Costly Signaling and Indirect Taxation

Tom Truyts
Center for Economic Studies - K.U. Leuven
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Abstract

Commodities communicate. Consumers choose a consumption bundle both for its intrinsic characteristics and for what this bundle communicates about their qualities (or 'identity') to spectators. This paper investigates optimal indirect taxation when consumption bundles serve both ordinary intrinsic consumption and costly signaling. Optimal indirect taxes are introduced into a monotonic signaling game with a finite typespace of consumers, who differ in one dimension (income) and use a finite dimensional visible consumption bundle to signal their income to spectators. It is shown that in the case of pure costly signaling, signaling goods can in equilibrium be taxed without burden, such that the optimal quantity taxes on these goods are infinite. When all visible commodities serve both intrinsic consumption and signaling, optimal taxes may be characterised by a generalisation of the Ramsey rule, which not only cares about efficiency and distribution in the traditional way, but also cares about reducing the distortions resulting from signaling.

1 A rose is a rose is a rose

Commodities communicate. This seems especially true for post-industrial economies, where brands, product design, lifestyles and (subcultural) identities drive culture and economy to extraordinary pluriformity. In assessing all possible consumption bundles, consumers care both about the intrinsic qualities of the bundles and about what their choice reveals about the consumer to spectators. The intrinsic qualities of a commodity are the (mostly physical) characteristics of the commodity itself, which would still be there when the commodity is consumed in total social isolation. Utility derived from these intrinsic characteristics is named 'intrinsic utility'. What a commodity (or bundle) communicates may be understood as the social meaning of this commodity and the locus of this social meaning is in the head of the spectators rather than the commodity. The social meaning of a commodity stems from the consumption choices of all consumers in society, thus introducing an interpersonal interdependency in the utility function. One may generally distinguish two irreducible dynamics governing social meaning: conformity and distinction. Conformist mechanisms originate from consumers' desire to confirm or claim their membership of some group and may to be thought of as cheap talk style signaling. Distinction at the other hand, concerns consumers distinguishing themselves from worse types. Distinction results in costly signaling, as only signals which are too costly for worse types to mimic may credibly communicate superior quality. Clearly, these two mechanisms interact in various ways in reality, but they are studied separately here for the sake of exposition.

This chapter considers optimal indirect taxation when commodities serve both intrinsic consumption and communication. Levying indirect taxes changes the relative prices and reduces the budget set of all and thereby has two different effects. Firstly, all consumers suffer a utility loss from their reduced consumption due to taxation. However, the overall utility loss for a consumer is less than it would have been for an equivalent reduction in consumption by this consumer alone, because taxes also change the social meaning of the consumption bundle. If all consume less, one also needs to spend less to stand out or fit in. As such, a reduced post tax consumption bundle may still communicate the same to spectators as the original bundle, such that the tax imposes no burden on the utility one gets from communicative qualities of the commodity. Building on the 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 chapter can be summarized as: if one taxes roses sufficiently, one rose will suffice again to get the same job done in rich societies.

This chapter investigates optimal indirect taxation, characterised by a generalisation of the multi-person Ramsey rule, in a framework of multidimensional monotonic signaling with multiple consumer types, which differ only in one dimension: income. The model exposed in this chapter builds on both the costly signaling literature initiated by Spence (1973) and surveyed in Riley (2001) and on the literature on optimal indirect taxation, as discussed in e.g. Atkinson and Stiglitz (1980) and Myles (1995). More specifically, the multidimensional signaling framework hinges on work by Cho and Sobel (1990) and Ramey (1996). A first part of the analysis in this chapter shows the case of commodities which are uniquely consumed for signaling and shows that these goods may in equilibrium be taxed without burden. This idea resembles and underpins the burden free taxes explored by Ng (1987) for the case of 'diamond goods'(cfr. infra). The optimal indirect taxation analysis when goods are used for both signaling and intrinsic consumption, in the second part of this chapter, resembles work on indirect taxation with externalities (e.g. Sandmo, 1975, Cremer, Gahvari and Ladoux, 1998) or merit goods (Blomquist and Micheletto, 2006), in the sense that the optimal consumer choice is biased away from the social welfare optimum. Signaling induces consumers to consume too much of some commodities from a welfare perspective, such that taxing these causes less welfare loss than other taxes.More generally, this line of reasoning relates to taxes on consumption motivated by relative concerns. Frank (1985, 1999) calls for a progressive tax on overall consumption, which is deemed to be largely driven by relative concerns and therefore self-defeating in terms of social welfare. This chapter differs from this last literature in the fact that it is explicit about the mechanism driving the relative concerns and that it establishes a rule for differential indirect taxation of commodity groups which are used for communication, based on their potential to serve for communication and other structural characteristics. Ireland (1994) explores commodity taxes in a unidimensional signaling model and shows a numerical example of how a small tax on a signaling commodity may be a Pareto improvement.

In the second section, the formal setting of the model and the signaling equilibrium are introduced which serves. The third section deals with the special case of pure costly signaling, in which commodities serve either only intrinsic consumption or signaling. It is shown that these last goods may be taxed without burden, such that the revenues derived from taxing such pure costly signaling goods are pure gain. The optimal quantity tax on the pure costly signal is then infinite. In the fourth section, all goods except one invisible good serve both intrinsic consumption and communication. Optimal commodity taxation is in this case characterised by a generalisation of the multi-person Ramsey rule (see e.g. Atkinson and Stiglitz, 1980), which deals with the case where consumer choice is biased by signaling motivations. The fifth section concludes.

2 Setting and signaling equilibrium

Imagine a population of N consumers, who differ only in income. Let the typespace be represented by $\Theta = \left\{1, ..., \bar{\theta}\right\} \subset \mathbb{N}_0 \backslash \left\{1\right\}$, such that the population consists of $\bar{\theta}$ types, indexed by $\theta \in \Theta$, which have income $m_\theta \in \mathbb{R}_+$. Assume without loss of generality that the different consumer types are indexed such that $m_\theta < m_{\theta'} \Leftrightarrow \theta < \theta'$. The prior probability that a consumer is of type θ is denoted π_θ and $\Pi = (\pi_1, ..., \pi_{\bar{\theta}})$ is a $\bar{\theta}$-dimensional vector containing all prior probabilities. All consumers may spend their income on $K > 1$ (with $K \in \mathbb{N}$) perfectly divisible commodities, indexed by $1 \leq k \leq K$. The K-dimensional vector of consumed commodities is represented by $C \equiv (c_1, ..., c_K) \in \mathbb{R}_+^K$ and the vector of commodities consumed by a type $\theta \in \Theta$ consumer is denoted $C_\theta \equiv (c_{\theta,1}, ..., c_{\theta,K}) \in \mathbb{R}_+^K$. Commodity c_1 is called the 'invisible' commodity, in the sense that its consumption is not observed by spectators, while $\bar{C} \equiv (c_2, ..., c_K) \in \mathbb{R}_+^{K-1}$ is a vector containing the visible consumption of a consumer. Again, $\bar{C}_\theta$ is the visible consumption pattern of a type θ consumer.

Let $P \equiv (p_1, ..., p_K) \in \mathbb{R}_{++}^K$ denote the vector of producer prices and $\bar{P} \equiv (p_2, ..., p_K) \in \mathbb{R}_{++}^{K-1}$ the producer price vector of all the visible commodities. All producer prices are assumed to be fixed. All consumers are assumed to be price-takers. Let $T \equiv (t_1, ..., t_K) \in \mathbb{R}^K$ be a vector of (linear) quantity taxes, with t_k a quantity tax on the k-th commodity and let $\bar{T} \equiv (t_2, ..., t_K)$ be the vector of quantity taxes on the visible commodities. These taxes may be either positive, zero or negative, such that they may also function as a subsidy. The budget constraint of a type θ consumer is $(P+T)' C \leq m_\theta$ and the budget set

$$\mathcal{B}(m_\theta, P, T) \equiv \left\{C : (P+T)' C \leq m_\theta, C \in \mathbb{R}_+^K\right\}$$

consists of all consumption bundles which a type θ consumer can afford.[1] Similarly, let

$$\bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T}) \equiv \left\{\bar{C} : \left(\bar{P}+\bar{T}\right)' \bar{C} \leq m_\theta, \bar{C} \in \mathbb{R}_+^{K-1}\right\}$$

be the set of all visible consumption bundles which a type θ consumer can buy.

Preferences may by assumption be represented by a utility function, which has consumption and the spectators' estimate of the consumer's income, denoted $\hat{m}$, as arguments:

$$U\left(C, \hat{m}\left(\beta\left(\bar{C}\right)\right)\right) : \mathbb{R}_+^K \times [m_1, m_{\bar{\theta}}] \to \mathbb{R}_+. \tag{1}$$

This utility function will sometimes be written $U\left(c_1, \bar{C}, \hat{m}\left(\beta\left(\bar{C}\right)\right)\right)$, i.e. with the vector C split up in invisible and visible consumption. This utility function is identical for all consumers and is common knowledge. Let $0 \leq \beta\left(\theta; \bar{C}\right) \leq 1$ denote the spectators' beliefs about the probability of a consumer with visible consumption $\bar{C}$ being of income type θ and $\beta\left(\bar{C}\right)$ the $\bar{\theta}$-dimensional vector of posterior beliefs defined over Θ. The set of all vectors of beliefs over typespace Θ is denoted as

$$\Omega\left(\Theta\right) = \left\{\beta\left(\bar{C}\right) \in \mathbb{R}^{\bar{\theta}} : \beta\left(\theta, \bar{C}\right) \geq 0, \sum_{\theta \in \Theta} \beta\left(\theta, \bar{C}\right) = 1\right\},$$

and for a smaller support $\tilde{\Theta} \subset \Theta$ denoted $\Omega\left(\tilde{\Theta}\right)$. The expected income, given beliefs $\beta\left(\bar{C}\right)$, is then $\hat{m}\left(\beta\left(\bar{C}\right)\right) = \sum_{\theta \in \Theta} \beta\left(\theta; \bar{C}\right) m_\theta$. This expected income, given the spectators' beliefs about the income type of a consumer with visible consumption bundle $\bar{C}_\theta$, is taken to be the argument in the signalers utility function.[2] A number of regularity conditions is imposed on the utility function.

Condition 1 *Let $U(.)$ satisfy the following conditions:*

1. *Let $U(.)$ be C^2 in all $K+1$ arguments.*

[1] Where X' denotes the transposition of vector X.

[2] In most signaling games, a receiver observes and interprets the visible consumption $\bar{C}$, and chooses a utility maximising action as best reply to the signal $\bar{C}$, according to his beliefs about the type of the sender after observing $\bar{C}$. It is assumed that the optimal responses of the receiver are described by a unique best reply function $BR\left(\hat{m}\left(\beta\left(\bar{C}\right)\right)\right)$, which is strictly monotonically increasing in $\hat{m}\left(\beta\left(\bar{C}\right)\right)$. The utility of the sender is assumed to increase strictly and monotonically in the reply of the receiver. The utility function in formula 1 takes the beliefs of the receiver, represented by the expected value $\hat{m}\left(\beta\left(\bar{C}\right)\right)$, directly as an argument, and is as such shorthand notation, omitting the receiver's best reply. Next to this interpretation, in which spectators' beliefs are instrumental, one may also interpret this specification as if $\hat{m}(.)$ is a good on itself, as consumers may also enjoy esteem for its own sake.

2. *Let* $\forall k \in \{2,...,K\} : \frac{\partial U(.)}{\partial c_k} \geq 0,\ \frac{\partial U(.)}{\partial c_1} > 0$ *and* $\frac{\partial U(.)}{\partial \hat{m}} > 0.$

3. *Let* $\frac{\partial^2 U(.)}{\partial^2 c_1} < 0.$

4. *For* $\theta < \theta'$ *and* $\bar{C} < \bar{C}'$: *if* $U\left(\frac{m_\theta - (\bar{P}+\bar{T})'\bar{C}}{p_1+t_1}, \bar{C}, \hat{m}\right) \leq U\left(\frac{m_\theta - (\bar{P}+\bar{T})'\bar{C}}{p_1+t_1}, \bar{C}', \hat{m}'\right)$, *then* $U\left(\frac{m_{\theta'} - (\bar{P}+\bar{T})'\bar{C}}{p_1+t_1}, \bar{C}, \hat{m}\right) < U\left(\frac{m_{\theta'} - (\bar{P}+\bar{T})'\bar{C}'}{p_1+t_1}, \bar{C}', \hat{m}'\right)$.[3]

5. *Let* $\frac{\partial U(0,\bar{C},\hat{m}(\beta(\bar{C})))}{\partial c_1} = +\infty\ \forall \bar{C} \in \bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T})$ *and* $\hat{m}(\beta(\bar{C})) \in [m_1, m_{\bar{\theta}}]$ *and let* $\frac{\partial U(.)}{\partial c_k}$ *and* $\frac{\partial U(.)}{\partial \hat{m}(\beta(\bar{C}))}$ *be bounded for* $C \in \mathbb{R}^K_{++}$ *for all* $k \in \{1,...,K\}$.

Under condition 1, utility maximisation implies that all consumers fully exploit their income, such that $c_{1,\theta} = m_\theta - (\bar{P}+\bar{T})'\bar{C}_\theta$ and that a signaling strategy $\bar{C}_\theta$ fully describes optimal behaviour of a type θ consumer, C_θ. The signaling problem consumers face under condition 1 is generally known is the literature as a monotonic signaling game and is largely inspired by Spence (1973). The essential characteristics of a monotonic signaling game are firstly that the optimal reaction of the receivers of the signal is strictly increasing (or monotonic) in the signal sent and that the utility of the sender is strictly increasing (monotonic) in the reaction of the receiver, which are both captured by the assumption that $\frac{\partial U(C,\hat{m}(\beta(\bar{C})))}{\partial \hat{m}} > 0$. Secondly, it is assumed that higher types can send any message at a lower marginal cost. This "single crossing" assumption is captured by the assumption that utility is strictly increasing and strictly concave in the invisible good. Hence the opportunity cost of any visible consumption bundle is always higher for lower income types. Part 4 of condition 1 is the full multidimensional single crossing condition, which ensures that second order derivatives are really such that the marginal opportunity cost in terms of utility from invisible good c_1 is always lower for higher income types at any level of $\bar{C}$. This condition is satisfied whenever for all $\bar{C}$ and all $\hat{m} \in [m_1, m_{\bar{\theta}}] : \forall k = 2,...,K : MRS_{c_k,\hat{m}} = -\frac{\frac{\partial U(.)}{\partial c_k}}{\frac{\partial U(.)}{\partial \hat{m}}} = -\frac{-\frac{p_k+t_k}{p_1+t_1}\frac{\partial U(.)}{\partial c_1} + \frac{\partial U(.)}{\partial c_k}}{\frac{\partial U(.)}{\partial \hat{m}}}$ is strictly decreasing in θ.[4] The condition that $\frac{\partial U(0,\bar{C},\hat{m}(\beta(\bar{C})))}{\partial c_1} = +\infty$ and that marginal utility is bounded elsewhere excludes corner solutions.

Definition 1 (Signaling Strategy) *A pure 'signaling strategy' of a type* θ *consumer given prices* P *and taxes* T *is a* $\bar{C}(\theta; P, T) \in \bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T})$ *and* $\bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T})$ *is the 'pure strategy space' of a type* θ *consumer.*

[3] Here, $\bar{C} < \bar{C}'$ means $\bar{C} \neq \bar{C}'$ and $\forall k = 2,...,K : c_k \leq c'_k$.

[4] In fact, Engers (1987) and Ramey (1996) provide a weaker condition under which the main results of this paper are still true. Let for a given visible consumption bundle $\bar{C}$ and impression $\hat{m}$ the set $Z(\theta|\bar{C},\hat{m}) \equiv \left\{MRS_{\bar{C},\hat{m}}(\theta')\,|\theta' \leq \theta\right\}$ contain all the vectors of marginal rates of substitution between the visible commodities and impression at levels $\bar{C}$ and $\hat{m}$ for types weakly lower than type θ. Engers' (1987) requires that if a vector z is in the convex hull of $Z(\theta|\bar{C},\hat{m})$ and $MRS_{\bar{C},\hat{m}}(\tilde{\theta}) \geq z$, then $\tilde{\theta} \leq \theta$.

Definition 2 (Mixed Signaling Strategy) *A 'mixed signaling strategy' $\mu(\theta, P, T)$ of a type θ consumer at prices and taxes P and T is a probability distribution over the strategy space $\bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T})$. If $\mu\left(\bar{C}; \theta, P, T\right)$ denotes the probability attributed to visible consumption pattern $\bar{C}$ (a 'pure strategy'), then all mixed strategies $\mu(\theta, P, T) : \bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T}) \to (\mathbb{R}_+)^{\bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T})}$ are such that $\int\limits_{\bar{\mathcal{B}}(m_\theta, P, T)} \mu\left(\bar{C}; \theta, P, T\right) d\bar{C} = 1$. The mixed strategy space of a type θ consumer is the set of all probability distributions over $\bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T})$ and denoted $\mathcal{D}(m_\theta, \bar{P}, \bar{T})$.*

Since consumers of the same income type are identical, one may write a pure strategy profile in terms of signaling strategies of the different types: $\left\langle \bar{C}(P, T) \right\rangle \in \prod\limits_{\theta \in \Theta} \mathcal{B}(m_\theta, \bar{P}, \bar{T})$. A mixed strategy profile in terms of consumer types is a $\bar{\theta}-$dimensional tuple of mixed signaling strategies $\langle \mu(P, T) \rangle \in \prod\limits_{\theta \in \Theta} \mathcal{D}(m_\theta, \bar{P}, \bar{T})$.

Within the setting exposed in this section, Perfect Bayesian Equilibrium and Sequential Equilibrium are equivalent equilibrium concepts for this signaling game (Fudenberg and Tirole, 1991). A sequential equilibrium consists of a tuple of utility maximising signaling strategies and consistent beliefs, where consistency means that beliefs are updated according to Bayes' rule.

Definition 3 (Sequential Equilibrium) *A tuple $\left\langle \left\langle \mu^*\left(\bar{C}; \theta, P, T\right) \right\rangle, \beta^*\left(\bar{C}\right) \right\rangle$ is a Sequential Equilibrium (SE) if $\mu^*\left(\bar{C}; \theta, P, T\right)$ maximises utility for each type θ given beliefs $\beta^*\left(\bar{C}\right)$ and beliefs $\beta^*\left(\bar{C}\right)$ are consistent given $\left\langle \mu^*\left(\bar{C}; \theta, P, T\right) \right\rangle$ in the sense of Bayesian rationality:*

1. *For each type $\theta \in \Theta$,*

$$\mu^*\left(\bar{C}; \theta, P, T\right) \in$$
$$\arg\max_{\mu(\bar{C})} \left\{ \int U\left(\frac{m_\theta - \left(\bar{P} + \bar{T}\right)' \bar{C}}{p_1 + t_1}, \bar{C}, \hat{m}\left(\beta^*\left(\bar{C}\right)\right) \right) \mu\left(\bar{C}\right) d\bar{C} \right\}$$

   given $\beta^*\left(\bar{C}\right)$.

2. *Beliefs are updated after observing a consumption pattern along Bayes' rule for all $\bar{C}' \in \operatorname{supp}\left\langle \mu^*\left(\bar{C}; P, T\right) \right\rangle$, such that* [5]

$$\beta^*\left(\theta; \bar{C}'\right) = \frac{\pi_\theta \mu^*\left(\bar{C}'; \theta, P, T\right)}{\sum\limits_{\theta \in \Theta} \pi_\theta \mu^*\left(\bar{C}'; \theta, P, T\right)}.$$

A sequential equilibrium is called 'separating' if the supports of the various equilibrium consumption patterns do not intersect, i.e. if

$$\forall \theta, \theta' \in \Theta, \theta \neq \theta' : supp\left(\mu^*\left(\bar{C}; \theta, P, T\right)\right) \cap supp\left(\mu^*\left(\bar{C}; \theta', P, T\right)\right) = \varnothing,$$

[5] With $supp\left(\mu^*\left(\bar{C}; P, T\right)\right) = \bigcup\limits_{\theta \in \times} \left(supp\left(\mu^*\left(\bar{C}; \theta, P, T\right)\right)\right)$.

such that equilibrium consumption patterns can be attributed by equilibrium beliefs to a single consumer type with probability 1.

The sequential equilibrium concept imposes however no restrictions on beliefs about out-of-equilibrium consumption patterns (except that they should 'support' the equilibrium) and this allows commonly for an unappealing multitude of counterintuitive equilibria. The class of monotonic signaling games typically has infinitely many sequential equilibria (e.g. Spence, 1973). For this reason, a number of Nash equilibrium refinements have been proposed for signaling games, which specifically impose restrictions on beliefs over out-of-equilibrium consumption patterns. One particular sequential equilibrium, however, has attracted most of the attention, as it is deemed the most plausible equilibrium of monotonic signaling games: the "Pareto Dominant Separating Equilibrium", also known as the "Riley outcome", after work by John Riley (1979) focussing extensively on this particular equilibrium. The Riley outcome is generated by a separating equilibrium in which each consumer type buys just enough of the signal to discourage imitation by lower types. This separating equilibrium Pareto dominates all other separating equilibria.

Definition 4 (Riley Outcome) *The Riley outcome is generated by the fully separating strategy profile which is a solution to the iterative constrained optimisation problem*

$$\max_{\bar{C}_\theta} U = \quad U\left(\frac{m_\theta - \left(\bar{P}+\bar{T}\right)' \bar{C}_\theta}{p_1+t_1}, \bar{C}_\theta, m_\theta\right) \tag{2}$$

$$s.t. \qquad \left(\bar{P}+\bar{T}\right)' \bar{C}_\theta \leq m_\theta \tag{3}$$

$$\forall\theta \in \left\{2,...,\bar{\theta}\right\} : U\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}_\theta}{p_1+t_1}, \bar{C}_\theta, m_\theta\right) \tag{4}$$

$$< U\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}^*_{\theta-1}}{p_1+t_1}, \bar{C}^*_{\theta-1}, m_{\theta-1}\right)$$

and beliefs which identify each type truthfully with probability one.

For the lowest type, the Riley outcome dictates a consumption pattern which maximises

$$\max_{\bar{C}_1} U = U\left(\frac{m_1 - \left(\bar{P}+\bar{T}\right)' \bar{C}_1}{p_1+t_1}, \bar{C}_1, m_1\right).$$

Hence, the lowest income consumers just maximise utility as if there were no signaling concerns. They have no lower types to distinguish themselves from, such that their consumption is unconstrained by signaling motivations. All the higher types choose a consumption pattern which maximises utility under the constraint that worse types (by the single crossing condition, the constraint on type $\theta - 1$ is sufficient to discourage all worse types) would be strictly worse off if they would imitate visible consumption pattern $\bar{C}^*_\theta$. Since such an equilibrium is fully separating, equilibrium beliefs satisfy $\beta\left(\theta;\bar{C}^*_\theta\right)=1$ and hence $\hat{m}\left(\beta\left(\bar{C}^*_\theta\right)\right)=m_\theta$. The strict inequality in constraint 4 implies that the actual values of a strategy profile leading to the Riley outcome cannot be computed if the constraint is binding (i.e. there is no maximum), such that only supremum can be found. This supremum is of course found by replacing the strict inequalities by weak inequalities in constraint 4, leading to the following constraint (further in this chapter named the 'Riley constraint'):

$$\begin{aligned} \forall\theta &\in \left\{2,...,\bar{\theta}\right\}: U\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}_\theta}{p_1+t_1},\bar{C}_\theta,m_\theta\right) \\ &\leq U\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}^*_{\theta-1}}{p_1+t_1},\bar{C}^*_{\theta-1},m_{\theta-1}\right). \end{aligned} \tag{5}$$

On the class of monotonic signaling games, the Riley outcome satisfies most common equilibrium refinement criteria. Cho and Kreps (1987) show that for $\bar{\theta}=2$ the so-called Intuitive Criterion leaves only the Riley outcome unrejected. For $\bar{\theta}>2$ however, the stronger Divinity (D1) criterion[6] is required to provide sufficient cutting power. Cho and Sobel (1990) demonstrate the existence and uniqueness in terms of outcome of the D1 equilibrium for the class of monotonic signaling games for a finite typespace and both a finite and infinite multidimensional signal space. This D1 equilibrium is shown to be the Riley outcome. Cho and Kreps (1987) and Cho and Sobel (1990) demonstrate that this D1 equilibrium necessarily satisfies strategic stability in the sense of Kohlberg and Mertens (1986). Motivated by this equilibrium selection literature, the remainder focusses solely on the D1 equilibrium or Riley outcome to characterise consumer behaviour.

To derive the optimal indirect tax vector T, one also needs to define the objectives and constraints of the policy maker within this setting. Let $\mu^*(\theta,P,T)$ represent an equilibrium mixed signaling strategy of a type θ consumer at prices P and taxes T and let $\beta^*(.)$ be the equilibrium beliefs. The indirect expected utility function of a consumer with income m_θ at prices P and taxes T, denoted $V(m_\theta,P,T)$, represents this consumer's expected utility when she behaves along an equilibrium strategy and when her actions are interpreted conform the equilibrium beliefs. It is obtained by substituting the optimal (mixed) signaling

[6] Divinity (D1) eliminates a first consumer type out of the support of the beliefs $\beta^*\left(\bar{C}^\diamondsuit\right)$ following an out-of-equilibrium consumption pattern $\bar{C}^\diamondsuit$, if a second type has a strict incentive to deviate to $\bar{C}^\diamondsuit$ whenever the first type under investigation has a weak incentive to deviate. Hence, let $M^+(\theta,\bar{C}^\diamondsuit)$ be the set of beliefs which induce a type θ consumer to deviate from the sequential equilibrium to an out-of-equilibrium consumption pattern $\bar{C}^\diamondsuit$, and let $M^o(\theta,\bar{C}^\diamondsuit)$ be the set of beliefs which makes type θ as well off with out-of-equilibrium consumption pattern $\bar{C}^\diamondsuit$ as she was in equilibrium. Then Divinity requires that all types θ for whom there is a type θ' which prefers $\bar{C}^\diamondsuit$ strictly to the equilibrium whenever θ prefers $\bar{C}^\diamondsuit$ weakly to the equilibrium, i.e. $M^+(\theta,\bar{C}^\diamondsuit)\cup M^o(\theta,\bar{C}^\diamondsuit)\subset M^+(\theta',\bar{C}^\diamondsuit)$, are eliminated from the support of the out-of-equilibrium beliefs.

strategy into the utility function:

$$V(m_\theta, P, T) \equiv \int\limits_{\mathcal{B}(m_\theta, \bar{P}, \bar{T})} U(\frac{m_\theta - (\bar{P}+\bar{T})' \bar{C}}{p_1 + t_1}, \bar{C}, \hat{m}(\beta^*(\bar{C})))\mu^*(\bar{C}; \theta, P, T)\, d\bar{C}.$$

Let $\mathbf{V}(P,T) \in \mathbb{R}_+^N$ represent a vector containing the maximised utility levels of all N consumers at prices P and indirect taxes T, given a signaling equilibrium. The optimal tax problem requires the specification of a social welfare function, where it is generally assumed that social welfare can be represented as a strictly increasing function of (only) the individual utility levels of all consumers. A Bergson-Samuelson social welfare function of some general form

$$W(\mathbf{V}(P,T)) : \mathbb{R}_+^N \to \mathbb{R}_+$$

may then be used to map all constellations of individual utility levels onto the positive real numbers, attributing higher values to more socially desirable constellations of utility levels.

Given a signaling equilibrium characterized by mixed strategies $\mu^*(\theta, P, T)$ and beliefs $\beta^*(\bar{C})$, the the expected tax revenue of an indirect taxation scheme T is

$$R(T) \equiv N \sum_{\theta \in \Theta} \pi_\theta \int\limits_{\bar{\mathcal{B}}(m_\theta, \bar{P}, \bar{T})} \left[\bar{T}' \bar{C} + t_1 \frac{m_\theta - (\bar{P}+\bar{T})' \bar{C}}{p_1 + t_1} \right] \mu^*(\bar{C}; \theta, P, T)\, d\bar{C}$$

The optimal taxation problem is then

$$\max_T W(\mathbf{V}(P,T)) \quad s.t. \;\; R(T, \Gamma^*) \geq \bar{R},$$

i.e. to find, given the equilibrium consumption patterns, an indirect taxation scheme which maximises social welfare under the government revenue constraint that the expected revenues are not smaller than some level $\bar{R} \in \mathbb{R}_+$.

As far as information is concerned, the underlying assumptions of this model are that all consumers know the preference ordering and the distribution of the different income types (and prices and taxes), but not the actual type of other consumers and that all know that all know etc. All consumers observe each other's visible consumption bundle. The government is equally supposed to know the preference orderings and prior distribution of the different consumer types, but does not know the actual type of each consumer and does not observe the actual consumption levels of consumers. Although seemingly contradictory, these last assumptions about the governments knowledge have in fact different functionalities: the assumption of known preference orderings serves to allow the government to maximise social welfare and could be known from investigating a representative sample. The only role of the assumption that factual consumption is not observed by the government, is to exclude any nonlinear indirect tax scheme. This assumption is therefore equivalent to restricting the attention to linear tax schemes, since any nonlinear scheme would be vulnerable to arbitrage under this assumption.

3 The pure costly signaling case

The simplest case is the baseline case of pure costly signaling, after Spence (1973), in which the visible consumption goods serve only one purpose: distinguishing oneself from worse types and thereby communicating one's income to spectators. This pure costly signaling case may be formalised by condition 2.

Condition 2 *Let* $\forall k \in \{2, ..., K\} : \frac{\partial U(.)}{\partial c_{k,\theta}} = 0, \frac{\partial^2 U(.)}{\partial c_{k,\theta} \partial c_{1,\theta}} = 0$ *and* $\frac{\partial^2 U(.)}{\partial c_{k,\theta} \partial \hat{m}} = 0$.

Since the vector $\bar{C}$ does not affect utility directly, the utility function can actually be rewritten as a function of two arguments,

$$U^{CS}\left(\frac{m_\theta - \left(\bar{P} + \bar{T}\right)' \bar{C}}{p_1 + t_1}, \hat{m}\left(\beta\left(\bar{C}\right)\right)\right).$$

Hence, in this case consumers only derive utility directly from the invisible good c_1 and from $\hat{m}(.)$, such that the $K-1$ visible goods in $\bar{C}$ affect utility only directly through $\hat{m}(.)$. Under condition 2, all $K-1$ visible goods are equivalent ways of conspicuously wasting purchasing power, such that it is of no importance on which of the $K-1$ visible consumption goods this purchasing power is wasted. Only the total expenditure on $\bar{C}$ matters and expenditures on all visible goods are interchangeable. This can also be seen by rewriting the consumer problem defining the Riley outcome 4 for the pure costly signaling case (and omitting $c_{1,\theta} \geq 0$):

$$\max_{\bar{C}_\theta} U^{CS}\left(\frac{m_\theta - \left(\bar{P} + \bar{T}\right) \bar{C}_\theta}{p_1 + t_1}, \hat{m}\left(\beta\left(\bar{C}_\theta\right)\right)\right)$$
$$U^{CS}\left(\frac{m_{\theta-1} - \left(\bar{P} + \bar{T}\right) \bar{C}_\theta}{p_1 + t_1}, m_\theta\right) \leq U^{CS}\left(\frac{m_{\theta-1} - \left(\bar{P} + \bar{T}\right) \bar{C}^*_{\theta-1}}{p_1 + t_1}, m_{\theta-1}\right). \tag{6}$$

Assume that $\bar{P} + \bar{T} \in \mathbb{R}^{K-1}_{++}$. To ensure separation, such that $\hat{m}\left(\beta\left(\bar{C}_\theta\right)\right) = m_\theta$, consumer type θ needs to spend exactly such an amount $\left(\bar{P} + \bar{T}\right) \bar{C}_\theta$ (or rather infinitesimally little more) to make a lower type indifferent between wasting $\left(\bar{P} + \bar{T}\right) \bar{C}_\theta$ from her income $m_{\theta-1}$ to be perceived as a θ type and wasting $\left(\bar{P} + \bar{T}\right) \bar{C}^*_{\theta-1}$ to appear of a type $\theta - 1$. Hence, denoting by $\bar{E}(m_\theta, P, T) \equiv \left(\bar{P} + \bar{T}\right)' \bar{C}_\theta$ the total expenditure on visible consumption goods of a consumer type θ, one may characterise the solution to the Riley problem for a type θ consumer as the unique amount of expenditure on visible consumption, $\bar{E}^*(m_\theta, P, T)$ which solves

$$\max_{\bar{E}} U^{CS}\left(\frac{m_\theta - \bar{E}}{p_1 + t_1}, m_\theta\right)$$
$$\forall \theta \in \left\{2, ..., \bar{\theta}\right\} : U^{CS}\left(\frac{m_{\theta-1} - \bar{E}}{p_1 + t_1}, m_\theta\right) \leq U^{CS}\left(\frac{m_{\theta-1} - \bar{E}^*(m_{\theta-1}, P, T)}{p_1 + t_1}, m_{\theta-1}\right) \tag{7}$$

$$c_{1,\theta} \geq 0.$$

A particular feature of this equilibrium expenditure is that it is independent of the post-tax prices of visible goods $\left(\bar{P}+\bar{T}\right)$, $\bar{E}^*(m_\theta, P, T) = \bar{E}^*(m_\theta, p_1, t_1)$. The Riley constraint only imposes consumers to waste enough in terms of opportunity costs to keep worse types from mimicking and there is no reason why the optimal amount of wasted c_1 should depend on $\left(\bar{P}+\bar{T}\right)$. One may easily see that any solution $\bar{E}^*$ to the iterative problem in equation 7 depends for all θ on the own income m_θ, on $m_{\theta-1}$ (and through $\bar{E}^*(m_{\theta-1}, P, T)$ on the incomes of all lower types), on p_1 and t_1 and on the utility function $U(.)$, but not on $\bar{P}$ and $\bar{T}$. These equilibrium features are summarised in the following lemma.

Lemma 1 *In the pure costly signaling case, in which the utility function satisfies conditions 1 and 2:*

1. *All D1 equilibria* $\left\langle\left\langle\mu^*\left(\bar{C};\theta,P,T\right)\right\rangle,\beta^*\left(\bar{C}\right)\right\rangle$ *are characterised by the Riley outcome, such that*

$$\operatorname{supp}\left(\mu^*\left(\bar{C};\theta,P,T\right)\right) \subseteq \left\{\bar{C} : \left(\bar{P}+\bar{T}\right)'\bar{C} = \bar{E}^*(m_\theta, p_1, t_1)\right\}$$

2. *Equilibrium expenditures on visible consumption are independent of prices of and taxes on visible goods* $\bar{P}$ *and* $\bar{T}$*.*

Hence, the set of D1 equilibria consists of all mixed strategy profiles which have a subset of the hyperplane defined by $\left(\bar{P}+\bar{T}\right)'\bar{C}_\theta = \bar{E}^*(m_\theta, p_1, t_1)$ for support. Since all these equilibria are fully separating, equilibrium beliefs attribute equilibrium signals with certainty to the consumer type consuming such a consumption pattern in equilibrium.

The infinite number of equilibrium mixed strategies considerably complicates the derivation of an optimal indirect tax tuple. Since expenditure on any two visible goods is completely interchangeable, one may without much loss of generality restrict $\bar{C}$ to be unidimensional for the remainder of this section on the pure costly signaling. It will be clear that the results obtained for $K = 2$ in this section easily extend to $K > 2$. Note that for $K = 2$ the equilibrium demand for visible consumption as a function of the own post tax price may be written

$$\bar{C}^*(m_\theta, P, T) \equiv \frac{\bar{E}^*(m_\theta, p_1, t_1)}{p_2 + t_2},$$

such that the own post-tax price elasticity of the demand for visible goods is then necessarily -1 everywhere:

$$\frac{\partial\bar{C}^*(m_\theta, P, T)}{\partial\left(p_2+t_2\right)}\frac{\left(p_2+t_2\right)}{\bar{C}^*(m_\theta, P, T)} = -\frac{\bar{E}^*(m_\theta, p_1, t_1)}{\left(p_2+t_2\right)^2}\frac{\left(p_2+t_2\right)}{\bar{C}^*(m_\theta, P, T)} = -1.$$

This means that in the pure costly signaling case the equilibrium demand functions for visible goods of all (except the lowest) consumer types are necessarily rectangular hyperbola as a function of the own price and hence so is the aggregate demand function as well.

The insensitivity of equilibrium expenditures on visible goods to the own price implies an interesting potential for indirect taxation in the pure costly signaling case: visible goods may in equilibrium be taxed without burden. As such, revenues from taxing the visible good are pure profit for society.

Lemma 2 *As long as the quantities of $\bar{C}$ are perfectly perceivable, the utility of consumers is unaffected by taxes on the visible good in equilibrium in the pure costly signaling case:*

$$\frac{\partial V^{CS}\left(m_\theta, P, T\right)}{\partial t_2} = 0,$$

in which $V^{CS}(m_\theta, P, T) \equiv U^{CS}\left(\frac{m_\theta}{p_1+t_1} - \frac{\bar{E}^*(m_\theta,p_1,t_1)}{p_1+t_1}, m_\theta\right)$ *and* $U^{CS}(.)$ *satisfies conditions 1 and 2.*

The reason for this remarkable feature is that both arguments of the utility function remain unaffected by taxes on visible consumption, as long as the signaling equilibrium is maintained. Firstly, since expenditure on visible goods is independent of the post-tax price of visible goods, the equilibrium amount of invisible consumption is not affected by a tax on visible goods. Secondly, as long as the fully separating equilibrium is maintained, all types will be recognised as the income type they really are, so that the second argument is not affected by changes in p_2 or t_2 either. As p_2 or t_2 increase, the equilibrium demand for visible good $\bar{C}$ diminishes. But since the equilibrium consumption of all types is affected by the post-tax price change, the changes are exactly compensated by a change in the meaning of each visible bundle $\hat{m}\left(\beta\left(\bar{C}\right)\right)$. In terms of roses: a husband who needs 10 roses to show his love in a rich society, would not succeed in convincing his wife if he would unilaterally decide to only buy two roses. But if roses became very scarce in the same society, such that the meaning of e.g. two roses is what 10 roses meant before, then the husband can confidently walk home with only two roses in his hand.

The optimal tuple of indirect taxes maximises the policy maker's problem:

$$\max_T \mathcal{L} = W\left(\mathbf{V}\left(P,T\right)\right) - \lambda\left[N\sum_{\theta\in\Theta}\pi_\theta\left(t_2\bar{C}^*(.) + t_1\frac{m_\theta - \bar{E}^*(m_\theta,p_1,t_1)}{p_1+t_1}\right) - \bar{R}\right],$$

in which λ represents the Lagrange multiplier. The first order condition for t_1 is then

$$\sum_{\theta\in\Theta} N\pi_\theta \frac{\partial W(.)}{\partial V^{CS}}\frac{\partial V^{CS}(.)}{\partial t_1} - \tag{8}$$

$$\lambda N\sum_{\theta\in\Theta}\pi_\theta\left[\begin{array}{c}\left(\frac{m_\theta}{p_1+t_1} - \frac{\bar{E}^*(m_\theta,p_1,t_1)}{p_1+t_1}\right) + \frac{t_2}{(p_2+t_2)}\frac{\partial\bar{E}^*(m_\theta,p_1,t_1)}{\partial t_1} \\ +t_1\left(-\frac{m_\theta}{(p_1+t_1)^2} - \frac{\frac{\partial\bar{E}^*(m_\theta,p_1,t_1)}{\partial t_1}(p_1+t_1) - \bar{E}^*(m_\theta,p_1,t_1)}{(p_1+t_1)^2}\right)\end{array}\right] = 0$$

and the first order condition for t_2 is

$$-\lambda N \sum_{\theta \in \Theta} \pi_\theta \left(\bar{C}(.) + t_2 \frac{\partial \bar{C}^*(.)}{\partial t_2} \right) = 0,$$

which may as $\frac{\partial \bar{C}^*(.)}{\partial t_2} = -\frac{\bar{E}^*(m_\theta, p_1, t_1)}{(p_2+t_2)^2}$ be rewritten as

$$-\lambda N \sum_{\theta \in \Theta} \pi_\theta \left(\frac{p_2}{p_2 + t_2} \bar{C}^*(.) \right) = 0. \tag{9}$$

The government's revenue constraint remains, if binding,

$$N \sum_{\theta \in \Theta} \pi_\theta \left(t_2 \bar{C}^*(.) + t_1 \frac{m_\theta - \bar{E}^*(m_\theta, p_1, t_1)}{p_1 + t_1} \right) - \bar{R} = 0. \tag{10}$$

From equation 8, one sees that $\lambda \neq 0$ as long as t_1 affects social welfare, i.e. as long as $\sum_{\theta \in \Theta} N \pi_\theta \frac{\partial W(.)}{\partial V^{CS}} \frac{\partial V^{CS}(.)}{\partial t_1} \neq 0$, which generically is the case. Since $p_2 > 0$, equation 9 can only be satisfied if

$$\frac{t_2}{p_2 + t_2} \rightarrow 1,$$

or that $t_2 \rightarrow \infty$, which clearly implies that $\bar{C}^*(m_\theta, P, T) \rightarrow 0$. Since taxing the visible good does in equilibrium not affect utility, this potential should be maximally exploited and the income wasted on costly signaling should be recuperated as much as possible. The overall revenues from taxing visible consumption can be written

$$Nt_2 \sum_{\theta \in \Theta} \pi_\theta \frac{\bar{E}^*(m_\theta, p_1, t_1)}{p_2 + t_2} = N \sum_{\theta \in \Theta} \pi_\theta \bar{E}^*(m_\theta, p_1, t_1) - p_2 N \sum_{\theta \in \Theta} \pi_\theta \frac{\bar{E}^*(m_\theta, p_1, t_1)}{p_2 + t_2}, \tag{11}$$

in which the last term at the right hand side represents the part of expenditures which the producers of visible goods still collect and $\frac{\bar{E}^*(m_\theta, p_1, t_1)}{p_2+t_2}$ the quantity of visible goods purchased at post-tax price $p_2 + t_2$. This quantity obviously converges to zero as t_2 goes to infinity, such that $N \sum_{\theta \in \Theta} \bar{E}^*(m_\theta, p_1, t_1)$ is the supremum of tax revenue from visible consumption goods. Substituting equation 11 in equation 10 and solving for t_1, one obtains

$$\frac{t_1}{p_1 + t_1} = \frac{\frac{\bar{R}}{N} - t_2 \sum_{\theta \in \Theta} \pi_\theta \frac{\bar{E}^*(m_\theta, p_1, t_1)}{p_2+t_2}}{\sum_{\theta \in \Theta} \pi_\theta \left(m_\theta - \bar{E}^*(m_\theta, p_1, t_1) \right)}, \tag{12}$$

which means that the tax rate on invisible goods should equal the ratio of the difference between per capita required tax revenue and per capita tax revenue raised on visible goods to total per capital expenditure on invisible goods.

Hence, t_1 should be a subsidy of invisible consumption if the burden-free tax revenues from visible consumption exceed the required revenues. If the required revenues exceed the burden-free revenue from taxing visible consumption, then these revenues should be raised by a tax on invisible consumption.

Proposition 1 *In the D1 equilibrium of the pure costly signaling game, in which the utility function satisfies conditions 1 and 2, visible consumption good can be taxed without burden. Optimal indirect taxes are in equilibrium therefore*

$$\frac{t_1}{p_1+t_1} = \frac{\frac{\bar{R}}{N} - t_2 \sum_{\theta\in\Theta} \pi_\theta \frac{\bar{E}^*(m_\theta,p_1,t_1)}{p_2+t_2}}{\sum_{\theta\in\Theta} \pi_\theta \left(m_\theta - \bar{E}^*(m_\theta,p_1,t_1)\right)}$$

$$\frac{t_2}{p_2+t_2} \rightarrow 1$$

The result is that each consumer type, by buying the infinitely taxed visible consumption good, conspicuously contributes just enough to the required tax revenue to distinguish herself from any lower income types. The policy maker collects all the means which need to be wasted for social distinction. This result can be interpreted as underpinning the burden free tax result of Ng (1987) for the case of pure diamond goods. Ng defines pure 'diamond goods' as goods which are uniquely valued for their value and therefore 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

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

This section shows that pure costly signaling goods are necessarily pure diamond goods.

Clearly, this result hinges crucially on the perfect divisibility and perfect observability of the visible good. Very high taxes on the visible good only leave the individual unaffected if the very small consumed quantities of the visible good of different types can be distinguished, such that the different consumer types can be identified by spectators. This assumption is clearly highly unrealistic, such that the optimal tax result rather implies very high than infinite taxes on visible goods.

4 The mixed signaling case

In reality, not too many (if any) consumption goods serve only costly signaling. Mostly, consumers use every day consumption goods, often with luxurious characteristics, to distinguish themselves from worse consumer types. These premium characteristics are mostly directly functional in some way: consumers still derive utility from them in complete social isolation. The difference is that these conspicuous premium characteristics are excessively costly for the extra utility they generate, compared to some other less conspicuous good which would generate more extra utility in social isolation. The conspicuous and costly premium characteristics have a second function however: they signal the type of their consumer, thus generating extra utility which would not be enjoyed in social isolation. Highly visual and premium consumption goods are therefore relatively more consumed than in social isolation, because they serve two purposes: intrinsic consumption and communication.

Formally, I take the utility function now to be strictly increasing and strictly concave in all K first arguments. Hence, similarly to the invisible good c_1, all visible goods now always generate intrinsic utility and the marginal utility they deliver is decreasing in the number of already consumed units. As far as intrinsic consumption is concerned, the visible consumption goods are ordinary consumption goods, similar to invisible consumption.

Condition 3 *Let* $\frac{\partial U(.)}{\partial c_{k,\theta}} > 0$ *and* $\frac{\partial^2 U(.)}{\partial^2 c_{k,\theta}} < 0 \ \forall k \in \{2, ..., K\}$.

Under the assumption of conditions 1 and 3, only sequential equilibria which generate the unique Riley outcome of this mixed signaling game survive the D1 criterium (cfr. supra). Therefore, the problem of each consumer type may be written in terms of the Riley problem in equations 2 to 4 under conditions 1 and 3, which becomes for the lowest income type 1:

$$\max_{C} \mathcal{L} = U(C, m_1) - \lambda_1 \left((P+T)' C - m_1 \right),$$

in which λ_1 is the Lagrange multiplier associated with the budget constraint of type 1. This is a simple everyday consumer problem, which generates the usual set of first order conditions which requires that the marginal utility of a cent invested in each of the K goods equals the marginal utility of income, while taking $\hat{m}(\beta(.)) = m_1$ as given:

$$\forall k = 1, ..., K : \frac{1}{p_k + t_k} \frac{\partial U(C_1^*, m_1)}{\partial c_{k,1}} = \lambda_1. \tag{13}$$

The optimal choice of the lowest consumer type is the consumption bundle she would choose in the absence of signaling concerns and which is sometime called her 'intrinsic optimum'. Similarly, the intrinsic optimum of all higher types θ, denoted C_θ^o, is characterised by

$$\forall k = 2, ..., K : \frac{1}{p_k + t_k} \frac{\partial U(C_\theta^o, m_\theta)}{\partial c_{k,\theta}} = \frac{1}{p_1 + t_1} \frac{\partial U(C_\theta^o, m_\theta)}{\partial c_{1,\theta}},$$

which is their optimal choice if $\hat{m}(\beta(.)) = m_\theta$ were exogenously fixed, e.g. because income is directly visible. If m_θ is not visible, then the unique D1 equilibrium consumption pattern C_θ^* of each type $\theta > 1$ is characterised by the

Riley outcome and is an iterative solution, given $C^*_{\theta-1}$, to:

$$\max_C \mathcal{L} = U(C, m_\theta) - \lambda_\theta \left((P+T)' C - m_\theta\right)$$

$$-\mu_\theta \left[\begin{array}{c} U\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}_\theta}{p_1+t_1}, \bar{C}_\theta, m_\theta\right) - \\ U\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}^*_{\theta-1}}{p_1+t_1}, \bar{C}^*_{\theta-1}, m_{\theta-1}\right) \end{array} \right],$$

where λ_θ and μ_θ are the Lagrange multipliers associated with respectively the budget and Riley constraint of a type θ consumer. The unique D1 equilibrium consumption pattern is then characterised by the iterative set of first order conditions of a type θ consumer, summarised in the following lemma.

Lemma 3 *If $U(.)$ satisfies conditions 1 and 3, the unique D1 equilibrium consumption pattern is characterised by the iterative equations*

$$\frac{1}{p_1+t_1}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{1,\theta}} = \lambda_\theta \tag{14}$$

$$\frac{1}{p_k+t_k}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{k,\theta}} = \lambda_\theta + \mu_\theta \left[\begin{array}{c} -\frac{1}{p_1+t_1} U'_1\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right) \\ +\frac{1}{p_k+t_k} U'_k\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right) \end{array} \right]$$

$$\lambda_\theta \geq 0,\ \mu_\theta \geq 0,\ \mu_1 = 0 \text{ and } \forall k = 2, ..., K, \forall \theta \in \Theta.$$

How to interpret this equilibrium consumption pattern? Clearly, if incomes are so distant that the Riley constraint is not binding, such that $\mu_\theta = 0$, each type θ consumer chooses her intrinsic optimum. If $\mu_\theta \neq 0$, the term between square brackets is the marginal cost of an increased consumption of good k by a cent to a type $\theta - 1$ mimicker of the θ type (i.e. how much less utility a cent spent on good k delivers compared to the invisible good 1 to type $\theta - 1$) and μ_θ is the valuation of this utility cost cost by the θ type consumer. The first term $\frac{\partial U\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)}{\partial c_{1,\theta}}$ is the same for all visible goods $\forall k = 2, ..., K$, while the term $U'_k\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)$ concerns the dependency of the marginal utility of a visible good k on invisible consumption. To appreciate the term between square brackets fully, first assume that utility would be separable in invisible consumption, such that $\forall k = 2, ..., K : U''_{1,k}(.) = 0$ and note that in this case the first order conditions of all $K - 1$ visible goods can be written

$$\forall k = 2, ..., K : \frac{1}{p_k+t_k}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{k,\theta}} = \frac{\lambda_\theta}{1-\mu_\theta} - \tag{15}$$

$$\frac{\mu_\theta}{1-\mu_\theta} \frac{U'_1\left(\frac{m_{\theta-1}-\left(\bar{P}+\bar{T}\right)'\bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)}{p_1+t_1}, \tag{16}$$

in which the right hand side is independent of k. Also, it follows from equation 14 that for all visible goods $k = 2, ..., K$

$$(1-\mu_\theta)\frac{1}{p_k+t_k}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{k,\theta}} = \frac{1}{p_1+t_1}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{1,\theta}} - \mu_\theta \frac{1}{p_1+t_1} U'_1\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right), \tag{17}$$

which implies that

$$\frac{1}{p_k+t_k}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{k,\theta}} < \frac{1}{p_1+t_1}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{1,\theta}}$$

since $U'_1\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right) > \frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{1,\theta}}$. This means that in the case of a utility function which is separable in invisible consumption, all types $\theta > 1$ mimic the visible intrinsically optimal consumption pattern of a (generically fictitious) higher income type. Equation 15 states that the marginal utility of a cent invested in each of the visible commodities should be equal in the optimum, just like in the intrinsic optimum. Equation 17 however, states that the marginal utility of a cent invested in a visible good is strictly smaller than that of a cent invested in the invisible good c_1 if the Riley constraint is binding ($\mu_\theta > 0$). This means that type $\theta > 1$ consumers inflate their visible consumption to a visible consumption pattern which consumers with a higher income would choose in the absence of signaling motives, just to discourage lower types from mimicking their visible consumption and thus pooling with them.

If visible consumption is not separable from invisible consumption, then the term $U'_k\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)$ in equations 14 causes a deviation in visible consumption away from the visible intrinsic optimum of higher income types, towards visible goods with a higher complementarity with the invisible good c_1 (and hence relatively smaller $U'_k\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)$).

$$\forall k = 2, ..., K : \frac{1}{p_k+t_k}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{k,\theta}} - \mu_\theta \frac{1}{p_k+t_k} U'_k\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)$$
$$= \frac{1}{p_1+t_1}\frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{1,\theta}} - \mu_\theta \frac{1}{p_1+t_1} U'_1\left(\frac{m_{\theta-1} - \left(\bar{P}+\bar{T}\right)' \bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)$$

A higher complementarity with invisible consumption implies that the marginal utility of such a visible commodity is relatively smaller if one consumes less invisible consumption c_1 (i.e. for lower income types). As such, imitating the visible good k of a higher type which is complementary with c_1 is more costly for lower types and this feature is exploited in the optimal visible consumption pattern of all but the lowest income type. For the remainder of this section, let

$$B_{k,\theta} \equiv \mu_\theta \left[\frac{\frac{\partial U\left(\frac{m_\theta - 1 - (\bar{P}+\bar{T})'\bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)}{\partial c_{k,\theta}}}{p_k + t_k} - \frac{\frac{\partial U\left(\frac{m_\theta - 1 - (\bar{P}+\bar{T})'\bar{C}^*_\theta}{p_1+t_1}, \bar{C}^*_\theta, m_\theta\right)}{\partial c_{1,\theta}}}{p_1 + t_1} \right]$$

represent the bias term due to signaling away from the equality of marginal utility per cent of expenditure on each good k, thus indicating how much less marginal utility a cent spent on good k delivers to a type θ consumer compared to a cent spent on the invisible good.

The bias away from the intrinsic optimum caused by signaling motives again reveals interesting opportunities for optimal indirect taxation. To see this, first note that changes in the commodity prices will again not break up the separating D1 signaling equilibrium, such that all types will in equilibrium be recognised by spectators as their true self, $\hat{m}\left(\bar{C}^*_\theta\right) = m_\theta$. Hence, the $K+1$th argument of the utility function will remain unaffected by indirect taxes. Second, since the Riley constraint generates an inequality in the marginal intrinsic utility which a marginal cent spent on each of the K commodities generates, a reduction in the consumption of the invisible good may be expected to induce more utility loss than an equivalent reduction of a visible good, as prescribed by the traditional Ramsey rule, would. Similarly, a reduction in the consumption of a visible good which is complementary with c_1 can be expected to generate a smaller utility loss than an equivalent reduction of a visible good which is less complementary with invisible consumption.

The policy maker's problem is to choose a tax policy T which satisfies the tax revenue constraint and which is such that the D1 signaling equilibrium maximises social welfare. The problem of the policy maker is

$$\max_T \mathcal{L} = W\left(\mathbf{V}\left(P,T\right)\right) - \xi\left(\bar{R} - N\sum_{\theta\in\Theta}\pi_\theta T' C^*_\theta\right),$$

with ξ the Lagrange multiplier associated with the government tax revenue constraint.

The first order condition for any tax t_j is

$$\begin{aligned} & N\sum_{\theta\in\Theta}\pi_\theta \frac{\partial W}{\partial U(C^*_\theta, m_\theta)} \sum_{k=1}^{K} \frac{\partial U(C^*_\theta, m_\theta)}{\partial c_{k,\theta}} \frac{\partial c^*_{k,\theta}}{\partial t_j} \\ +N\xi & \sum_{\theta\in\Theta}\pi_\theta \left(\sum_{k=1}^{K} t_k \frac{\partial c^*_{k,\theta}}{\partial t_j} + c^*_{j,\theta}\right) = 0 \qquad \forall j = 1, ..., K. \end{aligned} \tag{18}$$

Using equations 13 and 14, these first order conditions in equation 18 may be rewritten as:

$$\sum_{\theta\in\Theta}\pi_\theta\frac{\partial W}{\partial U(C_\theta^*,m_\theta)}\left((p_1+t_1)\lambda_\theta\frac{\partial c_{1,\theta}^*}{\partial t_j}+\sum_{k=2}^{K}(p_k+t_k)(\lambda_\theta+B_{k,\theta})\frac{\partial c_{k,\theta}^*}{\partial t_j}\right) \tag{19}$$
$$+\xi\sum_{\theta\in\Theta}\pi_\theta\left(\sum_{k=1}^{K}t_k\frac{\partial c_{k,\theta}^*}{\partial t_j}+c_{j,\theta}^*\right)=0 \qquad \forall j=1,...,K.$$

Define the marginal social benefit of an extra unit of income for a type θ consumer as $\omega_\theta \equiv \frac{\partial W}{\partial U(C_\theta^*,m_\theta)}\lambda_\theta$, let $\bar{c}_j^* \equiv \sum\limits_{\theta\in\Theta}\pi_\theta c_{j,\theta}^*$ represent average equilibrium consumption of good j and take the derivative of the budget constraint for some type θ with respect to tax t_j, such that

$$\sum_{k=1}^{K}(p_k+t_k)\frac{\partial c_{k,\theta}^*}{\partial t_j}=-c_{j,\theta}^*.$$

Using this, the first order conditions may be written

$$-\sum_{\theta\in\Theta}\pi_\theta\omega_\theta c_{j,\theta}^*+\sum_{\theta\in\Theta}\pi_\theta\frac{\partial W}{\partial U(C_\theta^*,m_\theta)}\sum_{k=2}^{K}(p_k+t_k)B_{k,\theta}\frac{\partial c_{k,\theta}^*}{\partial t_j} \tag{20}$$
$$+\xi\left(\sum_{\theta\in\Theta}\pi_\theta\sum_{k=1}^{K}t_k\frac{\partial c_{k,\theta}^*}{\partial t_j}+\bar{c}_j^*\right)=0 \qquad \forall j=1,...,K.$$

The expression in equation 20 may already be seen as an uncompensated version of the multi-person Ramsey rule, with an extra term due to signaling motives. Note also the strong resemblance between this optimal indirect tax prescription and that of Sandmo (1975) for optimal indirect taxes with externalities. Following Diamond and Mirrlees (1971) and Diamond (1975), one may obtain a variant of the usual compensated multi-person Ramsey rule by employing the Slutsky decomposition on the $\frac{\partial c_{k,\theta}^*}{\partial t_j}$ between round brackets, i.e. use

$$\frac{\partial c_{k,\theta}^*}{\partial t_j}=S_{k,j,\theta}-c_{j,\theta}^*\frac{\partial c_{k,\theta}^*}{\partial m_\theta}.$$

Here $S_{k,j,\theta}$ denotes element k,j of the Slutsky matrix of a type θ consumer in equilibrium, reflecting the first order effect of a change in the compensated demand of commodity k because of a marginal increase in the price of commodity j. One only considers the distortion generated by taxation along the compensated demand, because the income effects $c_{j,\theta}^*\frac{\partial c_{k,\theta}^*}{\partial m_\theta}$ would be generated by any form of taxation (also lump sum), such that this distortion is inevitable for any tax scheme. Substituting the Slutsky equation into equation 20, one obtains

$$\xi\left(\sum_{k=1}^{K} t_k \sum_{\theta\in\Theta} \pi_\theta S_{k,j,\theta}\right) = -\xi \bar{c}_j^* + \xi \sum_{\theta\in\Theta} \pi_\theta \sum_{k=1}^{K} t_k c_{j,\theta}^* \frac{\partial c_{k,\theta}^*}{\partial m_\theta}$$

$$+\sum_{\theta\in\Theta} \pi_\theta \omega_\theta c_{j,\theta}^* - \sum_{\theta\in\Theta} \pi_\theta \frac{\partial W}{\partial U(C_\theta^*, m_\theta)} \sum_{k=2}^{K} B_{k,\theta}\left(p_k + t_k\right) \frac{\partial c_{k,\theta}^*}{\partial t_j} \qquad \forall j = 1, ..., K$$

or

$$\frac{\sum_{k=1}^{K} t_k \sum_{\theta\in\Theta} \pi_\theta S_{k,j,\theta}}{\bar{c}_j^*} = -\left[1 - \sum_{\theta\in\Theta} \pi_\theta \frac{\omega_\theta c_{j,\theta}^*}{\xi \bar{c}_j^*} - \sum_{\theta\in\Theta} \pi_\theta \sum_{k=1}^{K} t_k \frac{c_{j,\theta}^*}{\bar{c}_j^*} \frac{\partial c_{k,\theta}^*}{\partial m_\theta}\right]$$

$$-\frac{1}{\bar{c}_j^*} \sum_{\theta\in\Theta} \frac{\pi_\theta}{\xi} \frac{\partial W}{\partial U(C_\theta^*, m_\theta)} \sum_{k=2}^{K} B_{k,\theta}\left(p_k + t_k\right) \frac{\partial c_{k,\theta}^*}{\partial t_j} \qquad \forall j = 1, ..., K.$$

Finally, defining

$$b_\theta = \frac{\omega_\theta}{\xi} + \sum_{k=1}^{K} t_k \frac{\partial c_{k,\theta}^*}{\partial m_\theta}$$

as the net social marginal valuation of income for a type θ consumer (i.e. net in the sense that it also counts the extra taxes the government receives when giving a type θ consumer an extra unit of income) and

$$\zeta_\theta \equiv \frac{1}{\xi} \frac{\partial W}{\partial U(C_\theta^*, m_\theta)}$$

as the cost of a marginal unit of utility for a type θ consumer in terms of tax revenues $\bar{R}$ in the welfare optimum, the main result of this section is stated in the following proposition.

Proposition 2 *If utility function $U(.)$ satisfies conditions 1 and 3 and all consumers choose their D1 equilibrium consumption pattern, then a system of optimal indirect taxes should satisfy*

$$\forall j = 1, ..., K: \quad \frac{\sum_{k=1}^{K} t_k \sum_{\theta\in\Theta} \pi_\theta S_{k,j,\theta}}{\bar{c}_j^*} = -\left[1 - \sum_{\theta\in\Theta} \pi_\theta \left(b_\theta \frac{c_{j,\theta}^*}{\bar{c}_j^*}\right)\right] - \Psi_j, \quad (21)$$

with

$$\Psi_j \equiv \frac{1}{\bar{c}_j^*} \sum_{\theta\in\Theta} \pi_\theta \zeta_\theta \left[\sum_{k=2}^{K} B_{k,\theta}\left(p_k + t_k\right) \frac{\partial c_{k,\theta}^*}{\partial t_j}\right]. \quad (22)$$

How should one understand the optimal indirect tax rule in equations 21 and 22? If $\forall\theta : \mu_\theta = 0$, such that all types would choose their intrinsic optimum and therefore $\forall j : \Psi_j = 0$, the tax rule in equation 21 reduces to the usual Ramsey rule in a multi-person setting. The left hand side represents the proportional reduction in consumption of the j-th commodity along the compensated demand function due to taxes. In a single person setting without signaling, efficiency requires that this proportional reduction is the same for all commodities, as shown by Frank Ramsey's (1929) seminal paper. In a multi-person setting, distributional concerns may cause the policy maker to deviate from this equality of proportional reductions, as is represented by the term between square brackets in equation 21, which may vary across the different commodities. The term $\sum_{\theta \in \Theta} \pi_\theta \left(b_\theta \frac{c^*_{j,\theta}}{\bar{c}^*_j} \right)$ may be understood as the covariance between the net marginal social valuation of income and the consumption of a commodity j. If this covariance is positive, indicating that the commodity is consumed relatively more by consumer types with a high b_θ, then the multiperson Ramsey rule prescribes that taxes should induce a relatively smaller proportional reduction in the consumption of commodity j. If the covariance is negative, such that the good is relatively more consumed by consumer types with a lower net social marginal valuation of income, then optimal commodity taxes should generate a relatively larger proportional reduction of (compensated) demand for the good.

Signaling motives however, provide a second reason to deviate from Ramsey's equality of proportional reductions in compensated (intrinsic) demand and this deviation is captured in the Ψ_j term. First, consider the expression in square brackets in equation 22. The $B_{k,\theta}$'s represent the difference in per cent marginal utility between the k-th commodity and invisible consumption (or the marginal utility of income λ_θ) for a type θ consumer. They are in general nonpositive $B_{k,\theta} \leq 0$ and strictly negative $B_{k,\theta} < 0$ if the Riley constraint is binding $(\mu_\theta > 0)$. This loss of marginal utility per cent due to signaling is multiplied for each visible good $k = 2, ..., K$ with the change in expenditures on this commodity due to a tax t_j, i.e. $(p_k + t_k) \frac{\partial c^*_{k,\theta}}{\partial t_j}$. The sum between square brackets captures therefore the change in marginal per cent utility loss due to signaling, which a marginal increase in tax t_j generates for a type θ consumer. This term is greater if tax t_j reduces the demand for a commodity with a high absolute value of $B_{k,\theta}$ (low intrinsic marginal utility) and decreases if the tax increases the demand for a commodity with a high absolute value of $B_{k,\theta}$ (and the other way around for low $|B_{k,\theta}|$ commodities). This change in overall loss of per cent marginal utility due to signaling motives of all consumer types θ is then multiplied with ζ_θ, the cost of a marginal unit of utility for a type θ consumer in terms of tax revenues $\bar{R}$ in the welfare optimum and then summed over all consumers (i.e. over all types weighted by their proportion in the population π_θ). This term altogether therefore captures the value in the welfare optimum, in terms of revenue, of the changes in intrinsic utility loss due to signaling motives as a result of an infinitesimal increase in tax t_j. This is finally normalised over the equilibrium average demand for commodity j. The overall term Ψ_j may therefore be understood as the value of the changes in the bias generated by signaling motives which a tax t_j induces, proportional to the equilibrium demand of commodity j. If a tax t_j reduces expenditures on commodities with a low intrinsic utility (high absolute value of $B_{k,\theta}$) and increases (or decreases less) expenditures with a relatively high intrinsic marginal per cent utility, thus reducing the inefficiencies from signaling, then Ψ_j is greater. And this implies that the optimal tax scheme should allow for a greater proportional reduction of commodity j along the compensated demand curve. Similarly, if a tax t_j would aggravate the inefficiencies from signaling, then this calls for a smaller proportional reduction of commodity j along the compensated demand curve than the Ramsey rule without signaling would prescribe.

5 Discussion and Conclusions

When consumers use their visible consumption bundle for intrinsic reasons as well as for costly signaling, their consumption choices are biased away from what they would choose in the absence of signaling motives. They buy relatively too many visible commodities and spend too little on invisible commodities, such that the intrinsic marginal utility of invisible consumption is strictly higher than that of visible consumption. The welfare loss induced by signaling has been recognised since ages and has motivated Roman and medieval policy makers to forbid certain forms of conspicuous consumption by sumptuary laws. It is easily understood within the framework of this chapter that forbidding one dimension of the visible consumption bundle cannot solve the problem and will merely lead to a shift of costly overconsumption towards other visible commodities. If the elimination of costly signaling is the goal of the policy maker, then altering the incentives to engage in signaling by affecting the information structure (e.g. revealing information about the true quality of people) or the rewards to relative superiority is the surest way to get there. Rather, this chapter has explored how costly signaling can also be an opportunity for the policy maker. The endogeneity of the social meaning of visible consumption with respect to taxes implies that the meaning of the pre-tax and post-tax equilibrium consumption bundles is identical, i.e. that both the pre-tax and post-tax consumption bundles reveal the true types of consumers in the separating equilibrium. As a consequence, no utility which stems from the communicative function of visible consumption is affected by taxes, such that the policy maker needs to focus only on the intrinsic utility of consumption. However, the marginal intrinsic utility per invested cent typically differs between the various commodities of the consumption bundle and this feature must be exploited to raise tax revenue with a minimal burden on the tax payers.

But doesn't taxing one signaling commodity just imply that it will be substituted by another and won't the tax authorities just be caught in a race behind the facts they can never win? Clearly, within the model exposed in this chapter, such a signaling substitution is not an issue. Substitution effects are in this chapter entirely driven by the structure of intrinsic utility, which determines both the intrinsic utility of the commodity the costs to imitators. These substitution effects are taken into account in the generalised Ramsey rule in equation 21. There is no other reason within the framework exposed here why taxes should shift choices towards untaxed commodities. Twenty euros spent on roses mean *ceteris paribus* the same before and after a tax on roses and in terms of communication it is of no importance whether one buys twenty or two roses for that amount. In general, requiring that one or more visible commodities are exempted from taxation should not pose too much of a problem within the current framework either. This merely implies a restriction on the policy makers problem, while consumer behaviour is still described just as much by equations 14. Hence, consumer choices (and meaning) are still fully determined by the intrinsic utilities of the different commodities and there is no reason from a communicative point of view why consumers would prefer to shift to the untaxed visible goods.

However, if the tax authority can for some reason not tax all the individual specimens of a visible commodity and if spectators cannot distinguish the taxed from the untaxed specimens, then taxes may impair the informational value of this commodity. What could be examples of causes for such an impossibility to tax all individual specimens? First, note that in the model presented in this chapter, consumers signal by what might be called their flow consumption pattern. For the case of visible durables and other visible commodities of which consumers keep a stock, spectators get to see both pre-tax and post-tax specimens. Similarly, some commodities might be produced at home by some consumers. And finally, fraude may also cause a number of specimens of a commodity to remain untaxed. If spectators cannot distinguish between the taxed and untaxed specimens of visible commodities, then the social meaning of these commodities should be some convex combination (by Bayesian updating) of the pre-tax and perfectly taxed post tax meaning. In such a case, money spent on a commodity which cannot be taxed completely does no longer communicate what it should and consumers will want to substitute such a commodity with other commodities which can be taxed more uniformly. This line of reasoning is reserved for future research.

6 References

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