bar{p}\bar{c}^t\right),\bar{c}^t,m_t\right)-\\ u_k\left(p_1^{-1}\left(m_{t-1}-\bar{p}\bar{c}^t\right),\bar{c}^t,m_t\right)\end{bmatrix}. \qquad (17)$$

If the Riley constraint in Eq. (6) is not binding, then type t chooses her intrinsic utility maximum. Otherwise, type t consumes too little invisible consumption to maximize intrinsic utility, i.e. $B_{t,k}>0$ such that the intrinsic marginal rate of substitution of invisible consumption for visible good k exceeds their relative price.[13] Rewrite Eq. (16) to see that $B_{t,k}$ measures type t's intrinsic marginal utility loss due to restrictions imposed by signaling upon good k consumption:

$$\frac{p_k}{p_1}u_1\left(c^t,m_t\right)-u_k\left(c^t,m_t\right)=B_{t,k}. \qquad (18)$$

If utility were strongly separable in invisible consumption, such that the marginal utility of each visible good is independent of invisible consumption (i.e. type), then type t's first order conditions for visible goods k and k' imply $\frac{u_k(c^t,m_t)}{u_{k'}(c^t,m_t)}=\frac{p_k}{p_{k'}}$, while the intrinsic marginal rate of substitution of invisible consumption for a visible good exceeds their relative price. Hence, type t discourages imitation by inflating visible consumption up to the visible consumption in the absence of signaling of (generically fictitious) higher income consumers. If preferences are not strongly separable in invisible consumption, then $B_{t,k}$ is larger for visible goods with a higher Edgeworth complementarity to the invisible good. Edgeworth complements to invisible consumption generate, at any $\bar{c}$, less intrinsic marginal utility to lower income types than to type t, and are thus harder to imitate for the former. Type t then shifts visible consumption towards Edgeworth complements to invisible consumption, because this reduces her sacrifices in terms of foregone invisible consumption needed to discourage imitation by lower types.

The signaling bias away from the intrinsic utility maximum implies opportunities for indirect taxation. As long as conditions 1, 2 and 4 are satisfied, the signaling equilibrium is not broken and $\hat{m}$ is unaffected by taxes. Yet, signaling generates an inequality in the intrinsic marginal utility of expenditures on different goods. Thus, a marginal reduction in expenditures on invisible consumption induced by taxes decreases utility more than an equivalent reduction in visible expenditures, and more so for visible Edgeworth

[12] Ng defines pure 'diamond goods' as goods valued for their value, which enter the utility function together with their price. For x a 'diamond good' and y a regular good, p_x and p_y their respective prices and m income, the consumer problem is then

$$\max_{x,y} U(p_x x,y) s.t. p_x x+p_y y\leq m.$$

[13] Verify in the proof of Theorem 1 that if t chooses $\bar{c}^t$ in a D1 S.E., then spectators attribute $\bar{c}>\bar{c}^t$ to a type $t'<t$ with zero probability. Suppose $\psi_t\neq 0$ and $u'_k(c^t,m_t)>\frac{p_k}{p_1}u'_1(c^t,m_t)$, then type t can strictly improve herself by consuming more good k and less c_1, and then $\bar{c}^t$ is not maximizing utility. Thus, $B_{t,k}>0$ if $\psi_t>0$.

complements to invisible consumption. Given the tax problem in Eq. (9), the first order condition for p_k is

$$\begin{aligned}&N\sum\nolimits_{t\in T}\pi_t\frac{\partial W}{\partial u(c^t,m_t)}\sum_{k'=1}^{K}\frac{\partial u\left(c^t,m_t\right)}{\partial c^t_{k'}}\frac{\partial c^t_{k'}}{\partial p_k}\\&+N\xi\sum\nolimits_{t\in T}\pi_t\left(\sum_{k'=1}^{K}(p_{k'}-1)\frac{\partial c^t_{k'}}{\partial p_k}+c^t_k\right)=0,\end{aligned}\tag{19}$$

with ξ the Lagrange multiplier associated with the tax revenue constraint. If the marginal social benefit of income for type t is denoted $\omega_t\equiv\frac{\partial W}{\partial u(c^t,m_t)}\lambda_t$ and $\tilde{c}_k\equiv\sum_{t\in T}\pi_t c^t_k$ represents average equilibrium consumption of good k, then Eq. (19) can be written as[14]

$$\begin{aligned}&-\sum\nolimits_{t\in T}\pi_t\omega_t c^t_k-\sum\nolimits_{t\in T}\pi_t\omega_t\sum_{k'=2}^{K}\overline{B}_{k',t}\frac{\partial c^t_{k'}}{\partial p_k}\\&+\xi\left(\sum\nolimits_{t\in T}\pi_t\sum_{k'=1}^{K}(p_{k'}-1)\frac{\partial c^t_{k'}}{\partial p_k}+\tilde{c}_k\right)=0,\end{aligned}\tag{20}$$

with $\overline{B}_{k',t}\equiv\frac{B_{k',t}}{\lambda}$. Eq. (20) is an uncompensated many-person Ramsey rule, with an extra term due to signaling. Note the resemblance to Sandmo's (1975) result for optimal indirect taxes with externalities. Following Diamond and Mirrlees (1971) and Diamond (1975), one obtains a compensated many-person Ramsey rule using the Slutsky decomposition

$$\frac{\partial c^t_{k'}}{\partial p_k}=\sigma^t_{k',k}-c^t_k\frac{\partial c^t_{k'}}{\partial m_t},\tag{21}$$

where $\sigma^t_{k',k}$ denotes element k',k of type t's Slutsky matrix in equilibrium, reflecting the change in the compensated demand of commodity k' due to a marginal increase in p_k (keeping $\hat{m}$ constant). One considers compensated demand because the income effects $c^t_k\frac{\partial c^t_{k'}}{\partial m_t}$ are generated by any form of taxation (also lump sum) and as such inevitable. Substituting the Slutsky equation into Eq. (20) and defining

$$b_t=\frac{\omega_t}{\xi}+\sum_{k'=1}^{K}(p_{k'}-1)\frac{\partial c^t_{k'}}{\partial m_t}$$

as the net social marginal valuation of income for type t (counting the extra tax revenue received when giving income to type t), the main result of this section is stated in the following proposition.[15]

Proposition 3. *If u satisfies conditions 1, 2 and 4 and all consumers choose their unique D1 equilibrium consumption pattern, then an optimal system of indirect taxes should satisfy for all $k=1,\ldots,K$:*

$$\frac{\sum\limits_{k'=1}^{K}(p_{k'}-1)\sum\limits_{t\in T}\pi_t\sigma^t_{k',k}}{\tilde{c}_k}=-\left[1-\sum_{t\in T}\pi_t\left(b_t\frac{c^t_k}{\tilde{c}_k}\right)\right]+\Omega_k,\tag{22}$$

with

$$\Omega_k\equiv\frac{1}{\tilde{c}_k}\sum_{t\in T}\pi_t\frac{\omega_t}{\xi}\sum_{k'=2}^{K}\overline{B}_{k',t}\frac{\partial c^t_{k'}}{\partial p_k}.\tag{23}$$

If the Riley constraint (6) is not binding for any type, such that all choose their intrinsic optimum (and all Ω_k are zero), then Eq. (22) reduces to the usual many-person Ramsey rule. The left hand side is the 'discouragement index' of good k: the proportional reduction in good k consumption along the compensated demand function due to taxes. Without distributional concerns, efficiency dictates the equality of discouragement indices, as shown by Ramsey (1927). Distributional concerns prescribe a deviation from this equality of discouragement indices: $\sum_{t\in T}\pi_t\left(b_t\frac{c^t_k}{\tilde{c}_k}\right)$ is (an affine mapping of) the covariance of net social marginal valuation of income and the individual share of commodity k consumption. A positive covariance indicates a good consumed relatively more by consumers with a high net social marginal valuation of income (e.g. the poor). The many-person Ramsey rule prescribes a smaller discouragement index for such goods.

Signaling provides a second reason to deviate from Ramsey's equality of discouragement indices, captured by Ω_k. The $\overline{B}_{k',t}$ express type t's intrinsic marginal utility loss due to signaling restrictions upon good k' consumption in monetary terms. Thus, the second summation in Eq. (23) collects the value of the overall change in signaling inefficiencies in type t's consumption due to a marginal increase in p_k. Note that this sum can be both positive and negative, depending on whether a marginal increase in p_k shifts type t's consumption towards or away from goods with a high $\overline{B}_{k',t}$. This measure is multiplied by $\frac{\omega_t}{\xi}$, the monetary marginal social valuation of income for type t, then aggregated over all consumers and finally inversely related to average consumption of good k, to represent the (monetary) social value of changes in signaling inefficiencies per unit of extra tax revenue, due to a marginal increase in p_k. Note that if taxing good k increases signaling inefficiencies for some types and reduces them for others, then whether or not signaling motivates a higher tax on good k depends on the relative social valuation of these types and on their relative numbers. An inequality averse social planner may thus refrain from taxes which make the poor consume more goods of low intrinsic marginal utility, even if this very much reduces signaling inefficiencies in the consumption choices of the rich. If a marginal increase of p_k reduces the social inefficiency from signaling more (Ω_k smaller), then the optimal tax scheme dictates a greater discouragement index for good k (remember that the LHS of Eq. (22) is negative) than the usual many-person Ramsey rule prescribes.

5. Extensions

This section discusses three extensions: preference heterogeneity, other equilibrium selection criteria and nonlinear income taxation.

Preference heterogeneity is deemed an obstacle for tackling signaling by indirect taxes. Ireland (2001) argues that "a four-wheel-drive car may be a necessary vehicle for the countryman but a status symbol for the townsman". First, if countrymen are ex ante distinguishable from townsmen, such that spectators know by which preferences to interpret visible consumption, then different 'preference types' merely play different signaling games. The resulting patterns of intrinsic marginal utilities enter the optimal tax rule much like different income types in the baseline model. Whether a good consumed mostly for intrinsic reasons by some and mostly for signaling by others, is taxed more due to signaling depends amongst others on the social valuation of these types and their relative numbers. Second, the importance of such undesired increases in distortions and of preference heterogeneity as a cap on the use of indirect taxes to correct for signaling is largely an empirical issue, and depends much on the overall similarities in intrinsic marginal utility patterns, induced by similarities in the signaling qualities of goods such as visibility and nonfalsifiability, against preference heterogeneity.

Although D1 is the dominant selection criterion for monotonic signaling games with multiple types, it is not uncontroversial.[16] Mailath et al. (1993) criticize D1 for always ruling out pooling. Higher types t always choose visible consumption to discourage imitation by lower types. They do so at potentially great cost, even for very small π_{t-1}

[14] Substitute Eqs. (14) and (17) into Eq. (19) for $\frac{\partial u(c^t,m_t)}{\partial c^t_{k'}}$. Then differentiate type t's budget constraint to p_k to obtain $\sum\limits_{k'=1}^{K}p_{k'}\frac{\partial c^t_{k'}}{\partial p_k}=-c^t_k$, and substitute this in Eq. (19).

[15] Substitute Eq. (21) into Eq. (20) for the $\frac{\partial c^t_{k'}}{\partial p_k}$ between brackets, add $\sum\limits_{k'=1}^{K}(p_{k'}-1)\sum_{t\in T}\pi_t\sigma^t_{k',k}$ to both sides of Eq. (20) and divide by $\xi\tilde{c}_k$.

[16] An extensive critique of D1 can be found in a.o. Fudenberg and Tirole (1991) and Mailath et al. (1993).

such that pooling with types $t-1$ barely diminishes $\hat{m}$. Selecting separation, even if pooling Pareto dominates the Riley outcome, seems unreasonable. Mailath et al. (1993) propose undefeated equilibrium[17] as an alternative, and advance one undefeated equilibrium: lexicographic maximum sequential equilibrium (LMSE).[18] Mailath et al. (1993) demonstrate that under conditions 1, 2 and 3 or 4, the LMSE is always undefeated, and that any fully separating undefeated equilibrium is always a LMSE.

For simplicity, I restrict the discussion of taxation for undefeated equilibria to two types and define average income $\bar{m} = \pi_1 m_1 + (1-\pi_1)m_2$. First consider pure costly signaling.

Proposition 4. *If u satisfies conditions 1, 2 and 3, then*

1. *a unique $\pi_1^* \in (0,1)$ exists such that pooling at $\bar{c} = 0$ is the unique LMSE strategy profile if $\pi_1 < \pi_1^*$, and the Riley outcome characterizes the unique LMSE and undefeated equilibrium if $\pi_1 > \pi_1^*$,*
2. *if $\pi_1 < \pi_1^*$, no burden free revenue is raised in LMSE, taxes equal a linear income tax with $p_1 = \frac{\bar{m}N}{\bar{m}N-R}$ and type 1 consumes less c_1 and achieves higher utility in the LMSE than in the Riley outcome.*

If lower types are sufficiently rare, then higher types prefer pooling. This reduces pure costly signaling, and thereby the potential for burden free taxes. Considering pooling thus lessens the importance of signaling for indirect taxes in the pure costly signaling case.

Does pooling also weaken the case for mixed signaling? Not necessarily. Suppose that Riley constraint (6) is binding and that the high type prefers pooling. Type 2 has no reason to choose visible consumption which coincides with type 1's intrinsic optimum. Rather, type 2 chooses her intrinsic optimum, given $\hat{m}$, such that for all goods k and k' consumption satisfies $\frac{u_k\left(p_1^{-1}(m_2-\bar{p}\bar{c}),\bar{c},\hat{m}\right)}{u_{k'}\left(p_1^{-1}(m_2-\bar{p}\bar{c}),\bar{c},\hat{m}\right)} = \frac{p_k}{p_{k'}}$. If the lowest type prefers pooling with type 2 in the latter's intrinsic optimum for $\hat{m} = \bar{m}$ to separation, then a pooling LMSE exists in which both types choose this consumption, denoted $\bar{c}^p$. If the lowest type's gain in impression on spectators from m_1 to $\bar{m}$ cannot compensate her utility loss from deviating from her intrinsic optimum to $\bar{c}^p$, then a S.E. in mixed strategies exists in which type 1 randomizes between her intrinsic optimum (and being recognized as type 1) and the intrinsic optimum of type 2 for $\hat{m} \in (\bar{m}, m_2)$.[19] In both cases, pooling with type 2 makes type 1 bias her consumption in a way similar to type 2 in the separating equilibrium. Type 1 consumes less invisible consumption in the pooling than in the D1 equilibrium, such that the intrinsic marginal rate of substitution of invisible consumption for a visible good exceeds their relative prices. Second, if visible good k is more Edgeworth complementary to invisible consumption than visible good k', then type $t-1$'s intrinsic marginal rate of substitution of good k' for good k exceeds their relative prices. Hence, pooling induces signaling inefficiencies in the consumption of the lowest rather than the highest type, and the pattern of intrinsic marginal utilities characterizing the inefficiency resembles that of higher types in the separating equilibrium. This motivates similar optimal indirect taxes as the D1 equilibrium. The relative importance of the signaling term in the tax rule for both equilibria depends, amongst other things, on the size of signaling inefficiencies in both equilibria, on the social planner's inequality aversion and on types' relative frequency.

How do nonlinear income taxes affect the indirect taxes in Eqs. (22) and (23)? The justification of indirect taxes was much undermined by Atkinson and Stiglitz (1976), who showed indirect taxation redundant in the presence of nonlinear direct taxation if households differ only in earning ability and have identical preferences which are weakly separable in leisure and consumption. Several departures from these conditions have suggested motivations for differential indirect tax schemes.[20] Our analysis suggests signaling as an additional argument for differential indirect taxes in the presence of nonlinear direct taxation.

If labor supply is inelastic, first best nonlinear income taxes equal type specific lump sum taxes, and equate in the optimum all post tax incomes. Then no type can distinguish herself, and since such a tax removes all signaling opportunities, signaling motivates no differential indirect tax in this case.

Optimal second best nonlinear direct taxes are beyond the scope of this article, but our analysis complements work by Norman Ireland (1998, 2001) on optimal direct taxes with status signaling. Ireland considers a continuum of ability types, who supply labor and spend the gained income on (intrinsic) consumption and pure costly signaling. Signaling induces consumers to exert too much effort, while income taxes imply disincentives for labor and thus offset signaling distortions in labor. Ireland (1998) derives conditions under which a linear income tax of which the revenues are uniformly redistributed is Pareto improving: lower types benefit from redistribution, while high types enjoy a decrease in equilibrium signaling. Ireland (2001) finds that signaling motivates a steeper but not necessarily a more progressive nonlinear income tax.

Our results on indirect taxes complement Ireland's analysis seamlessly. Ireland (1998, 2001) characterizes equilibrium pure costly signaling as equilibrium expenditures, which can be taxed without burden. Introducing indirect taxes in Ireland's framework results in an income tax to offset excessive labor supply and redistribute, and a burden free tax on pure costly signals which recuperates the means wasted on signaling. The case of mixed signaling is more complicated. Multiple intrinsically valuable visible goods complicate the optimal labor supply and optimal income tax most likely beyond analytic tractability. Nevertheless, if signaling induces different intrinsic marginal utilities of expenditures on different goods, then our analysis suggests that an optimal nonlinear tax scheme should generically be complemented with nonuniform indirect taxes.

6. Discussion

If consumers choose consumption both for intrinsic reasons and signaling, they spend too much on visible goods, such that their choices do not maximize intrinsic utility. The welfare loss induced by signaling motivated Roman and medieval rulers to restrict some forms of conspicuous consumption by sumptuary laws. Our model suggests that restricting some visible goods cannot solve the problem. Consumers then establish separation with the remaining freely choosable visible goods, which causes a greater signaling bias (greater difference between intrinsic marginal rates of substitution and relative prices) for these goods. This article rather advocates costly signaling as an opportunity for policy makers. The endogeneity of social meaning with respect to taxes implies that the equilibrium meaning of pretax and post-tax equilibrium consumption bundles is identical. As such, no utility from the communicative function of visible consumption is affected by taxes, and policy makers must focus only on intrinsic utility of consumption. In this sense, a welfarist approach and a

[17] A pure strategy S.E. $(\bar{c}',\beta')$ defeats another pure strategy S.E. $(\bar{c}^o,\beta^o)$ if a visible consumption pattern $\bar{c}^\diamond$ exists such that i) no type chooses $\bar{c}^\diamond$ in $(\bar{c}^o,\beta^o)$, and the set of types who choose $\bar{c}^\diamond$ in $(\bar{c}',\beta')$, denoted $\mathcal{S}$, is nonempty. ii) all types $t \in \mathcal{S}$, are better off in $(\bar{c}',\beta')$ than in $(\bar{c}^o,\beta^o)$, and at least one type is strictly better off in $(\bar{c}',\beta')$ iii) a type $t \in \mathcal{S}$ exists such that $\beta'_t(\bar{c}^\diamond) \neq \frac{\pi_t \mathcal{X}_{(t)}}{\sum_{t' \in \mathcal{S}} \pi_{t'} \mathcal{X}_{(t')}}$ for any $\mathcal{X} : T \rightarrow [0,1]$ which satisfies $\mathcal{X}(t') = 1$ if $t' \in \mathcal{S}$ and t' strictly prefers equilibrium $(\bar{c}^o,\beta^o)$, while $\mathcal{X}(t') = 0$ if $t' \in \mathcal{S}$. A pure strategy S.E. is undefeated if no other pure strategy S.E. can defeat it.

[18] A pure strategy S.E. $\left(\bar{c}',\beta'\right)$ lexicographically dominates another pure strategy S.E. $(\bar{c}^o,\beta^o)$ if a type j exists such that type j strictly prefers $\left(\bar{c}',\beta'\right)$ to $(\bar{c}^o,\beta^o)$, and all types $t > j$ weakly prefer $\left(\bar{c}',\beta'\right)$ to $(\bar{c}^o,\beta^o)$. A pure strategy S.E. is a LMSE if it is not lexicographically dominated.

[19] If $u(p_1^{-1}(m_1-\bar{p}\bar{c}^p),\bar{c}^p,\bar{m}) < u_1 < u(p_1^{-1}(m_1-\bar{p}\bar{c}^p),\bar{c}^p,m_2)$, then a S.E. can be found in which type 1 chooses her intrinsic optimum $\bar{c}^1$ with probability μ with type 2 at $\bar{c}^p_\mu \equiv \arg\max_{\bar{c} \geq 0} \left\{u\left(p_1^{-1}(m_2-\bar{p}\bar{c}),\bar{c},\frac{\mu\pi_1 m_1+\pi_2 m_2}{\mu\pi_1+\pi_2}\right)\right\}$, with μ such that $u^t = u\left(p_1^{-1}(m_1-\bar{p}\bar{c}^p_\mu),\bar{c}^p_\mu,\frac{\mu\pi_1 m_1+\pi_2 m_2}{\mu\pi_1+\pi_2}\right)$.

[20] E.g.: complementarities with leisure (Atkinson and Stiglitz, 1976), multidimensional heterogeneity (Cremer et al., 2001), externalities (Sandmo, 1975) or merit goods (Besley, 1988; Blomquist and Micheletto, 2006).

non-welfarist approach which only considers intrinsic utility prescribe identical optimal tax rules. In both cases, optimal indirect taxes exploit differences in the intrinsic marginal utility of expenditures on different goods. In the extreme case of pure costly signaling, this results in burden-free taxes. If luxuries are consumed more for communication, then our analysis adds an efficiency argument, next to equity, for taxing luxuries more. But if communication through consumption is not restricted to the rich, then efficiency gains can also be made for lower income types.

Some arguments are advanced in the literature against tackling signaling with indirect taxes. Ireland (2001, p.194) writes: "The main [arguments] are that the particular goods in question may change rapidly, and that they may be entangled with goods that are not affected by status contests. For instance, it would be difficult to tax a particular brand of sports shoe higher than other brands. After all, a fashionable sports shoe is still a sports shoe. Also, a four-wheel-drive car may be a necessary vehicle for the countryman but a status symbol for the townsman. Finally, the tax of certain goods at a discriminatory level may be outlawed by trade rules." Moreover, a continuous signaling game may strike readers as unrealistic: even the very rich buy at most a few cars, houses or mobile phones. This suggests a discrete signaling space, which can limit the opportunities for separation. However, cars come in many brands, models, option packs, building years and states of maintenance. Almost all houses are unique and the choice in clothing and other commodities is unseen in history. A discrete signaling game requires a consumption space of extreme dimensionality to reflect this, which likely allows for perfect separation among types and risks prescribing a tax scheme of a similarly unrealistic and practically irrelevant dimensionality. In our continuous approximation, goods can be understood as aggregates of similar commodities, e.g. clothing or cars. More consumption of a good represents a more expensive brand or model. Commodities in the same aggregate are assumed similar in essential signaling qualities such as regular visibility, recognizability and unfalsifiability. Finally, a visible good without luxurious label or design is as much a signal as the most exclusive item, and spectators have no reason to disregard information they observe in a consumer's visible consumption.

Despite the formal resemblance, the proposed tax differs from indirect taxes with a Pigovian component (e.g. Sandmo, 1975), because the tax rate induced by the signaling term in Eq. (23) does not generically reflect a marginal externality. What externality does type t's consumption inflict on whom? An increase in type t's visible consumption drives higher types to increase their visible consumption to preserve separation. But if this is the relevant externality, no Pigovian tax is prescribed in the two types pure costly signaling case, although burden-free tax revenue can be raised. If the relevant externality is rather a decrease in $\hat{m}$ for lower types, this is neither captured by the signaling component in Eq. (23), which reflects inequalities in intrinsic marginal utilities, and not externalities imposed upon other consumers. Clearly, this does not exclude additional Pigovian arguments. Charitable donations are typically encouraged by tax schemes, despite of clear evidence of signaling motives (e.g. Harbaugh, 1998) and humanity would be short of many cultural treasures without the wealth signaling of arts patrons. Positive externalities can motivate subsidies to signaling goods, while foregoing burden-free revenue.

Finally, two important limitations of our analysis need discussion. First, visible consumption was analyzed as a multidimensional signal about a single dimension of heterogeneity. Real world consumers communicate about many different qualities other than wealth, e.g. magnanimity (charitable donations), intelligence or courage, and signaling dynamics are complicated by non-monotonicities, discontinuities and other available information sources. Although the key intuitions of this text – deviations from intrinsic utility maximization motivate differential indirect taxes – remain valid, multidimensional heterogeneity, discontinuities or non-monotonicities certainly complicate, amongst others, the robustness of signaling equilibria with respect to price changes. Second, the partial equilibrium analysis of optimal taxation has neglected the production side. In a general equilibrium with perfect competition, one expects the suggested tax to enhance efficiency by shifting production towards goods which generate more intrinsic utility. This is not necessarily true if signaling goods are produced under imperfect competition, which seems likely for high end luxuries such as exclusive sportscars. If consumers buy goods of brands with great reputation and recognizability, producers may be able to charge prices well above production cost and thus extract rents from consumers. The effect of indirect taxes on production efficiency and rent extraction then depends on the production of brand reputation and status goods and on the pricing choices of producers of such reputable conspicuous goods.

Appendix A. Mathematical appendix

A.1. Proof of Theorem 1

This proof is largely an adaptation of the proofs of lemma 4.1 and propositions 4.1–4.5 in Cho and Sobel (1990) to the present setting.

1. **The problem in equations 5 to 4 is well defined** for this framework. The set of $\bar{c}$ satisfying inequality 6 is compact and nonempty since $m_t > m_{t-1}$ for all $t > 1$, and u is continuous.
2. **If type t' chooses $\bar{c}'$ in a S.E., then no $t'' < t'$ chooses $\bar{c}'' > \bar{c}'$ with positive probability**. Denote

$$z(\bar{c}, t, \hat{m}) \equiv u\left(p_1^{-1}(m_t - \bar{p}\bar{c}), \bar{c}, \hat{m}\right),$$

and assume $\bar{c}''$ and $\bar{c}'$ both feasible for both types. If t' chooses $\bar{c}'$ to get $\hat{m}'$ with a positive probability in a S.E., let $\hat{m}''$ then be the value for $\hat{m}$ making t' indifferent between $\left(\bar{c}', \hat{m}'\right)$ and $\left(\bar{c}'', \hat{m}''\right)$. Then by condition 2, t'' strictly prefers $\left(\bar{c}', \hat{m}'\right)$ to $\left(\bar{c}'', \hat{m}''\right)$: the indifference curves of t'' are steeper for each k in the $(c_k, \hat{m})$ plane such that t'' needs more compensation in $\hat{m}$ for an increase from $\bar{c}'$ to $\bar{c}''$ than t'. If $M^+\left(\bar{c}'', t'\right) \cup M^o\left(\bar{c}'', t'\right) \subseteq M^+\left(\bar{c}'', t''\right) \cup M^o\left(\bar{c}'', t''\right)$, then t'' strictly prefers $\left(\bar{c}', \hat{m}'\right)$ to her equilibrium bundle, a contradiction. Hence, in any D1 S.E. $\beta\left(t'' \middle| \bar{c}''\right) = 0$ and no t'' chooses $\bar{c}''$.
3. If $\bar{c}''$ and $\bar{c}'$ cannot be vector ordered, then construct a $\bar{c}^{\diamond}$ such that t' is indifferent between $(\bar{c}', \hat{m}')$ and $(\bar{c}^{\diamond}, \hat{m}')$, and that $\bar{c}'' > \bar{c}^{\diamond}$.Then proceed as above.
4. **No pooling above** 0. Assume otherwise, such that different types pool at $\bar{c}'$ to get $\hat{m}(\bar{c}')$ and that $t' > t''$ are the highest types in the pool. Then $m_{t'} > \hat{m}(\bar{c}')$ and for any $\bar{c}'' > \bar{c}'$ by point 2, $\beta(t''|\bar{c}') = 0$. Choose $\bar{c}''$ such that t'' is indifferent between $(\bar{c}', \hat{m}(\bar{c}'))$ and $(\bar{c}'', m_t)$. Then by condition 2, t' strictly prefers $(\bar{c}'', m_t)$ to $(\bar{c}', \hat{m}(\bar{c}'))$. Then t' cannot choose $\bar{c}'$ in a S.E.
5. **No pooling at** 0. Let $\bar{m}(t) \equiv \frac{\sum_{t'=1}^{t} \pi_{t'} m_{t'}}{\sum_{t'=1}^{t} \pi_{t'}}$ and note that t separates from the lower types iff for at least one $k > 2$:

$$\left[-\frac{p_k}{p_1} u_1\left(p_1^{-1} m_t, 0, \bar{m}(t)\right) + u_k\left(p_1^{-1} m_t, 0, \bar{m}(t)\right)\right] dc_k + \left[u\left(p_1^{-1} m_t, 0, m_t\right) - u\left(p_1^{-1} m_t, 0, \bar{m}(t)\right)\right] > 0. \tag{24}$$

Hence, u_1 cannot be so high as to inhibit the slightest visible consumption to gain by a discrete jump in $\hat{m}$. Condition 1, ii) requires that u_1 is bounded and u_{K+1} is bounded away from 0, such that a $dc_k > 0$ exists for which Eq. (24) applies.
6. **All D1 S.E. generate the Riley outcome**. If u^t are the utility levels in the Riley outcome, then in any D1 S.E. t gets u^t. Imagine a S.E.

in which t gets a different payoff u_o. As t separates in all S.E. and gets $\hat{m}=m_t$, it must be that $u_o \le u^t$, since the latter is a maximum by construction. On the other hand, it must be that $u_o \ge u^t$, since otherwise a $\bar{c}$ exists such that $t'<t$ cannot benefit from imitation and $u\left(\frac{m_t-\bar{p}\bar{c}}{p_1},\bar{c},m_t\right)>u_o$, which contradicts individual rationality.

7. **Existence**. A S.E. exists in which consumers play strategies with support on solutions to the Riley problem, $\bar{c}^t$, and equilibrium strategies are interpreted $\beta_t(\bar{c}^t)=1$. For each out-of-equilibrium bundle $\bar{c}^\diamond$, define for each type $\tilde{m}_t(\bar{c}^\diamond)$ by $z(\bar{c}^\diamond,t,\tilde{m}_t(\bar{c}^\diamond))=u^t$ and let

$$\tilde{t}\left(\bar{c}^\diamond\right)\equiv \min_T\left\{t\middle|\tilde{m}_t\left(\bar{c}^\diamond\right)=\min_{t'\in T}\tilde{m}_{t'}\left(\bar{c}^\diamond\right)\right\}.$$

Then set the beliefs at $\beta_t\left(\bar{c}^\diamond\right)=1\Leftrightarrow t=\tilde{t}\left(\bar{c}^\diamond\right)$ and $\beta_t\left(\bar{c}^\diamond\right)=0$ otherwise. Hence, D1 concentrates all mass of out-of-equilibrium beliefs on the type most willing to consume $\bar{c}^\diamond$. Note that if $\bar{c}^\diamond>\bar{c}^{t-1}$ and $\bar{c}^\diamond<\bar{c}^t$, then condition 2 implies $\beta_{t-1}\left(\bar{c}^\diamond\right)=1$.
These beliefs are D1 by construction. Strategies are optimal by construction. No equilibrium $\bar{c}$ of a higher type is an improvement by construction. No equilibrium $\bar{c}$ of a lower type is an improvement: if Eq. (6) is binding, then $z\left(\bar{c}^{t-1},t-1,m_{t-1}\right)=z\left(\bar{c}^t,t-1,m_t\right)$ and condition 2 means $z\left(\bar{c}^{t-1},t,m_{t-1}\right)<z\left(\bar{c}^t,t,m_t\right)$. If Eq. (6) is not binding, then $z\left(\bar{c}^t,t,m_t\right)\ge z\left(\bar{c}^{t-1},t,m_t\right)>z\left(\bar{c}^{t-1},t,m_{t-1}\right)$, with the first inequality because t maximizes utility without constraints, and second by monotonicity of utility in $\hat{m}$. No out-of-equilibrium bundle is strictly better than a S.E. consumption pattern: consumers get the same $\hat{m}$ for an equivalent or strictly higher bundle than the S.E. bundle.

A.2. Proof of Proposition 1

1. If condition 3 or 4 and $K=2$ applies, then $u\left(\frac{1}{p_1}(m_{t-1}-\bar{p}\bar{c}),\bar{c},m_t\right)\le\bar{u}^{t-1}$, $\bar{c}>\bar{c}^{t-1}$ and $\bar{p}\bar{c}\le m_t$ define a compact convex set on which a continuous and strictly concave function u is maximized.
2. For $K\ge 3$ define the set of maximal $\bar{c}$ satisfying Eq. (6) with equality

$$L_t^o\equiv sup\left\{\bar{c}\middle|u\left(p_1^{-1}(m_{t-1}-\bar{p}\bar{c}),\bar{c},m_t\right)=\bar{u}^{t-1}\text{ and }\bar{c}\ge 0\right\}$$

and the constrained choice set of t

$$L_t\equiv\left\{\bar{c}\middle|\exists\bar{c}'\in L_t^o:\bar{c}\ge\bar{c}'\text{ and }pc\le m_t\text{ and }\bar{c}\ge 0\right\}.$$

L_t^o contains all $\bar{c}$ which give type $t-1$ utility $\bar{u}^{t-1}$ if $\hat{m}=m_t$, and which are undominated in the $\ge$ vector ordering by any other such $\bar{c}$. We show that $u\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},m_t\right)$ has a unique maximum on L_t. This maximum lies either in $L_t\backslash L_t^o$ or in L_t^o. If in $L_t\backslash L_t^o$, it is the global and unique maximum for t by the strict concavity of u. Then Eq. (6) is not binding and type t chooses her intrinsic optimum s.t. $\frac{u_k\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},m_t\right)}{u_{k'}\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},m_t\right)}=\frac{p_k}{p_{k'}}$. If Eq. (6) is binding, then t's maximum is in L_t^o, and we show that $u\left(p_1^{-1}(m_t-\bar{p}\bar{c}),\bar{c},m_t\right)$ has a unique maximum on L_t^o under conditions 1, 2 and 4.
3. Note that each $\bar{c}\in L_t^o$ is fully characterized by $\tilde{c}\equiv(c_3,\ldots,c_K)$. Define $\tilde{p}\equiv(p_3,\ldots,p_K)$, and $f(\tilde{c})$ such that $(f(\tilde{c}),\tilde{c})\in L_t^o$, i.e.

$$u\left(\frac{m_{t-1}-p_2f(\tilde{c})-\tilde{p}\tilde{c}}{p_1},f(\tilde{c}),\tilde{c},m_t\right)=u^{t-1}.$$

Denote for this proof $u_k^t=u_k\left(\frac{m_t-p_2f(\tilde{c})-\tilde{p}\tilde{c}}{p_1},f(\tilde{c}),\tilde{c},m_t\right)$ and $u_k^{t-1}=u_k\left(\frac{m_{t-1}-p_2f(\tilde{c})-\tilde{p}\tilde{c}}{p_1},f(\tilde{c}),\tilde{c},m_t\right)$ as shorthand notation. Then we need $\tilde{u}(\tilde{c},m_t,m_t)=u\left(p_1^{-1}(m_t-p_2f(\tilde{c})-\tilde{p}\tilde{c}),f(\tilde{c}),\tilde{c},m_t\right)$ being strictly concave w.r.t. $\tilde{c}$. Note that $\frac{\partial f}{\partial c_k}=s_{k,2}^{t-1}(\bar{c},m_t)$ such that the first order condition for c_k is

$$\frac{\partial\tilde{u}}{\partial c_k}=-u_1^t\frac{p_k}{p_1}+u_k^t+\left(-u_1^t\frac{p_2}{p_1}+u_2^t\right)\frac{\partial f}{\partial c_k}=\left(u_1^t\frac{p_2}{p_1}-u_2^t\right)\Delta s_{k,2}^t(\bar{c},m_t)=0.$$

4. Note that if Eq. (6) is binding, then at $\bar{c}\in L_t^o$, we must have $s_{k,2}^t(\bar{c},m_t)<0$ for all k and $p_1u_2^t<p_2u_1^t$, i.e. both numerator and denominator of $s_{k,2}^t(\bar{c},m_t)$ are negative. Assume otherwise, such that e.g. $p_1u_3^t>p_3u_1^t$, then t can improve herself by shifting consumption from c_1 to c_3 and moving strictly above L_t^o, and $\bar{c}$ cannot be a maximum. This motivates the definition of L_t^o s.t. no $\bar{c}$ can be in L_t^o which gives $t-1$ the same utility as a $\bar{c}'$ with $\bar{c}'>\bar{c}$.
5. If $u_1^t\frac{p_2}{p_1}-u_2^t>0$ on L_t^o, the first order condition for an interior maximum is

$$\nabla\tilde{c}\left(\Delta s^t(\bar{c},m_t)\right)=0. \tag{25}$$

A sufficient condition for a unique maximum is the negative definiteness of the Hessian of $\tilde{u}$:

$$\left(\frac{\partial}{\partial c_{k'}}\left(u_1^t\frac{p_2}{p_1}-u_2^t\right)\Delta s_{k,2}^t(\bar{c},m_t)\right)_{k,k'=3,\ldots,K}$$

6. Consider the Lagrangian and its first order conditions

$$\mathcal{L}=u(c,m_t)-\lambda_t(pc-m_t)-\psi_t\left(u\left(p_1^{-1}(m_{t-1}-\bar{p}\bar{c}),\bar{c},m_t\right)-\bar{u}^{t-1}\right)$$

$$u_k(c,m_t)-\lambda_t p_k-\psi_t\begin{pmatrix}-\dfrac{p_k}{p_1}u_1\left(p_1^{-1}(m_{t-1}-\bar{p}\bar{c}),\bar{c},m_t\right)\\+u_k\left(p_1^{-1}(m_{t-1}-\bar{p}\bar{c}),\bar{c},m_t\right)\end{pmatrix}=0 \tag{26}$$

$$u_2(c,m_t)-\lambda_t p_2-\psi_t\begin{pmatrix}-\dfrac{p_2}{p_1}u_1\left(p_1^{-1}(m_{t-1}-\bar{p}\bar{c}),\bar{c},m_t\right)\\+u_2\left(p_1^{-1}(m_{t-1}-\bar{p}\bar{c}),\bar{c},m_t\right)\end{pmatrix}=0 \tag{27}$$

$$u_1(c,m_t)-\lambda_t p_1=0. \tag{28}$$

Substituting Eq. (28) into Eqs. (26) and (27) for λ_t and then substituting Eq. (26) into Eq. (27) for ψ_t, we obtain Eq. (25).

A.3. Proof of Proposition 2

The first order conditions for p_1 and $\bar{p}$ and the budget constraint are

$$\begin{aligned}&N\sum\nolimits_{t\in T}\pi_t\frac{\partial W(\cdot)}{\partial v^{CS}}\frac{\partial v^{CS}(\cdot)}{\partial p_1}-\\&\lambda N\sum\nolimits_{t\in T}\pi_t\left[\frac{c_1^t}{p_1}+\left(\frac{\bar{p}-1}{\bar{p}}-\frac{p_1-1}{p_1}\right)\frac{\partial e(t,p_1)}{\partial p_1}\right]=0,\end{aligned} \tag{29}$$

$$-\lambda N\sum_{t\in T}\pi_t\frac{e(t,p_1)}{(\bar{p})^2}=0. \tag{30}$$

$$N\sum_{t\in T}\pi_t\left(\frac{p_1-1}{p_1}(m_t-e(t,p_1))+\frac{\bar{p}-1}{\bar{p}}e(t,p_1)\right)=\bar{R}. \tag{31}$$

with λ the Lagrange multiplier for the budget constraint. In Eq. (29), one sees that $\lambda\neq 0$ as long as p_1 affects social welfare, i.e.

$\sum_{t\in T} N\pi_t \frac{\partial W(.)}{\partial V^{CS}} \frac{\partial V^{CS}(.)}{\partial p_1} \neq 0$, which is generically true. Because in equilibrium $e(t,p_1)>0$ for all but the lowest type, Eq. (30) is only satisfied if $\bar{p}\to+\infty$, which implies that $\bar{c}^t\to 0$. The overall revenues from taxing visible consumption are

$$N\frac{\bar{p}-1}{\bar{p}}\sum_{t\in T}\pi_t e(t,p_1) = N\sum_{t\in T}\pi_t\left(e(t,p_1)-\bar{c}^t\right). \tag{32}$$

Substituting Eq. (32) in Eq. (31) and collecting p_1 at the LHS, one obtains Eq. (13).

A.4. Proof of Proposition 4

Since $e(2,p_1)$ solves

$$u^{\mathcal{P}}\left(p_1^{-1}(m_1-e(2,p_1)),m_2\right) = u^{\mathcal{P}}\left(p_1^{-1}m_1,m_1\right), \tag{33}$$

and conditions 1 and 2 imply that

$$u^{\mathcal{P}}\left(p_1^{-1}m_2,m_2\right) > u^{\mathcal{P}}\left(p_1^{-1}(m_2-e(2,p_1)),m_2\right) > u^{\mathcal{P}}\left(p_1^{-1}m_2,m_1\right).$$

As such, a unique π_1^* exists for which

$$u^{\mathcal{P}}\left(p_1^{-1}m_2,\pi_1^* m_1+(1-\pi_1^*)m_2\right) = u^{\mathcal{P}}\left(p_1^{-1}(m_2-e(2,p_1)),m_2\right),$$

such that type 2 strictly prefers pooling if $\pi_1<\pi_1^*$. In this case, pooling at $\bar{c}=0$ is the only LMSE, for any $\bar{p}>0$. If no pure costly signaling good is bought, no burden free taxation exists, and $p_1=\frac{\bar{m}}{\bar{m}-\frac{R}{N}}$.

For part 2 of the proposition, note that condition 2 means that $\frac{d\hat{m}}{de}|_{u=\text{constant}}$ is strictly decreasing with m_t, which implies $\frac{\partial^2\hat{m}}{\partial^2 e}|_{u=\text{constant}}>0$, i.e. that the indifference curves in the $(e,\hat{m})$ plane are strictly convex. Take a convex combination for $\pi_1\in(0,1)$ of the bundles at both sides of Eq. (33), such that $u^{\mathcal{P}}(p_1^{-1}(m_1-(1-\pi_1)e(2,p_1)),\bar{m}) > u^{\mathcal{P}}(p_1^{-1}m_1,m_1)$. Finally, in the undefeated equilibrium, with $p_1=\frac{\bar{m}}{\bar{m}-\frac{R}{N}}$, type 1 consumes strictly more c_1 than in the above convex combination for $p_1\approx\frac{\bar{m}-(1-\pi_1)e(2,p_1)}{\bar{m}-\frac{R}{N}}>\frac{\bar{m}}{\bar{m}-\frac{R}{N}}$, i.e. the price of c_1 in the D1 equilibrium:

$$\frac{\bar{m}-\frac{R}{N}}{\bar{m}}m_1 > (m_1-(1-\pi_1)e(2,p_1))\frac{\bar{m}-\frac{R}{N}}{\bar{m}-(1-\pi_1)e(2,p_1)} \Leftrightarrow m_1<\bar{m}.$$

Hence, type 1 obtains a strictly higher utility in the pooling than in the D1 equilibrium, but consumes strictly less c_1 in the former.

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