Tax avoidance on a social network

TARC DISCUSSION PAPER 019-17

DUCCIO GAMANNOSSI DEGL'INNOCENTI
UNIVERSITY OF EXETER

MATTHEW D. RABLEN
UNIVERSITY OF SHEFFIELD

Tax Avoidance on a Social Network*

Duccio Gamannossi degl'Innocenti[†]
d.gamannossi@exeter.ac.uk

Matthew D. Rablen[‡]
m.rablen@sheffield.ac.uk

November 16, 2017

Abstract

We relate tax avoidance behaviour to a substantial literature on self and social comparison in judgements. Taxpayers engage in tax avoidance (which is both risky and costly) as way to potentially boost their present consumption relative to others in their "local" social network, and relative to the past. The unique Nash equilibrium of the model relates optimal avoidance to a (Bonacich) measure of network centrality: more central taxpayers avoid more. We provide formal comparative statics results for optimal avoidance and, using simulation, address policy questions. We find evidence in favour of targeting tax authority interventions at highly central taxpayers (celebrities) in social networks, and document a role for self comparison in explaining persistent post-intervention behavioural effects. Our approach helps to marry analytical and agent-based approaches to tax avoidance.

JEL Classification: H26, D85, K42.
Keywords: Tax avoidance, Social networks, Network centrality, Optimal auditing, Social comparison, Self comparison.

*Acknowledgements: We thank Julie Corah, Mandy Chik, Frederick Nelson, and participants at the 5th Annual TARC Workshop (Exeter) for helpful comments. We are grateful to the ESRC for financial support under grant ES/K005944/1.

[†]Department of Economics, University of Exeter, Exeter, EX4 4PU, UK.
[‡]Department of Economics, University of Sheffield, Sheffield, S1 4DT, UK.

1 Introduction

Individuals take a variety of actions to reduce their tax liabilities. The UK tax authority, for instance, distinguishes three distinct types of action (H.M. Treasury and H.M. Revenue and Customs, 2011): those that breach tax law (tax evasion); those that use the tax law to get a tax advantage that lawmakers never intended (tax avoidance); and those that use tax allowances for the purposes intended by lawmakers (tax planning). By these definitions, both tax evasion and tax avoidance are responsible for significant losses in public revenue: estimates provided by the UK tax authority put the value of tax avoidance at £1.7 bn. and the value of tax evasion at £5.2 bn. (H.M. Revenue and Customs, 2016). Given the first order significance of tax avoidance, it is of note that the first economic studies relating to tax compliance (e.g., Allingham and Sandmo, 1972; Srinivasan, 1973; Yitzhaki, 1974) neglect the possibility of tax avoidance altogether, and the economic literature that followed has largely retained this bias.

In this paper we link avoidance behaviour to a mass of evidence that people continually engage in comparisons – with others (social comparison) and with themselves in the recent past (self comparison – or "habit"). Utility, evidence for developed economies suggests, is in large part derived from consumption relative to these comparators, rather than from its absolute level (e.g., Ferrer-i-Carbonell, 2005; Luttmer, 2005; Clark and Senik, 2010; Mujcic and Frijters, 2013). The evolutionary processes that might explain this phenomenon are explored in Postlewaite (1998), Rayo and Becker (2007) and Samuelson (2004), among others. Researchers have proposed that self and social comparison can explain economic phenomena including the Easterlin paradox (Clark *et al.*, 2008; Rablen, 2008), the equity-premium puzzle (Constantinides, 1990; Galí, 1994); stable labour supply in the face of rising incomes (Neumark and Postlewaite, 1998); upward rather than downward sloping wage profiles (Loewenstein and Sicherman, 1991; Frank and Hutchens, 1993); the feeling of poverty (Sen, 1983); the demand for risky activities (Becker *et al.*, 2005); and migration choices (Stark and Taylor, 1991). There are important consequences for consumption and saving behaviour (Dybvig, 1995; Chapman, 1998; Carroll *et al.*, 2000), for the desirability of economic growth (Layard, 1980, 2005), for monetary policy (Fuhrer, 2000), and for tax policy (Boskin and Sheshinki, 1978; Ljungqvist and Uhlig 2000; Koehne and Kuhn, 2015).

Despite the overwhelming evidence of a concern for self and social comparison, neither has ever been formally explored in the context of the tax avoidance decision. Here, therefore, we provide a network model of the tax avoidance decision in which taxpayers are assumed to have an intrinsic concern for income relative to a benchmark that can reflect both self and social comparison.[1] Taxpayers observe the consumption of a subset of other taxpayers (the "reference group") with whom they are linked on a social network. In this context, taxpayers may seek to avoid tax so as to consume more relative to those they compare against. Taxpayers also benchmark their current consumption in part against its lagged values. The model exhibits strategic complementaries in avoidance choices, so that more avoidance by one taxpayer reinforces other taxpayers' decisions to avoid also. Following the lead of Ballester *et al.* (2006), we utilise linear-quadratic utility functions to provide a characterisation of Nash equilibrium. We show that there is a unique Nash equilibrium in which avoidance is a weighted network centrality measure of the form proposed by Bonacich (1987). Network centrality is a concept developed in sociology to quantify the influence or power of actors in a social network: it counts the number of all paths (not just shortest paths) that emanate from a given node, weighted by a decay factor that decreases with the length of these paths. In this sense, our contribution combines sociological and economic insights in seeking to understand tax avoidance behaviour.

Although the model is simple enough to admit an analytic solution, it is also sufficiently rich that it may be used to address a range of questions of interest to academics and practitioners in tax authorities. Here we focus on three such questions: first, we investigate how changes in the exogenous parameters affect avoidance; second, we explore how the marginal revenue effects that arise from performing one extra intervention vary across taxpayers with different levels of network centrality; and last we consider the dynamic profile of behavioural responses to an successful anti-avoidance intervention by the tax authority.

An important feature of our model is that it addresses explicitly the role of *local* comparisons on a social network. By contrast, the existing analytical literature on the related study of tax evasion allows only *global* (aggregate) social information to enter preferences: the global statistic that taxpayers are assumed to both have a concern for, and to be able to observe, is modelled as either (i) the proportion of taxpayers who report honestly (Gordon, 1989; Myles and Naylor, 1996; Davis *et al.*, 2003; Kim, 2003; Traxler, 2010); (ii) the average post-tax consumption level (Goerke, 2013); (iii) the level of non-compliance as a share of GDP (Dell'Anno, 2009); or (iii) the average tax payment (Mittone and Patelli, 2000; Panadés,

[1] The economics of networks is a growing field. For recent overviews, see Ioannides (2012), Jackson and Zenou (2015), and Jackson *et al.* (2017).

2004). While reducing social information to a single statistic known to all taxpayers has a benefit in terms of analytical tractability, it is problematic in a number of respects. First, from the perspective of modelling with explicit social networks, assuming that taxpayer's observe aggregate-level information is implicitly the assumption that the social network is the complete network (in which every taxpayer is directly linked to all other taxpayers). Yet there are reasons to think that relative consumption externalities are, in fact, heterogeneous across individuals. In particular, we know that people's reference group is typically composed of "local" comparators such as neighbours, colleagues, and friends (Luttmer, 2005; Clark and Senik, 2010).[2] Moreover, implicitly assuming a complete network implies that all taxpayers are equally connected socially, thereby ruling out, in particular, the existence of highly-connected "stars" or "celebrities". Yet, such features of social networks may matter for the targeting of tax audits (Andrei *et al.*, 2014).

The only literature that has enriched the introduction of social information (again in the tax evasion context) is that which uses agent-based simulation techniques as an alternative to analytical methods. Even here, however, the majority of studies allow for this feature in only a limited way that, in particular, does not allow fully for heterogeneity in connectedness: authors often impose symmetry on the network of links, as in, e.g., Davis *et al.* (2003) and Hashimzade *et al.* (2014, 2016) and/or assume the size of the reference group to be equal across taxpayers (e.g., Korobow *et al.*, 2007; Hokamp and Pickhardt, 2010; Bloomquist, 2011; Hokamp, 2014).[3] We offer a model that is both analytically tractable and that allows for local comparisons on an arbitrary social network. In this sense, our approach lies in the cleavage between existing analytical and agent-based approaches, and is complementary to each. Extending analytical understanding of network effects upon tax avoidance – in particular being able to prove formal comparative statics properties of the model – aids the interpretation of simulation output from related agent-based models.

To our knowledge, no previous contribution has allowed simultaneously for both self and social comparison in the tax compliance decision. Goerke (2013), however, allows for social comparison by assuming an intrinsic concern for relative consumption by taxpayers. The

[2] More generally, relative consumption externalities may be viewed as a form of *peer effect*. In other contexts, generative models of peer effects predict heterogeneous exposure. For instance, when job information flows through friendship links, employment outcomes vary across otherwise identical agents with their location in the network of such links (Calvó-Armengol and Jackson, 2004).

[3] Zaklan *et al.* (2008) and Andrei *et al.* (2014) are among exceptions that do explore more general network structures.

primary focus of his contribution is, however, the derived impact on tax compliance from endogenous changes in labour supply, whereas we treat income as an exogenous parameter. In the remaining literature that considers a social dimension to the tax compliance decision, taxpayers are assumed to derive utility solely from absolute consumption, but nonetheless react to social information because they experience social stigma – the extent of which depends on the compliance behaviour of other taxpayers – if revealed to be noncompliant. The focus of much of this literature is on the potential for multiple equilibria, whereas our model yields a unique equilibrium. While a concern for relative utility is compatible with the simultaneous existence of social stigma towards non-compliers, the two approaches differ in emphasis. Underlying the idea of social stigma is the concept of *social conformity*, in which agents seek to belong to the crowd, whereas the presumption of relative consumption theories is that individuals seek to stand out from the crowd. A small literature relating to this point in the context of tax compliance supports the notion that social information impacts compliance behaviour (Alm *et al.*, 2017; Alm and Yunus, 2009), but rejects social conformity as the underlying mechanism (Fortin *et al.*, 2007).[4]

A recent contribution that allows explicitly for self comparison in the tax compliance decision is Bernasconi *et al.* (2016). There are, however, important differences in approach and results. In our model taxpayers are myopic, and habit reflects only recent consumption outcomes, whereas these authors consider far-sighted taxpayers and assume habit to reflect the full history of consumption. Stronger habit is associated with higher avoidance in our model, for it generates a negative internality on myopic taxpayers: higher past consumption outcomes reduce present utility. To overcome this internality, taxpayers must gamble (avoid) more. Conversely, Bernasconi *et al.* find that stronger self comparison improves tax compliance.

This article adds to the small, but growing, economic literature that models the tax avoidance choice (Alm, 1988; Alm and McCallin, 1990; Alm *et al.*, 1990; Cowell, 1990; Slemrod, 2001; Neck *et al.*, 2012; Gamannossi degl'Innocenti and Rablen, 2016). Like us, Alm and McCallin (1990) describe avoidance as a risky asset owing to the possibility of effective anti-avoidance measures by the tax authority, whereas the remaining papers characterise avoidance as a riskless, albeit costly, asset. None of these papers consider avoidance in a social network

[4] We also note that acts of tax avoidance appear often to attract less social stigma than acts of tax evasion (see, e.g., Kirchler *et al.*, 2003).

setting, however. Much of the remaining literature on tax avoidance is concerned with whether income tax has "real" effects upon labour supply or simply leads to changes in the "form" of compensation (e.g., Gruber and Saez, 2002; Slemrod and Kopczuk, 2002; Slemrod 1995; Piketty *et al.*, 2014).[5] We also connect to a broader literature that applies network theory to the analysis of crime (e.g., Glaeser *et al.*, 1996; Ballester *et al.*, 2006).

The plan of the article is as follows: section 2 develops a formal model of tax avoidance on a social network. Section 3 analyses – using both formal and simulation methods – the predictions of the model for optimal avoidance, and for understanding the effects of tax authority interventions. Section 4 concludes. All proofs are in the Appendix.

2 Model

Let $\mathcal{N}$ be a set of taxpayers of size N. A taxpayer $i \in \mathcal{N}$ has an income W_i drawn from an income distribution defined on the interval $[\underline{W}, \overline{W}]$, where $0 < \underline{W} < \overline{W}$. If a taxpayer were to pay income tax on their full income, W_i, they would receive a net disposable income $X_i \equiv X_i(W_i)$. Taxpayers can, however, choose to avoid paying an amount of tax $A_{it} \in [0, W_i - X_i]$. Avoidance technology is, though, costly, for devising avoidance schemes that reduce a tax liability without ostensibly violating tax law invariably requires a detailed understanding of tax law, coupled with a degree of ingenuity, that few taxpayers possess.[6] Satisfying this demand for tax avoidance is, therefore, a substantial industry dedicated to the development and marketing of avoidance schemes (see, e.g., Sikka, 2012; Committee of Public Accounts, 2013; Addison and Mueller, 2015).

As in Gamannossi degl'Innocenti and Rablen (2016), we assume that the avoidance scheme available to taxpayer i offers a reduction of A_{it} in theoretical tax liability at a cost ϕA_{it}, where $\phi \in (0, 1)$. In this way, ϕ may be interpreted as measuring the degree of competition in the market for tax avoidance schemes, with lower values of ϕ indicating the presence of stronger competitive forces. We emphasise here, however, that the theoretical tax reduction of ϕA_{it}, on which the fee for avoidance technology is based, is not necessarily the tax reduction that is ultimately achieved: should the tax authority successfully intervene legally against

[5] In these studies, the term "tax avoidance" typically refers to all form-changing actions that reduce a tax liability. This definition overlaps with ours but is broader in that it includes actions that fall in to our notion of tax planning.

[6] People not only have difficulties in understanding tax law, but also show poor knowledge of tax rates (Blaufus *et al.*, 2015; Gideon, 2017) and basic concepts of taxation.

the avoidance scheme we assume it obtains the right to reclaim the avoided tax A_{it} (but cannot levy a fine). Accordingly, all monetary risks associated with the possible detection and termination of the tax avoidance scheme are borne by the taxpayer.[7]

The probability that taxpayer i's attempt to avoid tax is unsuccessful in a given period is $p_i \in (0,1)$. This parameter captures the joint likelihood that the tax authority learns of the avoidance activity, that it chooses to mount a legal intervention (it may not have the resources to challenge all schemes), and that the legal intervention is successful. Allowing for taxpayer heterogeneity in p_i implies that the tax authority may condition its enforcement upon observable features of the taxpayer.

Taxpayers are assumed to derive utility from their level of consumption (income) relative to a reference level R_i (the determination of which we shall come to later). As is standard in agent-based modelling, although taxpayers live for multiple periods, each makes a succession of single-period decisions and so is "myopic".[8] In each period, taxpayers behave as if they maximise expected utility, where utility is denoted by $U(z) = [b - az/2]\, z$. We restrict utility to satisfy the standard conditions $U' > 0$ and $U'' < 0$ for all taxpayers, sufficient conditions for which are that $a \in \left(0, \frac{b}{\max_{i \in \mathcal{N}} W_i}\right)$ and $b > 0$.

The expected utility of taxpayer i is therefore given by

$$\mathbf{E}(U_{it}) \equiv [1 - p_i]\, U(C_{it}^s - R_{it}) + p_i U(C_{it}^u - R_{it}), \tag{1}$$

where consumption in the successful avoidance state (C_{it}^s) and in the unsuccessful state (C_{it}^u) is given by:

$$\begin{aligned} C_{it}^s &\equiv X_i + [1 - \phi]\, A_{it}; && (2) \\ C_{it}^u &\equiv C_{it}^s - A_{it}. && (3) \end{aligned}$$

An obvious objection to this formulation is that it neglects entirely the possibility of absolute utility. Although an absolute component to utility surely exists, we omit it here for simplicity

[7] Although systematic information regarding the precise contractual terms upon which avoidance schemes are typically sold is scarce, we understand from a detailed investigation in the UK that, for the majority of mass-marketed schemes, enforcement risk is indeed borne by the taxpayer as described (Committee of Public Accounts 2013, 11).

[8] For a small theoretical literature that does not assume myopic taxpayers see, e.g., Levaggi and Menoncin (2012, 2013). Note, however, that Manski (1991) and McFadden (2006) argue that individuals faced with dynamic stochastic decision problems that pose immense computational challenges may look to other individuals to infer satisfactory policies, consistent with our modelling of the role of social networks.

and emphasis.[9] Optimal avoidance in period t is the solution to the problem $\max_{A_i} \mathbf{E}(U_{it})$ subject to the Cournot constraint that reference consumption, R_{it}, is taken as given. The first order condition for optimal avoidance is given by

$$[1-p_i][1-\phi]\,U'(C^s_{it}) - p_i\phi U'(C^u_{it}) = 0,$$

which can be solved to give optimal avoidance at an interior solution satisfying $A_{it} \in (0, W_i - X_i)$ as

$$A_{it} = \frac{1-p_i-\phi}{a\zeta_i}\{b - a[X_i - R_{it}]\}, \tag{4}$$

where $\zeta_i \equiv [1-p_i-\phi]^2 + p_i[1-p_i] > 0$. Given that marginal utility, $b - a[X_i - R_{it}]$, is positive by the assumed restrictions on a, the expression for optimal avoidance in (4) will indeed satisfy $A_{it} \in (0, W_i - X_i)$ for all i if

$$0 < 1 - \max_{i\in\mathcal{N}}\{p_i\} - \phi < \min_{i\in\mathcal{N}}\left\{\frac{a\zeta_i[W_i - X_i]}{b - a[X_i - R_{it}]}\right\}. \tag{5}$$

In what follows we shall take the inequalities in (5) to hold. The left-side inequality is equivalent to the condition that expected consumption,

$$q_{it} \equiv \mathbf{E}(C_{it}) = X_i + [1-p_i-\phi]\,A_{it}, \tag{6}$$

is increasing in avoided tax A_{it} (so the avoidance gamble has a positive expected return).

2.1 Reference consumption

Reference consumption, R_{it}, is a function of self and social comparison. To formalise the notion of social comparison, we assume that a taxpayer's realised consumption is observed by a subset of other taxpayers belonging to $\mathcal{N}$, a set we term the *reference group.*

We represent the observability of consumption in the form of a bidirectional network, where a link from taxpayer i to taxpayer j indicates that i observes j's consumption. Links are permitted to be subjectively weighted, for some members of the reference group may be more focal comparators than are others. We focus on (strongly) connected networks – a

[9] In international studies, measures of subjective wellbeing measures typically become uncorrelated with average national income above a threshold estimated at $5,000 (in 1995, PPP) by Frey and Stutzer (2002). Since most citizens of developed countries lie above this threshold, our model may be a reasonable approximation in such cases.

network is connected when there is a path (though not necessarily a direct link) between every pair of taxpayers.[10] The network, which may also update over time, can be represented as an $N \times N$ matrix $\mathbf{G}_t$ of subjective weights $1 \geq g_{ijt} \geq 0$, where $g_{iit} = 0$ (the adjacency matrix). Hence, the reference group of taxpayer i is the set of taxpayers for whom $g_{ijt} > 0$, and $\sum_j g_{ijt}$ measures the total psychological weight a taxpayer places on members of the reference group.

People predominantly compare with others who are similar to them on prescribed dimensions (McPherson *et al.*, 2001), perhaps because these comparisons are the most informative (Clark and Senik, 2010). It follows that changes in the psychological weight attached to different comparator taxpayers in the network may arise, for instance, as a response to recent changes in consumption. To capture this effect in a simple way, we suppose the g_{ijt} can evolve as lagged functions of absolute consumption differences, $|C_{i,t-1} - C_{j,t-1}|$. In particular, g_{ijt} is negatively related to $|C_{i,t-1} - C_{j,t-1}|$ so that comparison is more intensive between taxpayers i and j the closer are $C_{i,t-1}$ and $C_{j,t-1}$.

With the social network defined, we then write reference consumption as

$$R_{i,t}\left(q_{-i,t}\right) \equiv \iota_h C_{i,t-1} + \iota_s \sum\nolimits_{j \neq i} g_{ijt} q_{jt} > 0, \tag{7}$$

where $\sum_{j \neq i} g_{ijt} q_{jt}$ is the weighted mean over the reference group of expected consumption (reflecting social comparison) and $C_{i,t-1}$ is the "habit" level of consumption (reflecting self comparison), which, as is common, we equate with realised consumption in the previous period.[11] The parameters $\iota_h > 0$ and $\iota_s > 0$ are the psychological weights taxpayers place on, respectively, self and social comparison. In this sense, the total psychological weight placed on social comparison, $\iota_s \sum_{j \neq i} g_{ijt} q_{jt}$, contains a component common across taxpayers, given by ι_s, and an idiosyncratic component given by $\sum_{j \neq i} g_{ijt} q_{jt}$. We use the shorthand $q_{-i,t}$ to refer to the set of all q_{jt} excluding q_{it}.

[10] This restriction does not play any explicit role except to simplify our discussion of comparative statics effects. In an unconnected or weakly connected network taxpayers whom nobody observes generate no consumption externality on others, and taxpayers who do not observe any other taxpayer are not subject to a consumption externality, in which case our strict comparative statics findings in general become weak.

[11] For examples of this approach see, e.g., Muellbauer (1988), Carroll and Weil (1994) and Guariglia and Rossi (2002).

2.2 Nash Equilibrium

Using (7) in the first order condition (4), we now solve for the unique Nash equilibrium of the model. To do this, we first define a notion of network centrality due to Bonacich (1987), which computes the (weighted) discounted sum of paths originating from a taxpayer in the network:

Definition 1 *For a network with (weighted) adjacency matrix* $\mathbf{G}$*, diagonal matrix* $\boldsymbol{\beta}$ *and weight vector* $\boldsymbol{\alpha}$*, the weighted Bonacich centrality vector is given by* $\mathbf{b}(\mathbf{G}, \boldsymbol{\beta}, \boldsymbol{\alpha}) = [\mathbf{I} - \mathbf{G}\boldsymbol{\beta}]^{-1} \boldsymbol{\alpha}$ *provided that* $[\mathbf{I} - \mathbf{G}\boldsymbol{\beta}]^{-1}$ *is well-defined and non-negative.*

In Definition 1, the matrix $\boldsymbol{\beta}$ specifies discount factors that scale down (geometrically) the relative weight of longer paths, while the vector $\boldsymbol{\alpha}$ is a set of weights. Ballester *et al.* (2006) show that $[\mathbf{I} - \mathbf{G}\boldsymbol{\beta}]^{-1}$ will be well-defined, as required by Definition 1, when $\mathbf{I} > \rho(\mathbf{G})\boldsymbol{\beta}$, where $\rho(\mathbf{G})$ is the largest absolute value of the eigenvalues of $\mathbf{G}$. Intuitively, this condition is that the magnitude of the local externality that a taxpayer's avoidance imparts upon other taxpayers cannot be too large. If local externality effects are too strong then the set of linear equations that define an interior Nash equilibrium of the model have no solution. In this case, multiple corner equilibria can instead arise (see, e.g., Bramoullé and Kranton, 2007). Focusing on the case when local externality effects are not too large, we have the following Proposition:

Proposition 1 *If* $\mathbf{p} < \mathbf{I} - \boldsymbol{\phi}$, $\boldsymbol{\alpha}_t < [\mathbf{I} - \mathbf{H}_t\boldsymbol{\beta}][\mathbf{W} - \mathbf{X}]$, *and* $\mathbf{I} > \rho(\mathbf{H}_t)\boldsymbol{\beta}$ *there is a unique interior Nash equilibrium, at which the optimal amount of tax avoided is given by*

$$\mathbf{A}_t = \mathbf{b}(\mathbf{H}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t),$$

where

$$\begin{aligned} h_{ijt} &= \frac{[1 - p_i - \phi][1 - p_j - \phi]}{\zeta_i} g_{ijt}; \\ \beta_{ii} &= \iota_s; \\ \alpha_{i1t} &= \frac{1 - p_i - \phi}{a\zeta_i} \{b - a[X_i - R_{it}(X_{-i,t})]\}. \end{aligned}$$

According to Proposition 1, a taxpayer's optimal avoidance corresponds to a Bonacich centrality on the social network $\mathbf{H}_t$, weighted to reflect a taxpayers marginal utility of consumption. By this measure, taxpayers that are more central in the social network avoid more.[12] The three conditions under which this result holds are comprised of the two interior conditions in (5), now written in matrix form as functions of the exogenous variables, and the condition that local externality effects are not too strong. The uniqueness of equilibrium avoidance follows intuitively from the observation that, under linear-quadratic utility, each taxpayer's best response function is linear in the avoidance of every other taxpayer. The social network $\mathbf{H}_t$ transforms the underlying comparison intensity weights, g_{ijt}, by a factor $[1-p_i-\phi][1-p_j-\phi]\zeta_i^{-1}$ in order to reflect potential differences in the probability of successful avoidance across taxpayers. It follows that, in the special case that all taxpayers face a common success probability, no adjustment to the underlying comparison intensity weights is warranted. In this case, therefore, optimal avoidance is a weighted Bonacich centrality measure on the untransformed network $\mathbf{G}_t$:

Corollary 1 *If $\boldsymbol{\alpha} < [\mathbf{I} - \mathbf{G}_t\boldsymbol{\beta}]\,[\mathbf{W} - \mathbf{X}]$, $\mathbf{I} > \rho(\mathbf{G}_t)\,\boldsymbol{\beta}$ and $p_i = p < 1-\phi$ for all i the unique interior Nash equilibrium for avoidance is given by $\mathbf{A}_t = \mathbf{b}(\mathbf{G}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t)$, where*

$$
\begin{aligned}
G_{ijt} &= g_{ijt}; \\
\beta_{ii} &= \frac{\iota_s[1-p-\phi]^2}{\zeta}; \\
\alpha_{i1t} &= \frac{1-p-\phi}{a\zeta}\left\{b - a\left[X_i - R_{it}\left(X_{-i,t}\right)\right]\right\}.
\end{aligned}
$$

3 Analysis

The model of the previous section is sufficiently rich that it may be used to address a wide range of questions of interest to academics and practitioners in tax authorities. Here we limit ourselves to a focus on three such questions: first, we investigate how changes in the exogenous parameters affect optimal avoidance; second, we explore how the various direct and indirect marginal revenue effects that arise from performing one extra intervention vary across taxpayers with different levels of network centrality; and last we consider the dynamic profile of behavioural responses to a legal intervention by the tax authority.

[12] Our interpretation of the matrix of weights, $\boldsymbol{\alpha}_t$, follows from noting that marginal utility in the linear-quadratic specification is given by $U'(z) = b - az$. Accordingly, the term in braces in the expression for α_{i1t} is the marginal utility from ones own legal consumption, X_i, relative to a reference level of consumption. The latter utilises the weighted average of legal consumption of the members of the reference group.

3.1 Comparative statics

An advantage of the existence of an analytical solution to the model is that we may formally derive general comparative statics results. We therefore characterise the way in which equilibrium responds to changes in the underlying exogenous parameters for an arbitrary social network. Because the effects of habit and network updating are not contemporaneous, but rather occur at the first lag, it is necessary in the context of comparative statics to distinguish between the short-run (contemporaneous) effect and the long-run effect (allowing for lagged adjustments). Accordingly, for an arbitrary exogenous variable, z, we analyse the "short-run" comparative static, $\partial A_{it}/\partial z$ and the "long-run" comparative static $\mathbf{E}\left(\partial A_{i,t+1}/\partial z\right)$.

As precise computation of the short-run derivatives for an arbitrary N is burdensome, we instead utilise the supermodularity of the taxpayer's objective function in avoidance choices to deduce the signs of the comparative statics effects from the theory of monotone comparative statics (Edlin and Shannon, 1998; Quah, 2007).[13] We then reason the long-run comparative static properties of the model from the findings for the short-run.

Proposition 2 *At an interior Nash equilibrium the comparative statics of optimal avoidance are given by*

Variable	*Short-run*	*Long-run*
b, $C_{i,t-1}$, ι_h, ι_s, X_j	$+$	$+$
a, p_i, p_j	$-$	$-$
ϕ	$-/+$	$-/+$
X_i	$-$	$-/+$

The first results in Proposition 2 we consider are for the pair of parameters $\{a, b\}$ belonging to the utility function. Noting that the coefficient of absolute risk aversion is given by $\mathcal{A}(z) = a\left[b - az\right]^{-1} > 0$, increases in a associate with increased risk aversion, while increases in b associate with decreased risk aversion. Consistent with this observation, increases in a cause optimal avoidance to decrease, while b increases optimal avoidance. Long-run adjustments reinforce these effects: taking a as an example, an increase in a at time t causes a short-run fall in avoidance; as avoidance has positive expected returns, this lowers the expected realisation of C_t. The lower expected realisation of C_t implies that, in expectation, the taxpayer will, at time $t+1$, shift their comparison intensity weights towards taxpayers with lower expected consumption, implying that the expectation (as of time t) of the term

[13] See Tremblay and Tremblay (2010) for an excellent introduction to these methods.

$\sum_{j\neq i} g_{ij,t+1}q_{j,t+1}$ falls. As both C_t and $\sum_{j\neq i} g_{ij,t+1}q_{j,t+1}$ enter $R_{i,t+1}$ positively, the expected value of reference consumption at time $t+1$ unambiguously falls. It is straightforward to observe from (4) that A_{it} is contemporaneously increasing in R_{it}, hence a fall in the expected value of $R_{i,t+1}$ causes the expected value of $A_{i,t+1}$ to fall also. Hence, $\mathbf{E}\left(\partial A_{i,t+1}/\partial a\right) < 0$.

An increase in one's own probability of successful avoidance raises optimal avoidance, but so also does an increase in the success probability of another taxpayer in the social network. When another taxpayer's success probability increases they increase their avoidance, thereby increasing the need for other taxpayers to do likewise to maintain a given level of relative consumption. Long-run adjustments reinforce these effects. There is no clear relationship between optimal avoidance and the competitiveness of the market for avoidance, as measured by ϕ. Increases in ϕ induce a substitution away from avoidance, but this makes the taxpayer poorer, and therefore less risk averse, which induces more avoidance. These competing income and substitution effects also make unclear the effect of the associated long-run adjustments. In the event that the substitution effect empirically dominates the income effect, however, a negative relationship is predicted in both the short- and long-run.

The parameter, ι_s, which measures the extent to which taxpayers care about social comparison, is positively associated with avoidance. Taxpayers impose a negative externality upon other taxpayers when their expected consumption increases, and the size of this externality is directly regulated by ι_s. The greater the externality, the more avoidance is pushed upwards in the struggle among taxpayers to maintain relative consumption. The parameters $C_{i,t-1}$ and ι_h, which both reflect the role of self comparison, are also positively associated with avoidance, but the economic intuition (relative to social comparison) differs. Whereas social comparison generates negative *externalities*, self comparison generates negative *internalities*: past consumption outcomes affect negatively the evaluation of current consumption. To overcome this internality, taxpayers must seek a present consumption level that beats $C_{i,t-1}$,which entails avoiding more. The effects of self and social comparison therefore interact positively: the desire to out-consume one's reference group induces avoidance, which then pushes up past consumption (in expectation), causing a further increase in avoidance on account of the concern for self comparison.

3.1.1 Avoidance and Income

The final set of results in Proposition 2 deal with the comparative static effects of the level of income. Although an increase in the income of other taxpayers in the social network has the unambiguous effect of raising own avoidance, the effect of movements in own income exhibit potentially important differences in the short- and long-run effects, so we consider this case in more detail. Noting that (i) income W_i enters optimal avoidance only through $X_i(W_i)$; and (ii) that W_i enters $X_i(W_i)$ positively, the sign of $\partial A_{it}/\partial W_i$ is the sign of $\partial A_{it}/\partial X_i$. In our model we obtain in the short-run that $\partial A_{it}/\partial X_i < 0$, so also $\partial A_{it}/\partial W_i < 0$. Interestingly, however, the negative relationship between income and avoidance in the short-run may readily be overturned in the long-run. The key to this finding is that, although W_i lowers A_{it} in the short-run, it may nonetheless increase expected consumption. To see this, observe that the full short-run equilibrium effect of W_i on q_i (accounting for equilibrium adjustments in A_{it}) is given by

$$\frac{dq_{it}}{dX_i} = 1 + [1 - p_i - \phi] \frac{\partial A_{it}}{\partial X_i},$$

so dq_{it}/dX_i is positive so long as $\partial A_{it}/\partial X_i$ is not too large (in absolute value), i.e., $dq_{it}/dX_i > 0 \Leftrightarrow |\partial A_{it}/\partial X_i| < [1 - p_i - \phi]^{-1}$. When increases in X_i raise short-run expected consumption, the long-run effects on avoidance act against the short-run effect. Specifically, the increase in q_{it} increases the expectation of C_t and of $\sum_{j \neq i} g_{ij,t+1} q_{j,t+1}$, which implies that the expectation of $R_{i,t+1}$ increases, thereby driving up optimal avoidance in $t+1$.

In Figure 1 we demonstrate the potential for differing short- and long-run effects.[14] To introduce homophily in income, comparison intensity weights at time t are given by

$$g_{ijt} = \varsigma_1 - \frac{\varsigma_2 |C_{i,t-1} - C_{j,t-1}|}{\max_{i \in \mathcal{N}} \{C_{i,t-1}\} - \min_{i \in \mathcal{N}} \{C_{i,t-1}\}}.$$

where $\varsigma_1 \in (\varsigma_2, 1)$ and $\varsigma_2 \in [0, 1)$ are constants that must be chosen to respect the non-negativity of the g_{ijt}. In particular, ς_2 regulates the degree of homophily in income, with no homophily arising if $\varsigma_2 = 0$. As is seen in the Figure (drawn for $\varsigma_1 = 1$, $\varsigma_2 = 0.8$), the short-run effect of an increase in W_i is to lower avoidance; moreover this effect is observed to be linear in W_i. Once all sources of dynamic adjustment are allowed for, however, we observe in Figure 1 a positive long-run relationship between avoidance and income. While detailed empirical evidence is limited, this long-run finding is consistent with a widely held

[14] The parameters required to replicate all figures in this paper are $a = 1$, $b = 50$, $\iota_s = 4$, $\iota_h = 1$, $\phi = 0.35$, $p_i = p = 0.625$, $N = 750$, $X_i(W_i) = 0.55 W_i$. Our qualitative results are, however, robust to a range of parameter specifications. Figures are produced in R using RStudio random seed no. 14082017; our codes are available upon request. We report the average result of 200 replications to wash-out the random effects caused by the contingent realisation of tax authority interventions. To eliminate start-up effects, the results we report omit the first 20 periods of each simulation.

presumption that tax avoidance is more prevalent among the wealthy.[15] In sum, our findings point to an important role for self and social comparison in mediating the relationship between income and avoidance. Specifically, a positive long-run relationship between these variables arises when increases in income induce taxpayers to, in turn, compare to richer taxpayers, and thereby acquire a higher level of habit consumption.

3.2 Intervention strategy

In this section we investigate the implications of the model for the design of intervention rules by tax authorities. Conventionally, the literature on optimal auditing assumes that a tax authority can condition its intervention decisions solely on the income declaration contained within a taxpayer's tax return. If, however, a tax authority can (at least partially) observe the network of links between taxpayers, it is of interest to examine the differing implications of targeting taxpayers with different degrees of centrality in the social network.

Can tax authorities observe links in social networks? Although surely the full gamut of links cannot be observed, importantly, there exist some individuals – celebrities – for whom it is common knowledge that many people are linked to them. Also, even for non-celebrities, the idea that tax authorities know at least something about people's associations is becoming more credible with the advent of "big data". The UK tax authority, for instance, uses a system known as "Connect", operational details of which are in the public domain (see, e.g., Baldwin and McKenna, 2014; Rigney, 2016; Suter, 2017). Connect cross-checks public sector and third-party information, seeking to detect relationships among actors. According to Baldwin and McKenna (2014), the system produces "spider diagrams" linking individuals to other individuals and to other legal entities such as "property addresses, companies, partnerships and trusts."

The revenue effects of an intervention are commonly broken down three ways (e.g., DeBacker *et al.*, 2015): the *direct effect* is the contemporaneous recovery of tax that would otherwise have been avoided; the *own indirect effect* refers to the expected additional revenue arising from future changes in avoidance behaviour by the affected taxpayer, while the *other indirect effect* refers to the expected additional revenue arising from spillover effects in avoidance

[15] We see from Proposition 2 that, unlike the effect of own income, the cross effect from one taxpayer becoming richer on the avoidance of other taxpayers is unambiguous and positive. This effect arises as one taxpayer becoming richer requires other taxpayers to avoid more to preserve their level of relative consumption.

behaviour by the unaffected taxpayers. The relative magnitudes of these three effects is investigated empirically in DeBacker *et al.* (2015, 2017). Different from these studies, we do not seek to examine the magnitude of these three effects – instead we exploit the local reference group heterogeneity allowed for by our approach to examine how the magnitude of each effect varies across taxpayers who are more or less central in the social network.

As in Andrei *et al.* (2014), we analyse these three revenue effects in "scale-free" networks, generated using the algorithm of Barabási and Albert (1999).[16] As well as closely approximating the structure of real-world social networks, scale-free networks generate considerable variation in connectedness (centrality): there exist celebrity taxpayers, who are highly connected in the network, alongside other taxpayers who are very weakly connected within the network. Here, to focus on the role of connectedness in the network, we eliminate all other sources of taxpayer heterogeneity, so $w_i = w$ and $p_i = p$ for all $i \in \mathcal{N}$ and the social network is taken to be fixed, i.e., $g_{ijt} = g_{ij}$ for all $t \in T$. We consider the marginal revenue effects from conducting one additional intervention against a taxpayer with a given Bonacich centrality, $\mathbf{b}(\mathbf{G}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t)$, which, by Corollary 1, is identical to the taxpayer's avoidance. To the extent that these effects persist for several periods following an intervention, the measured effects are aggregated over the full lifetime of the effect (we discuss the dynamic profile of these effects in the next section). For each of the three effects, we normalise the results so that the largest value of each effect across taxpayers (which turns out always to be for the most central taxpayer) is assigned the value unity.

The results of this exercise are presented in Figure 2, which shows the raw simulation data, accompanied by lines of best fit.[17] The own direct effect is entirely mechanical: by intervening, the taxpayer is required to pay A_{it} in tax; the amount that they would otherwise have succeeded in avoiding. Hence, given the equivalence of centrality and avoidance, centrality and the own direct effect are related one-for-one. The own indirect effect is mathematically non-linear, but we find that the extent of non-linearity is so negligible that the effect cannot be visually distinguished from linear. After normalisation, therefore, the line for the own indirect effect lies essentially "on top of" the line for the own indirect effect in Figure 2.

[16] We adjust as necessary the outcome of the Barabasi-Albert algorithm to ensure strong connectedness of the resulting graph. We do this by reciprocating the edges for any node with an in- or out-degree equal to one.

[17] Taxpayers with the same optimal avoidance, as given by the Bonacich centrality measure $\mathbf{b}(\mathbf{G}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t)$, may nevertheless respond differently to changes in X_i owing to heterogeneity in the underlying parameters making up $\mathbf{b}(\mathbf{G}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t)$. Nonetheless, as can be seen in Figure 2, the amount of noise in the relationship between X_i and $\mathbf{b}(\mathbf{G}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t)$ across taxpayers is minimal.

In contrast, the indirect effect on the avoidance of others is highly non-linear (elastic) in centrality: the taxpayer with the lowest centrality in the network has around 35% of the centrality of the most central taxpayer, yet commands an indirect effect on other taxpayers of just 0.44% of that of the most central taxpayer. *Ceteris paribus, it is desirable to intervene against those taxpayers with the highest Bonacich centrality, as measured by* $\mathbf{b}(\mathbf{G}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t)$*, for these taxpayers (i) engage in the most avoidance themselves; (ii) decrease their avoidance the most following an intervention; and (iii) have the most impact on the avoidance of other taxpayers following an intervention.*

3.3 Dynamic responses to intervention

There is growing interest in understanding behavioural responses to tax authority interventions. In the tax evasion context, for instance, behavioural responses to being audited have recently been analysed from both theoretical (Bernasconi *et al.*, 2014) and empirical (Gemmell and Ratto, 2012; DeBacker *et al.*, 2015, 2017; Advani *et al.*, 2016; Mazzolini *et al.*, 2017) standpoints. These studies find that audits have persistent effects on subsequent compliance behaviour, with an effect still discernible four or more years after the initiation of an audit. Typically, these studies emphasise the role of taxpayer learning (about the probability of audit and the effectiveness of the audit process in detecting noncompliance) in accounting for this phenomenon, while Dubin (2007) notes that it could be due to the delayed audit cycle (the audit itself may not conclude for several years, and taxpayers might rationally alter their reporting behaviour while an audit is in progress).

The analogous phenomenon to audit-response in the context of tax avoidance is the behavioural response to a successful legal intervention. In our model the objective probability that an intervention is successful is known (ruling out learning) and we disregard time lags in the legal process (ruling out intervention cycle effects). In this context it is interesting that, under empirically plausible assumptions concerning the evolution of habit consumption, our model predicts a persistent behavioural effect from an intervention, albeit the effect does disappear eventually (i.e., there is no permanent effect). In this sense, we highlight the role of self comparison as an additional explanatory factor (to those so far considered in the literature) in accounting for post-intervention compliance behaviour.

The best empirical evidence on habit effects is from the (behavioural) literature on the determinants of wellbeing, where Di Tella *et al.* (2010) report adaptation effects to income changes persisting for four years. For this part of the analysis, therefore, periods are interpreted explicitly as years. Accordingly, we here generalise habit consumption from being just the first lag of consumption to being an autoregressive function of the first four lags of realised consumption, with decreasing psychological weights, $w_{t-1} > \ldots > w_{t-4}$, attached to each lag. Figure 3 reports the temporal profile of the change in avoidance (own effect) following an intervention relative to a baseline simulation in which the intervention does not take place. The weights used to draw Figure 3 exhibit exponential decay for longer lags (specifically, we set $w_{t-k} = 0.5^k$, $k = 0, \ldots, 4$). Avoidance is seen to fall sharply in the year immediately after an intervention by the tax authority, as would be expected, but then to return to approximately its baseline level in the fifth year post intervention. The indirect effect on the avoidance behaviour of other taxpayers has a very similar dynamic profile, so is omitted from the Figure for visual clarity.

4 Conclusion

Tax avoidance is estimated to cost, e.g., the German government, up to 34 percent of income taxes paid (Lang *et al.*, 1997). We link the tax avoidance decision with a large literature on the role in individual decision-making of self and social comparison. In our model, taxpayers compare their consumption with others in their social network, and also to their own consumption in the recent past. Unlike earlier models that allow only for social comparisons at the aggregate level, each taxpayer makes "local" comparisons on their part of the social network. Engaging in tax avoidance is a tool by which taxpayers can seek to raise their consumption relative to others, and to their own prior consumption. In this setting, we show that a linear-quadratic specification of utility yields a unique solution for optimal avoidance corresponding to a weighted Bonacich centrality measure on a social network: by this measure, taxpayers that are more central in the social network avoid more.

Our model provides a rich framework for understanding how a variety of variables, some under the control of the tax authority, will influence avoidance behaviour. Although optimal avoidance depends in quite a complex way on the underlying parameters, we are able in many cases to sign unambiguously its comparative statics. We also simulated the model to investigate its implications for intervention policy and for the dynamics of behavioural responses to tax authority interventions. Our results show that there are objective grounds for tax authorities to target taxpayers who are central in the network. In particular, the revenue raised from other taxpayers following an intervention displays increasing returns as a function of network centrality. We also show how the lagged adjustment of habit consumption can lead tax authority interventions to have a relatively persistent effect on avoidance behaviour, which does not return to baseline until around five years after the intervention has taken place.

We finish with some possible avenues for future research. First, the comparative statics exercises we have performed are by no means exhaustive: it would, for instance, also be of interest to investigate systematically the effects of adding or removing links within the social network. Second, while we have focused on tax avoidance, it seems straightforward to extend the model to consider tax evasion behaviour, or indeed criminal activity more generally. While these extensions must await a dedicated treatment, we hope our contribution at least clarifies the role of self and social comparison in driving tax avoidance behaviour.

References

Addison, S. and Mueller, F. (2015). "The dark side of professions: The Big Four and tax avoidance", *Accounting, Auditing & Accountability Journal* 28(8), pp. 1263–1290.

Advani, A., Elming, W., and Shaw, J. (2016). "The dynamic effects of tax audits". Paper presented at the Royal Economic Society Annual Conference, Bristol, UK.

Allingham, M.G. and Sandmo, A. (1972). "Income tax evasion: A theoretical analysis", *Journal of Public Economics* 1(3-4), pp. 323–338.

Alm, J. (1988). "Compliance costs and the tax avoidance-tax evasion decision", *Public Finance Review* 16(1), pp. 31–66.

Alm, J., Bahl, R., and Murray, M.N. (1990). "Tax structure and tax compliance", *Review of Economics and Statistics* 72(4), pp. 603–613.

Alm, J., Bloomquist, K.M., and McKee, M. (2017). "When you know your neighbour pays taxes: Information, peer effects and tax compliance", *Fiscal Studies*, doi: 10.1111/1475-5890.12111

Alm, J. and McCallin, N.J. (1990). "Tax avoidance and tax evasion as a joint portfolio choice", *Public Finance / Finances Publiques* 45(2), pp. 193–200.

Alm, J. and Yunus, M. (2009). "Spatiality and persistence in U.S. individual income tax compliance", *National Tax Journal* 62(1), pp. 101–124.

Andrei, A.L., Comer, K., and Koelher, M. (2014). "An agent-based model of network effects on tax compliance and evasion", *Journal of Economic Psychology* 40(1), pp. 119–133.

Baldwin, R. and McKenna, A. (2014) "Well connected", *Taxation* 174 (4467).

Ballester, C., Calvó-Armengol, A., and Zenou, Y. (2006). "Who's who in networks. Wanted: the key player", *Econometrica* 74(5), pp. 1403–1417.

Barabási, A.-L. and Albert, R. (1999). "Emergence of scaling in random networks", *Science* 286 (5439), pp. 509–512.

Becker, G., Murphy, K., and Werning, I. (2005). "The equilibrium distribution of income and the market for status", *Journal of Political Economy* 113(2), pp. 282–310.

Bernasconi, M., Corazzini, L., and Seri, R. (2014). "Reference dependent preferences, hedonic adaptation and tax evasion: Does the tax burden matter?", *Journal of Economic Psychology*, 40(1), pp. 103–118.

Bernasconi, M., Levaggi, R., and Menoncin, F. (2016). "Dynamic tax evasion with habit formation", Working Paper No. 31, Department of Economics, Ca' Foscari University of Venice.

Blaufus, K., Bob, J., Hundsdoerfer, J., Sielaff, C., Kiesewetter, D., and Weimann, J. (2015). "Perception of income tax rates: evidence from Germany", *European Journal of Law and Economics* 40(3), pp. 457–478.

Bloomquist, M.K. (2011). "Tax compliance as an evolutionary coordination game: An agent-based approach", *Public Finance Review* 39(1), pp. 25–49.

Bonacich, P. (1987). "Power and centrality: A family of measures", *American Journal of Sociology* 92(5), pp. 1170–1182.

Boskin, M. and Sheshinski, E. (1978). "Optimal redistributive taxation when individual welfare depends upon relative income", *Quarterly Journal of Economics* 92(4), pp. 589–601.

Bramoullé, Y. and Kranton, R. (2007). "Public goods and networks", *Journal of Economic Theory* 135(1), pp. 478–494.

Calvó-Armengol, A. and Jackson, M.O. (2004). "The effects of social networks on employment and inequality", *American Economic Review* 94(3), pp. 426–454.

Carroll, C.D., Overland, J., and Weil, D.N. (2000). "Saving and growth with habit formation", *American Economic Review* 90(3), pp. 341–355.

Carroll, C.D. and Weil, D.N. (1994), "Saving and growth: a reinterpretation", *Carnegie-Rochester Conference Series on Public Policy* 40(1), pp. 133–192.

Chapman, D.A. (1998). "Habit formation and aggregate consumption", *Econometrica* 66(5), pp. 1223–1230.

Clark, A.E., Frijters, P., and Shields, M.A. (2008). "Relative income, happiness, and utility: An explanation for the Easterlin paradox and other puzzles", *Journal of Economic Literature* 46(1), pp. 95–144.

Clark, A.E. and Senik, C. (2010). "Who compares to whom? The anatomy of income comparisons in Europe", *Economic Journal* 120(544), pp. 573–594.

Committee of Public Accounts (2013). *Tax Avoidance: Tackling Marketed Avoidance Schemes*, HC 788. London: The Stationery Office.

Constantinides, G.M. (1990). "Habit formation: a resolution of the equity premium puzzle", *Journal of Political Economy* 98(3), pp. 519–543.

Cowell, F.A. (1990). "Tax sheltering and the cost of evasion", *Oxford Economic Papers* 42(1), pp. 231–243.

Davis, J.S., Hecht, G., and Perkins, J.D. (2003). "Social behaviours, enforcement, and tax compliance dynamics", *Accounting Review* 78(1), pp. 39–69.

DeBacker, J., Heim, B.T., Tran, A., and Yuskavage, A. (2015). "Once bitten, twice shy? The lasting impact of IRS audits on individual tax reporting". Paper presented at the NBER Public Economics Program Meeting, Cambridge, MA.

DeBacker, J., Heim, B.T., Tran, A., and Yuskavage, A. (2017). "The effects of IRS audits on EITC claimants", Mimeo.

Dell'Anno, R. (2009). "Tax evasion, tax morale and policy maker's effectiveness", *Journal of Socio-Economics* 38(6), pp. 988–997.

Di Tella, R., Haisken-DeNew, J., and MacCulloch, R. (2010). "Happiness adaptation to income and to status in an individual panel", *Journal of Economic Behavior & Organization* 76(3), pp. 834–852.

Dubin, J.A. (2007). "Criminal investigation enforcement activities and taxpayer noncompliance", *Public Finance Review* 35(4), pp. 500–529.

Dybvig, P.H. (1995). "Duesenberry's ratcheting of consumption: Optimal dynamic consumption and investment given intolerance for any decline in standard of living", *Review of Economic Studies* 62(2), pp. 287–313.

Edlin, A.S. and Shannon, C. (1998). "Strict monotonicity in comparative statics", *Journal of Economic Theory* 81(1), pp. 201–219.

Ferrer-i-Carbonell, A. (2005). "Income and well-being: an empirical analysis of the comparison income effect", *Journal of Public Economics* 89(5-6), pp. 997–1019.

Fortin, B., Lacroix, G., and Villeval, M.-C. (2007). "Tax evasion and social interactions", *Journal of Public Economics* 91(11-12), pp. 2089–2112.

Frank, R.H. and Hutchens, R.M. (1993). "Wages, seniority, and the demand for rising consumption profiles", *Journal of Economic Behavior & Organization* 21(3), pp. 251–276.

Frey, B.S. and Stutzer, A. (2002). *Happiness and Economics*, Princeton: Princeton University Press.

Fuhrer, J.C. (2000). "Habit formation in consumption and its implications for monetary-policy models", *American Economic Review* 90(3), pp. 367–390.

Galí, J. (1994). "Keeping up with the Joneses: consumption externalities, portfolio choice, and asset prices", *Journal of Money, Credit, and Banking* 26(1), pp. 1–8.

Gamannossi degl'Innocenti, D. and Rablen, M.D. (2016). "Income tax avoidance and evasion: A narrow bracketing approach", *Public Finance Review*, doi:10.1177/1091142116676362

Gemmell, N. and Ratto, M. (2012). "Behavioral responses to taxpayer audits: Evidence from random taxpayer inquiries", *National Tax Journal* 65(1), pp. 33–58.

Gideon, M. (2017). "Do individuals perceive income tax rates correctly?", *Public Finance Review* 45(1), pp. 97–117.

Glaeser, E., Sacerdote, B., and Scheinkman, J. (1996). "Crime and social interactions", *Quarterly Journal of Economics* 111, pp. 507–548.

Goerke, L. (2013). "Relative consumption and tax evasion", *Journal of Economic Behavior & Organization* 87(1), pp. 52–65.

Gordon, J.P.P. (1989). "Individual morality and reputation costs as deterrents to tax evasion", *European Economic Review* 33(4), pp. 797–805.

Gruber, J. and Saez, E. (2002). "The elasticity of taxable income: evidence and implications", *Journal of Public Economics* 84(1), pp. 1–32.

Guariglia, A. and Rossi, M. (2002), "Consumption, habit formation, and precautionary saving: evidence from the British Household Panel Survey", *Oxford Economic Papers* 54(1), pp. 1–19.

Hashimzade, N., Myles, G.D., Page, F., and Rablen, M.D. (2014). "Social networks and occupational choice: The endogenous formation of attitudes and beliefs about tax compliance", *Journal of Economic Psychology* 40(1), 134–146.

Hashimzade, N., Myles, G.D., and Rablen, M.D. (2016). "Predictive analytics and the targeting of audits", *Journal of Economic Behavior & Organization* 124(1), pp. 130–145.

H.M. Revenue and Customs (2016). *Measuring Tax Gaps 2016 Edition: Tax Gap Estimates for 2014-15.* London: H.M. Revenue and Customs.

H.M. Treasury and H.M. Revenue and Customs (2011). *Tackling Tax Avoidance.* London: H.M. Treasury and H.M. Revenue and Customs.

Hokamp, S. (2014). "Dynamics of tax evasion with back auditing, social norm updating, and public goods provision – an agent-based simulation", *Journal of Economic Psychology* 40(1), pp. 187–199.

Hokamp, S. and Pickhardt, M. (2010). "Income tax evasion in a society of heterogeneous agents – evidence from an agent-based model", *International Economic Journal* 24(4), pp. 541–553.

Ioannides, Y. (2012). *From Neighborhoods to Nations: The Economics of Social Interactions*, Princeton: Princeton University Press.

Jackson, M.O., Rogers, B.W., and Zenou, Y. (2017). "The economic consequences of social-network structure", *Journal of Economic Literature* 55(1), pp. 49–95.

Jackson, M.O. and Zenou, Y. (2015). Games on networks. In P. Young and S. Zamir (Eds.), *Handbook of Game Theory*, Vol. 4, pp. 34–61, Amsterdam: Elsevier.

Kim, Y. (2003). "Income distribution and equilibrium multiplicity in a stigma-based model of tax evasion", *Journal of Public Economics* 87(7-8), pp. 1591–1616.

Kirchler, E., Maciejovsky, B., and Schneider, F. (2003). "Everyday representations of tax avoidance, tax evasion, and tax flight: do legal differences matter?", *Journal of Economic Psychology* 24(4), pp. 535–553.

Koehne, S. and Kuhn, M. (2015). "Optimal taxation in a habit formation economy", *Journal of Public Economics* 122(1), pp. 31–39.

Korobow, A., Johnson, C., and Axtell, R. (2007). "An agent-based model of tax compliance with social networks", *National Tax Journal* 60(3), pp. 589–610.

Lang, O., Nöhrbaß, K.-H., and Stahl, K. (1997). "On income tax avoidance: the case of Germany", *Journal of Public Economics* 66(2), pp. 327–347.

Layard, R. (1980). "Human satisfactions and public policy", *Economic Journal* 90(360), pp. 737–750.

Layard, R. (2005). *Happiness. Lessons from a New Science*, London: Allen Lane.

Levaggi, R. and Menoncin, F. (2012). "Tax audits, fines and optimal taxation in a dynamic context", *Economics Letters* 117(1), pp. 318–321.

Levaggi, R. and Menoncin, F. (2013). "Optimal dynamic tax evasion", *Journal of Economic Dynamics and Control* 37(11), pp. 2157–2167.

Ljungqvist, L. and Uhlig, H. (2000). "Tax policy and aggregate demand management under catching up with the Joneses", *American Economic Review* 90(3), pp. 356–366.

Loewenstein, G. and Sicherman, N. (1991). "Do workers prefer increasing wage profiles?", *Journal of Labor Economics* 9(1), pp. 67–84.

Luttmer, E.F.P. (2005). "Neighbors as negatives: Relative earnings and well-being", *Quarterly Journal of Economics* 120(3), pp. 963–1002.

Manski, C.F. (1991). "Nonparametric estimation of expectations in the analysis of discrete choice under uncertainty". In *Nonparametric and Semiparametric Methods in Econometrics and Statistics: Proceedings of the Fifth International Symposium in Economic Theory and Econometrics*, pp. 259–275, Melbourne: Cambridge University Press.

Mazzolini, G., Pagani, L., and Santoro, A. (2017). "The deterrence effect of real-world operational tax audits", DEMS Working Paper no. 359, University of Milan-Bicocca.

McFadden, D. (2006). "Free markets and fettered consumers", *American Economic Review* 96(1), pp. 5–29.

McPherson, M., Smith-Lovin, L, and Cook, J.M. (2001). "Birds of a feather: homophily in social networks", *Annual Review of Sociology* 27(1), pp. 415–444.

Mittone, L. and Patelli, P. (2000). "Imitative behaviour in tax evasion". In F. Luna and B. Stefansson (Eds.), *Economic Modelling with Swarm*, Ch. 5, Amsterdam: Kluwer.

Muellbauer, J. (1988), "Habits, rationality, and myopia in the life cycle consumption function", *Annals of Economics and Statistics* 9(1), pp. 47–70.

Mujcic, R. and Frijters, P. (2013). "Economic choices and status: measuring preferences for income rank", *Oxford Economic Papers* 65(1), pp. 47–73.

Myles, G.D., and Naylor, R.A. (1996). "A model of tax evasion with group conformity and social customs", *European Journal of Political Economy* 12(1), pp. 49–66.

Neck, R., Wächter, J.U., and Schneider, F. (2012). "Tax avoidance versus tax evasion: On some determinants of the shadow economy", *International Tax and Public Finance* 19(1), pp. 104–117.

Neumark, D. and Postlewaite, A. (1998). "Relative income concerns and the rise in married women's employment", *Journal of Public Economics* 70(1), pp. 157–183.

Panadés, J. (2004). "Tax evasion and relative tax contribution", *Public Finance Review* 32(2), pp. 183–195.

Piketty, T., Saez, E., and Stantcheva, S. (2014). "Optimal taxation of top labor incomes: A tale of three elasticities", *American Economic Journal*: *Economic Policy* 6(1), pp. 230–271.

Postlewaite, A. (1998). “The social basis of interdependent preferences”, *European Economic Review* 42(3-5), pp. 779–800.

Quah, J.K.-H. (2007). “The comparative statics of constrained optimization problems”, *Econometrica* 75(2), pp. 401–443.

Rablen, M.D. (2008). “Relativity, rank and the utility of income”, *Economic Journal* 118(528), pp. 801–821.

Rayo, L. and Becker, G.S. (2007). “Evolutionary efficiency and happiness”, *Journal of Political Economy* 115(2), pp. 302–337.

Rigney, P. (2016). *The All Seeing Eye – An HMRC Success Story?* London: Institute of Financial Accountants.

Samuelson, L. (2004). “Information-based relative consumption effects”, *Econometrica* 72(1), pp. 93–118.

Sen, A. (1983). “Poor, relatively speaking”, *Oxford Economic Papers* 35(2), pp. 153–169.

Sikka, P. (2012). “The tax avoidance industry”, *Radical Statistics* 107, pp. 15–30.

Slemrod, J. (1995). “Income creation or income shifting? Behavioral responses to the tax reform act of 1986”, *American Economic Review* 85(2), pp. 175–180.

Slemrod, J. (2001). A general model of the behavioral response to taxation. *International Tax and Public Finance*, 8(2), pp. 119–128.

Slemrod, J. and Kopczuk, W. (2002). “The optimal elasticity of taxable income”, *Journal of Public Economics* 84(1), pp. 91–112.

Srinivasan, T.N. (1973). “Tax evasion: A model”, *Journal of Public Economics* 2(4), pp. 339–346.

Stark, O. and Taylor, J. (1991). “Migration incentives, migration types: the role of relative deprivation”, *Economic Journal* 101(408), pp. 1163–1178.

Suter, L. (2017). *Taxman Unleashes Snooper Computer: What Information Does it Have on You?*, 7th January, London: Telegraph Media Group.

Traxler, C. (2010). “Social norms and conditional cooperative taxpayers”, *European Journal of Political Economy* 26(1), pp. 89–103.

Tremblay, C.H. and Tremblay, V.J. (2010). “The neglect of monotone comparative statics methods”, *Journal of Economic Education* 41(2), pp. 177–193.

Yitzhaki, S. (1974). “A note on ‘Income tax evasion: A theoretical analysis’”, *Journal of Public Economics* 3(2), pp. 201–202.

Zaklan, G., Lima, F.W.S., and Westerhoff, F. (2008). “Controlling tax evasion fluctuations”, *Physica A: Statistical Mechanics and Its Applications* 387(23), pp. 5857–5861.

Appendix

Proof of Proposition 1. Using (6) and (7), optimal avoidance in (4) is written in full as

$$A_{it} = \frac{1-p_i-\phi}{a\zeta_i}\left\{b - a\left[X_i - \iota_h C_{i,t-1} - \iota_s \sum\nolimits_{j\neq i} g_{ijt}\left[X_j + [1-p_j-\phi]\,A_{jt}\right]\right]\right\}. \quad \text{(A.1)}$$

Then the set of N equations defined by (A.1) for taxpayers $i \in \mathcal{N}$ can be written in matrix form as $\mathbf{A}_t = \boldsymbol{\alpha}_t + \mathbf{H}_t\boldsymbol{\beta}\mathbf{A}_t$ where the elements of $\{\boldsymbol{\alpha}_t, \boldsymbol{\beta}, \mathbf{H}_t\}$ are as in Proposition 1. It follows that $[\mathbf{I} - \mathbf{H}_t\boldsymbol{\beta}]\,\mathbf{A}_t = \boldsymbol{\alpha}_t$, so $\mathbf{A}_t = [\mathbf{I} - \mathbf{H}_t\boldsymbol{\beta}]^{-1}\boldsymbol{\alpha}_t \equiv \mathbf{b}(\mathbf{H}_t, \boldsymbol{\beta}, \boldsymbol{\alpha}_t)$. ■

Proof of Proposition 2. First observe that A_{it} and A_{jt} ($j \neq i$) are complementary. We have

$$\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial A_{jt}} = a g_{ijt}\iota_s[1-p_i-\phi][1-p_j-\phi]\begin{cases} =0 & \text{if } g_{ijt}=0; \\ >0 & \text{otherwise.}\end{cases}$$

With this result we are able to utilise the theory of monotone comparative statics. In particular, we establish globally the sign of the derivative $\partial^2\mathbf{E}(U_{it})/[\partial A_{it}\partial z]$ for each exogenous variable z. It then follows, given our restriction to strongly connected networks, that if $\partial^2\mathbf{E}(U_{it})/[\partial A_{it}\partial z] \geq 0$ for all i, with $\partial^2\mathbf{E}(U_{it})/[\partial A_{it}\partial z] > 0$ for at least one such i, then $\partial A_{it}/\partial z > 0$, and if $\partial^2\mathbf{E}(U_{it})/[\partial A_{it}\partial z] \leq 0$ for all i, with $\partial^2\mathbf{E}(U_{it})/[\partial A_{it}\partial z] < 0$ for at least one such i, then $\partial A_{it}/\partial z < 0$. Differentiating in (1) we obtain

$$\begin{aligned}
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial b} &= 1-p_i-\phi > 0; \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial \phi} &= a\{X_i + 2A_{it}[1-p_i-\phi] - \iota_h\} - a\iota_s\sum\nolimits_{j\neq i} g_{ijt}\{X_i + 2A_{jt}[1-p_i-\phi]\} - b \gtrless 0; \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial p_i} &= a\{X_i + A_{it}[1-2\phi] - R_{it}\} - b < 0; \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial p_j} &= -aA_i g_{ijt}\iota_s[1-p_i-\phi]\begin{cases} =0 & \text{if } g_{ijt}=0; \\ <0 & \text{otherwise;}\end{cases} \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial X_i} &= -a[1-p_i-\phi] < 0; \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial X_j} &= a g_{ijt}\iota_s[1-p_i-\phi]\begin{cases} =0 & \text{if } g_{ijt}=0; \\ >0 & \text{otherwise;}\end{cases} \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial \iota_s} &= a[1-p_i-\phi]\sum\nolimits_{j\neq i} g_{ijt}q_{jt} > 0; \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial \iota_h} &= a[1-p_i-\phi]C_{i,t-1} > 0; \\
\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it}\partial C_{i,t-1}} &= a\iota_h[1-p_i-\phi] > 0.
\end{aligned}$$

The exception is the exogenous variable a, for which we show that $\partial^2\mathbf{E}(U_{it})/[\partial A_{it}\partial a]$ is signed locally to an interior equilibrium. Under a set of regularity conditions – that utility is C^2 and concave, $U(.) > 0$ for positive values of the argument, and that the problem has a unique solution that obeys the first order conditions and varies smoothly with the variable of interest (a here) – Quah (2007, p. 420) shows that signing $\partial^2 \mathbf{E}(U_{it}) / [\partial A_{it} \partial a]$ local to the (unique) interior maximum is sufficient to determine the equilibrium sign of $\partial A_{it}/\partial a$. As these regularity conditions hold in the current context, we utilise this approach to establish the equilibrium sign of $\partial A_{it}/\partial a$. We obtain

$$\left.\frac{\partial^2 \mathbf{E}(U_{it})}{\partial A_{it} \partial a}\right|_{\partial EU_{it}/\partial A_{it}=0} = -\frac{[1 - p_i - \phi]\, b}{a} < 0.$$

We prove the ambiguity in sign of $\partial \mathbf{E}(\partial A_{i,t+1})/\partial X_i \gtreqless 0$ by example within the main text. ■

Figures

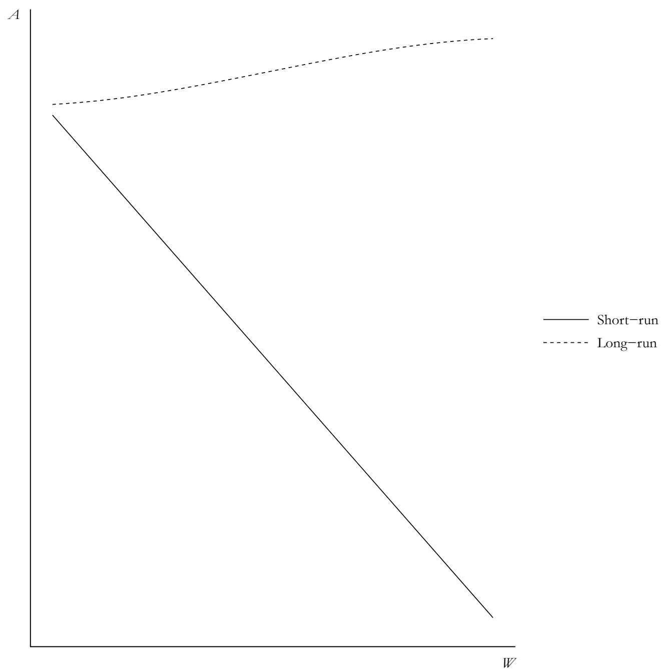

Figure 1: Short- and long-run comparative statics effects of an increase in taxpayer wealth.

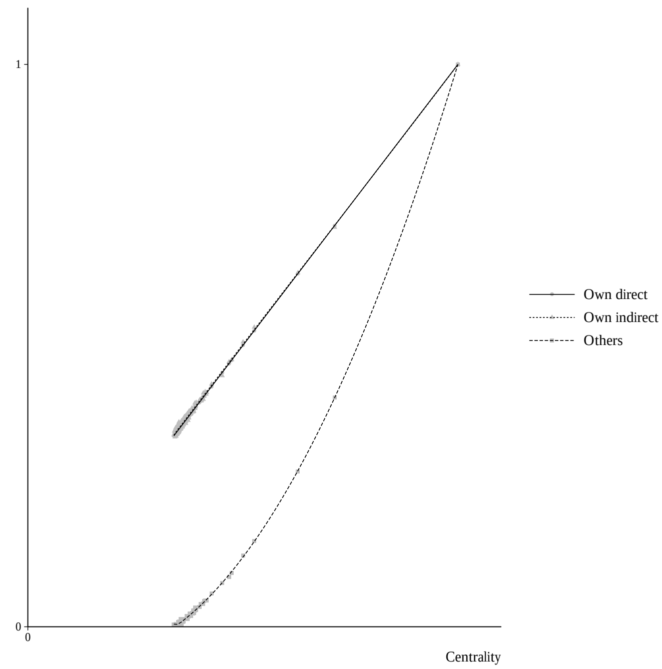

Figure 2: Marginal revenue effects of one additional intervention for taxpayers at each level of network centrality (avoidance)

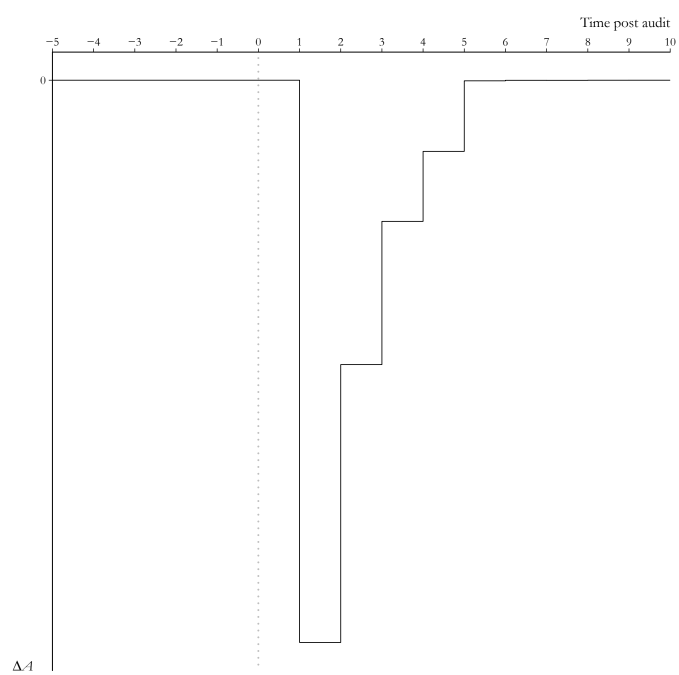

Figure 3: Temporal profile of the change in avoidance behaviour following an intervention.