Tax Evasion and Laffer Curves

PRELIMINARY AND INCOMPLETE*

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Abstract

We provide a theory of the Laffer curve (LC) using a simple model of tax evasion with strategic complementarities, which arise from the assumption that the cost of being caught while evading is decreasing as more people evade their taxes. We find that with either sufficiently low or sufficiently high tax rates, there is a unique equilibrium, therefore a unique level of tax evasion and tax revenues. If taxes are in between, there can be multiple equilibria which imply two LCs, one with high and one with low tax evasion. The policy implication of this result is that if taxes are sufficiently high, it is possible to increase tax revenues by reducing taxes, even though locally the LC was upward sloping. Using data on VAT evasion, we find empirical evidence that supports our assumption of strategic complementarities and the presence of multiple LCs. We structurally estimate our model and find that countries with strong institutions coordinate more often on the good equilibrium. We then provide a numerical example by calibrating the LCs for Greece, showing that an increase in the VAT rate would reduce tax revenues.

JEL Classification Codes: H26, H30, C72

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1 Introduction

In the past few years, several countries have come under intense pressure to reduce their government debt and budget deficit. The case of Greece is a prominent recent

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example where its creditors have demanded this directly. Furthermore, several other countries have faced indirect yet severe pressure by the bond markets.

One of the most controversial elements in the policy debate regarding the optimal way of reducing debt and deficit is estimating the effect of changing the tax rate on tax revenues. The issue is effectively illustrated by a textbook Laffer Curve (LC). As depicted in Figure 1, if we are in the downward sloping region of the LC, a decrease of the average tax rate will increase tax revenues. The more orthodox view, however, is that we are in the upward sloping region, hence an increase in the tax rate will increase tax revenues. This view justifies recent policy interventions implemented by the IMF.

We introduce a simple theory of tax evasion which implies a significantly different LC than usual.[1] In particular, consistently with the orthodox view, the LC can be locally increasing, yet, a tax hike can decrease tax revenues. The reason for this result is that the model can lead to two overlapping LCs, as in Figure 2. Each LC is associated with a Nash equilibrium of the underlying model.

Our theory of the LC is based on a simple model of tax evasion with strategic complementarities, which arise due to the key property that the cost of evading (weakly) decreases as more people choose to evade their taxes. We achieve this by modelling the probability of being caught evading as a decreasing function of the number of evaders. However, the literature has emphasised other mechanisms such as those summarized by Fortin et al. [2007], where individual tax evasion decisions are affected by social norms and social interactions.

While all of these mechanisms can be studied in our model, our emphasis on the auditing technologies is motivated by three observation. First, it seems intuitive that some countries (e.g. due to financial distress or weak institutions) may find it increasingly difficult to guarantee tax enforcement when a large number of tax payers evade. This institutional interpretation is corroborated by our finding that countries where we detect strong evidence for strategic complementarity and multiple equilibria are those considered to have weak institutions according to other independent rankings. Second, since auditing is embedded in the institutional setting of a country, which is to some degree observable, there is scope for an empirical assessment of the extent to which our channel generates strategic interaction and multiple equilibria. This is very difficult for mechanisms that rely on implicit preferences about social norms, but possible within our setup as we are able to recover detection probabilities using data on tax enforcement. In fact, our empirical assessment finds that this mechanism is a powerful source of strategic complementarities.[2] Finally, since the government designs the auditing system, there is scope for policy reform.

While strategic complementarities can give rise to multiple equilibria, the model has sharp predictions: for each level of taxation, we can specify whether the equilibrium is unique or, if not, identify the equilibria with the lowest and highest evasion. These are pure Nash equilibria which we call “good” and “bad”, respectively. Furthermore, we can safely ignore all equilibria in between, using results from the literature on

[1]We abstract from the usual labor-leisure tradeoff in order to cleanly analyse the effect of tax evasion.

[2]Instead, as further discussed in the literature review, Fortin et al. [2007] find that the preference based mechanism is not a powerful source of strategic complementarity.

supermodular games, as we explain in Section 2.[3]

We now further elaborate on these two cases. First, when the equilibrium is unique for any tax rate, we obtain the usual hump-shaped LC, depicted in Figure 1. As tax rates increase, everyone (weakly) increases their tax evasion. However, for low tax rates the LC is increasing because the dominant effect is the increase of the tax rate on those who pay their taxes, whereas for high tax rates the LC is decreasing, because the dominant effect is the increase of the agents who choose to evade.

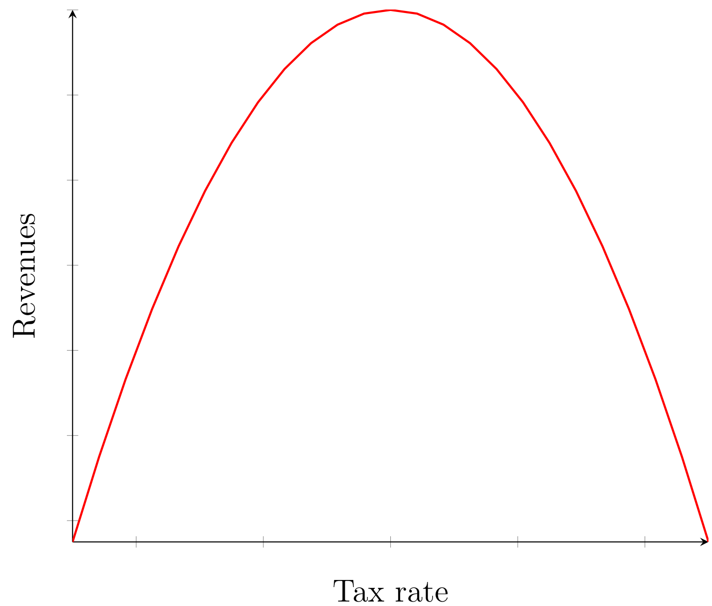

Figure 1: LC with a unique equilibrium

In the second case there are two equilibria, which generate two LCs. For low tax rates, the good and the bad equilibria coincide, so there is a unique equilibrium of low tax evasion. The same is true for high tax rates, where there is a unique equilibrium of high tax evasion. However, in between, the good and the bad equilibria are different, specifying low and high tax evasion, respectively. This is depicted in Figure 2, with the three regions denoted A^*, B^* and AB, respectively.

This latter case has interesting policy implications: if the economy is in region AB and on a low LC, a tax break can increase revenues. This is because, as is evident

[3] As it is well known, games with strategic complementarities (often called supermodular games) have several attractive properties. First, they always have a "good" pure Nash equilibrium, which is defined as the equilibrium where everyone has minimum (among all other equilibria) evasion and a "bad" equilibrium, where everyone has maximum evasion. Moreover, the good and the bad equilibria are the minimum and the maximum elements of the set compatible with iterated strict dominance, rationalizability and correlated equilibrium. If the good and the bad equilibria coincide, then the game has a unique pure Nash equilibrium. Second, mixed strategy equilibria are unstable, so we can safely ignore them. Third, we concentrate our analysis on the good and the bad equilibria, because they are the only pure Nash equilibria that are necessarily monotonic with respect to taxes (i.e. evasion increases with taxes). When generating an economy using plausible assumptions on income distribution, it is very difficult to obtain more than two equilibria.

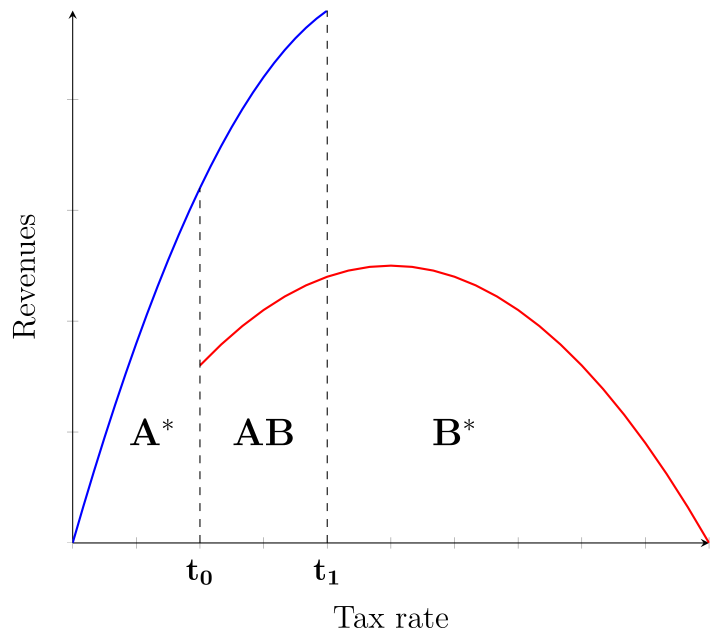

Figure 2: LC with two equilibria

from Figure 2, a tax cut to region A^* induces a jump to a higher LC. Conversely, a tax hike can decrease revenues if the equilibrium prior to the tax hike was on the high LC. Importantly, both these possibilities occur even though the LC was upward sloping at the initial tax rate. While this particular result depends on parameter values, the lesson is more general: to design an optimal policy intervention, policy makers should first detect the presence of multiple LCs and understand on which LC a country is. Instead, the current focus on the slope of the equilibrium LC may be highly misleading in the presence of multiple LCs: even if a country is in a region where the LC is positively sloped, it may still be revenue maximising to cut taxes and move to a higher LC.

The uncovered mechanism would be especially important if the empirically relevant case was the one with multiple equilibria and LCs. As it is well known the identification of strategic complementarity, and multiple equilibria, raises difficult identification issues (Manski [1993]). To circumvent these issues the literature on social interactions used laboratory or field experimental data (citations). However, the fiscal institutional settings that generate strategic complementarity in our model cannot be estimated this way but would be part of the set-up of the experiment. For instance, Fortin et al. [2007] assume monitoring to be independent of evasion, instead, Alm et al (1993) and Alm and McKee (2004) assume auditing strategies that respond to evasion. The slope of p is key in our model and we would like to estimate that from real data.[4] We es-

[4] According to Phillips (2014), tax authorities do not make their auditing selection strategies public (Alm and McKee [2004] reports that the IRS has refused to disclose their selection strategy and has even gone to court to maintain confidentiality) but previous literature has acknowledged the possibility of auditing strategies that do not involve random sampling (which would induce detection probability independent of evasion). See Allingham and Sandmo (1972), Witte and Woodbury (1985), Graetz et al. (1986), Reinganum and Wilde (1986), Klepper and Nagin (1989), Alm et al. (1993a), Erard and Feinstein (1994), Andreoni et

timate such a relationship using data on VAT tax evasion for a panel of EU countries and a period of time between 2004 and 2015 and data on the effectiveness of the tax authorities from the European Commission: these latter data contain information on the amount of taxation recovered through audits. To tackle endogeneity issues, we instrument tax evasion with immigration inflows to each country, which turns out to be a strong instrument. We find a strongly significant negative relationship.

Because a negative relationship is necessary, but not sufficient for multiplicity of equilibria, we also provide testable implications for the case where the game has a unique equilibrium, using the correlations between taxes due, evasion and the probability of detection, which we back out from the effectiveness of the tax authorities. We find that the data reject uniqueness and therefore are consistent with the case of multiple LCs.

We also perform the same test on each country individually, in order to further validate our theory. In particular, given our interpretation of a decreasing cost of being caught as a proxy for weak institutions and ineffective governance, we expect to reject uniqueness more often for countries with those characteristics. Our results confirm this intuition, as we fail to reject uniqueness only for Finland, Sweden, Denmark and Germany, which are in the top 12 among 149 countries, according to the ranking on effective governance published by the Legatum Institute [2017]. The countries for which we reject uniqueness are on average much lower in the ranking.[5]

It is worth stressing that our empirical approach of using panel data does not allow us to estimate our model in its entirety, but we are able to identify key elements with which we can test for the presence of multiple equilibria. However, we are not able to identify LCs fully. Even in the presence of multiple equilibria, we don't know how far the two LCs are from each other, and how steep they are.

To illustrate the possible quantitative effects of the presence of multiple LCs, we first structurally estimate our model in Section 4. We find that multiplicity is pervasive, but do not observe jumping between good and bad equilibria in all countries. Moreover, we find that countries with "strong" institutions coordinate more often closer to the good equilibrium than countries with weak institutions.

We also construct a calibrated example using data from Greece in Section 5. We match the equilibrium for 2008, before the financial crisis and the bailout, when the VAT rate was low, at 19%. By constructing the LCs in Figure 10, we find that the AB region is in between the 7% and 20% VAT rates. Moreover, an increase of the VAT rate from 19% to 21% would decrease tax revenues from 13.5% to 11% of GDP. In reality, Greece had to eventually increase the VAT rate to 23% and there is overwhelming evidence that tax revenues did not increase as expected.

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al. (1998), Rhoades (1999), Dubin (2007), Kleven et al. (2011).

[5]In particular, we reject uniqueness for the UK (10th), Ireland (13th), Estonia (21st), Spain (30th), Czech Republic (31st), Slovenia (36th), Poland (37th), Latvia (40th), Slovakia (42nd), Greece (53rd) and Hungary (56th).

1.1 Related literature

The theoretical literature on tax evasion stems from Becker [1968], Ehrlich [1973], Allingham and Sandmo [1972] and Yitzhaki [1974], where the decision to evade taxes depends on the probability of detection and the punishment if caught.

Fortin et al. [2007] introduce strategic complementarities by adding a term in the utility function that captures preferences for social conformity and fairness. Depending on the parameter values, these motives can induce strategic complementarity or substitutability. They structurally estimate the model, using data from a laboratory experiment in order to address challenges of the identification of social interactions (Manski [1993]). They find no evidence of social conformity and strategic interaction. However, in their set-up strategic interaction can only stem from preferences for social conformity and fairness. In particular, they assume monitoring and punishment to be independent of evasion. We show how this channel that stems from the fiscal institutional setting can lead to strategic complementarity and multiple equilibria even when agents are completely individualistic and "amoral". Given their result, we will focus on fiscal institutions and ignore the behavioural channel that stems from preferences.

There is a large literature that focuses on how to design the auditing mechanism to maximize compliance (see Gilpatric et al. [2011] and references therein). This literature finds that endogenous rather than random audit mechanisms improve the effectiveness of the monitoring system at detecting cheating behaviour but has also recognized the possibility that endogenous audits lead to multiple equilibria.

In macroeconomics, Cooper [1999] provides several applications with strategic complementarities and multiple equilibria, whereas Cooper [2002] discusses the estimation and identification issues that arise due to multiplicity.[6]

In the economics of crime, Conley and Wang [2006] study an equilibrium model where heterogeneous agents choose whether to work or commit crimes, and the arrest rate depends on the size of the police force. Multiple interior equilibria arise also in the random search model of crime of Burdett et al. [2003, 2004].[7] Adda et al. [2014] construct and calibrate a structural model of the market for cannabis and crime, using data from a policing experiment which depenalized the possession of small quantities of cannabis in the London borough of Lambeth, between 2001 and 2002. Within an equilibrium framework, individuals decide whether to buy cannabis and from which London borough, and whether to commit other non drug-related crimes, whereas the police decides how to allocate its forces across the various boroughs. They find that depenalization led to a reallocation of the police force towards non-drug crime, which fell, although overall welfare decreased and drug consumption increased.

Fu and Wolpin [2017] are the first to empirically implement a model of crime with multiple equilibria. Frey and Torgler [2004] analyze data from a survey of 30 European countries. They find that high perceived tax evasion of others implies low willingness to pay taxes. This is consistent with the strategic complementarity of actions that

[6] Morris and Shin [2000] argue that multiplicity of equilibria is an implication of two assumptions, that fundamentals are common knowledge and that agents know the actions of others in equilibrium. If the actions of others depend on noisy signals then the unique equilibrium determined by the fundamentals and the knowledge that everyone is rational.

[7] A survey of the literature is provided in Draca and Machin [2015].

we have in our model. Weibull and Villa [2005] provide a theoretical model of social norm against criminal activity. Deviations from the norm result in feelings of guilt and shame. These feelings are stronger when the fraction of the population obeying the norm is larger. We incorporate this feature in our model by making the expected non monetary cost of being caught a decreasing function of the tax evasion in the population.

Kleven et al. [2011] analyze a tax enforcement field experiment in Denmark and find that a change in the probability of detection has a strong positive impact on reported income. This finding justifies our focus on the detection probability. There is also the compliance puzzle that evasion is low even though audit rates and penalties are low. Kleven et al. [2011] explain this through third party reporting, and find that for those who are able to cheat, cheating is sensitive to monitoring activity.

The paper is organized as follows. In Section 2, we develop the theoretical model. In Section 3, we discuss empirical evidence that supports our theory, test for a decreasing cost of being caught while evading and for multiplicity of equilibria. In Section 4, we structurally estimate our model. In Section 5, we provide a numerical example of the LC using data from VAT evasion in Greece.

2 Model

Consider an economy with a continuum of agents, $I = [0,1]$. Agent i's strategy space is $S^i = [0,1]$, denoting the probability of evading taxes, with typical element s_i. His utility is

$$U_i(s_i, s_{-i}) = y_i - (s_i k_i p(e) + (1 - s_i)t_i),$$

where y_i is his income, t_i is the tax he will pay if he does not evade and k_i is the (expected) monetary/incarceration cost if he is caught evading.[8] In case the agent evades his taxes, the probability of being detected, multiplied by the guilt or shame felt when caught, is denoted $p(e)$, where $e = \int_0^1 s_i di$ is the share of people evading. Because of risk neutrality, we do not need to distinguish between the probability of detection and the guilt, so to save on the notation we use one variable for both.

The model is very general in that it allows full heterogeneity in how taxes and punishments are imposed. However, we assume that $p : [0,1] \to [0,1]$ is a decreasing function of the average evasion in the economy, so that $p' < 0$. This is a crucial assumption in our model. As Proposition 1 shows, $p' < 0$ implies that there is strategic complementarity between s_i and s_{-i}, so that

$$U_i(s'_i, s'_{-i}) - U_i(s_i, s'_{-i}) \geq U_i(s'_i, s_{-i}) - U_i(s_i, s_{-i}),$$

for all $s'_i \geq s_i$ and $s'_{-i} \geq s_{-i}$.[9] This property says that if all other players (weakly) increase their probability of tax evasion, it becomes more profitable for player i to

[8] By allowing k_i to be an expected rather than a deterministic cost, it is possible that $k_i < t_i$, for example in the case where the probability of actually being charged is very low.

[9] We define $s'_{-i} \geq s_{-i}$ if $s'_j \geq s_j$ for all $j \neq i$.

increase his own probability as well. We call a game *supermodular* if it satisfies this property for all players.[10]

In Section 3.3, we provide empirical support for our assumption that $p' < 0$. Here, we offer two theoretical justifications. The first is about the probability of detection. Suppose that the tax collectors' resources are fixed and cannot be expanded, for example because the country is under a bailout program. At each period of time, a tax collector randomly picks a tax payer and makes a preliminary check on his tax affairs. If this preliminary investigation raises suspicions of tax evasion, then he conducts a full investigation which takes several periods to build a case against him. If no suspicions are raised, the tax collector randomly picks another tax payer. If many tax payers evade, the probability of raising suspicions when initially checked is high, which means that the tax collector will spend most periods fully investigating, rather than randomly checking other tax payers. As a result, the probability of being picked initially (and therefore also the probability of being detected when tax evading) drops when more people evade their taxes.

The second justification stems from the feelings of guilt or shame one feels when convicted of tax evasion. We expect that as more people evade their taxes, this practice becomes more socially acceptable, hence diminishing guilt and shame. A similar assumption is made in Weibull and Villa [2005].

The best response function specifies $BR_i(s_{-i}) = 1$ if $t_i > k_i p(e)$ and $BR_i(s_{-i}) = 0$ if $t_i < k_i p(e)$. A strategy profile s^* is a Nash equilibrium (NE) if $s_i^* = BR_i(s_{-i}^*)$ for all $i \in I$.

Supermodular games have interesting properties. Before enumerating them, we provide some definitions.

Definition 1. *An equilibrium strategy profile s is good if, for any other equilibrium strategy profile s', we have $s_i \leq s_i'$ for all $i \in I$. It is bad if $s_i \geq s_i'$ for all $i \in I$.*

An equilibrium strategy profile is good if in any other equilibrium, *all* players evade taxes with a (weakly) higher probability. Similarly, it is bad if in all other equilibria *all* players are evading taxes with a (weakly) lower probability. A good or a bad equilibrium may not exist, however a supermodular game always has both, as the following Proposition shows. Moreover, we show that both these equilibria are increasing in t: $t_i' \geq t_i$ for all $i \in I$ implies $s_i' \geq s_i$ for all $i \in I$.

The following Proposition confirms that the game is supermodular and enumerates the properties that are most useful for our analysis.

Proposition 1. *Suppose $p' < 0$. Then, the game is supermodular and has the following properties:*

1. *There is strategic complementarity between s_i and t_i,*
2. *There is always a good and a bad equilibrium,*
3. *Both the good and the bad equilibria are increasing in t: if $t' \geq t$ then $s' \geq s$.*

[10] Two other properties are required for supermodularity, which are satisfied in our model for all $i \in I$. First, S_i is compact. Second, U_i is upper-semicontinuous in (s_i, s_{-i}). Supermodular games have been studied extensively. For more details, see Topkis [1979], Vives [1990] and Milgrom and Roberts [1990].

Proof. Note that $\frac{\partial U_i}{\partial s_i} = -k_i p(e) + t_i$. Given the assumption on the function p, we have strategic complementarity between s_i and s_{-i} because $\frac{\partial^2 U_i}{\partial s_i \partial e} = -kp'(e) > 0$. Hence, the game is supermodular. Also note that there is strategic complementarity between s_i and t_i because $\frac{\partial^2 U_i}{\partial s_i \partial t_i} = 1 > 0$. Points 2 and 3 are Theorems 5 and 6 in Milgrom and Roberts [1990].

□

Although a supermodular game can have multiple equilibria, the Proposition ensures that there is always a good equilibrium where everyone's probability of tax evasion is the lowest, and a bad equilibrium where everyone's probability is the highest, than in any other equilibrium.[11] If the equilibrium is unique, it is both good and bad. Moreover, point 3 shows that both these two equilibria are "well-behaved", because as taxes increase weakly for all, the probability of tax evasion for *all* players increases weakly. This is not true in general for other equilibria. For these reasons, and given that other equilibrium strategies are bounded by these two, for the rest of the paper we concentrate only on these two equilibria.[12]

We now characterize the NE. Let $\frac{t}{k} : I \to \mathbb{R}_+$ be a random variable which maps each agent i to his $\frac{t_i}{k_i}$ ratio. Define F such that $F(\frac{t_0}{k_0}) = \{i \in I : \frac{t}{k}(i) \leq \frac{t_0}{k_0}\}$ is the mass of agents who have cost ratio $\frac{t_0}{k_0}$ or less.

Proposition 2. *Suppose that the mass of agents having any $\frac{t_i}{k_i}$ ratio is of measure zero. Then, a NE is characterized by a cutoff point $\frac{t_0}{k_0}$, such that $1 - F(\frac{t_0}{k_0})$ of agents with a higher ratio evade ($s_i = 1$), everyone else does not ($s_i = 0$) and $p(1 - F(\frac{t_0}{k_0})) = \frac{t_0}{k_0}$.*

Proof. From the best response function and because U_i is linear in s_i, in any equilibrium there is measure zero of players i with $s_i \in (0, 1)$. Hence, without loss of generality, either $s_i = 1$ or $s_i = 0$. Moreover, if in an equilibrium agent i evades, so that $s_i = 1$, then all j with $\frac{t}{k}(j) \geq \frac{t}{k}(i)$ evade as well, because $\frac{t_j}{k_j} \geq \frac{t_i}{k_i} > p(e) = p(\bar{s}_{-j})$. □

This characterization covers all NE if the mass of agents with any $\frac{t_0}{k_0}$ is of measure zero. If it is not, then we could have a NE where some agents with the same $\frac{t_0}{k_0}$ ratio evade, whereas others do not. To avoid these knife-edge cases, we make this assumption throughout the paper.

We now provide a graphical representation of the equilibria. Without loss of generality, we order agents in terms of decreasing tax to punishment ratio, so that $i > j$ implies $\frac{t}{k}(i) \leq \frac{t}{k}(j)$. Then, a NE is characterized by a number c, so that each $i \in [0, c]$ evades and each $i \in [c, 1]$ do not evade, where $p(c) = \frac{t}{k}(c)$. Moreover, $\frac{t}{k}(0) \leq p(0)$ implies the existence of a no evasion equilibrium and $\frac{t}{k}(1) \geq p(1)$ implies the existence of an all evade equilibrium.

[11]This is a stronger statement than requiring that at some equilibrium the average tax evasion is the lowest (or the highest) than in any other equilibrium. This latter statement is trivially satisfied irrespective of whether the game is supermodular.

[12]It is interesting to note that, as shown by Echenique and Edlin [2004], mixed strategy equilibria in supermodular games are unstable under a variety of dynamic adjustments processes, therefore we do not consider them.

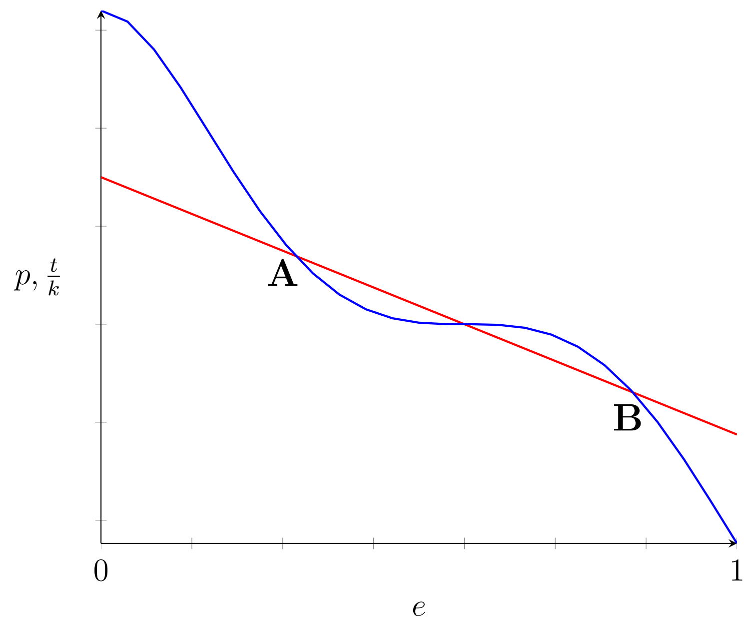


Figure 3: Two interior equilibria

In Figure 3, the straight blue line is the graph of function p, whereas the curved red line is the graph of $\frac{t}{k}$. Whenever the red line intersects the blue line from above, we have a stable Nash equilibrium. Point A denotes the good equilibrium with minimum evasion and point B denotes the bad equilibrium with maximum evasion. In between, there is another equilibrium which standard arguments show that is unstable, in the sense that a small perturbation around it will "lead" to another equilibrium, so we ignore it.

Suppose that $\frac{t_i}{k_i}$ increase for everyone, for example because the tax rate increases. Then, the graph of $\frac{t}{k}$ moves to the right. Consistent with point 3 of Proposition 1, both A and B move to the right, so that tax evasion increases in both equilibria.[13] As we keep increasing taxes, at some point the good (minimum evasion) equilibrium disappears discontinuously. This is depicted in Figure 4, where the unique equilibrium is B^*.[14] Similarly, as taxes decrease, the graph of $\frac{t}{k}$ moves to the left and both the good and the bad equilibria move to the left. At some point, the bad equilibrium disappears discontinuously. This is depicted in Figure 5, where the unique equilibrium is A^*.

Every equilibrium traces a LC as t increases. If c is the cutoff point of a NE with a particular tax structure t, then total taxes are $T(c) = \int_0^c t_i di$. There can be multiple equilibria, implying multiple LCs, however these curves may merge for some t.

[13]However, in the middle (unstable) equilibrium tax evasion decreases. As we argued above, we ignore this equilibrium due to its instability.

[14]Formally, B^* is both a good and a bad equilibrium.

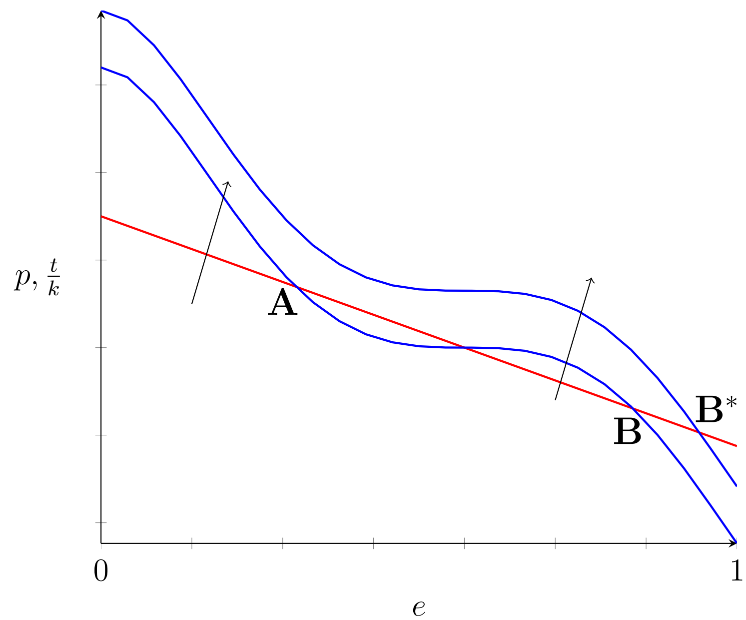


Figure 4: One bad interior equilibrium

2.1 The probability of being caught

One of the most important variables in our analysis is the probability p of being caught when evading taxes, as a function of how many evade. Our main assumption is that p is a decreasing function, so that the probability of being caught given that you evade is decreasing as more agents evade. In this section we microfound the equilibrium p through probability theory and we relate it to observables, and in particular using a measure of the tax authorities' effectiveness. We later use this construction in the empirical part of Section 3.3.

It is useful to think of this game as if it was played in two stages. In the first, the agents decide whether to evade or not. In the second stage, the tax authority performs tax audits. Let the total number of people be normalized to 1, e be the number of tax evaders, and a the number of agents who are audited. Let $P(e|a) = \frac{P(a \cap e)}{P(a)}$ be the probability of an agent evading given that he is being audited. Assuming that auditing an evader implies that he is convicted, $P(e|a)$ denotes the effectiveness of the tax authorities, or how well targeted the audits are.

An agent who evades cares about the probability of being audited given that he evades,

$$P(a|e) = \frac{P(a \cap e)}{P(e)} = \frac{P(e|a)P(a)}{P(e)}. \tag{1}$$

The latter is the probability of being caught, our function p. Thus our aim is to see whether $P(a|e)$ is decreasing in the number of evaders.

OECD [2015], Table 6.9, provides data on the value of taxes recovered due to explicit verification efforts or audits by the tax authorities, divided by the total number of taxes earned. We denote this variable as m. Let $\bar{t}$ be the average taxes paid by each person

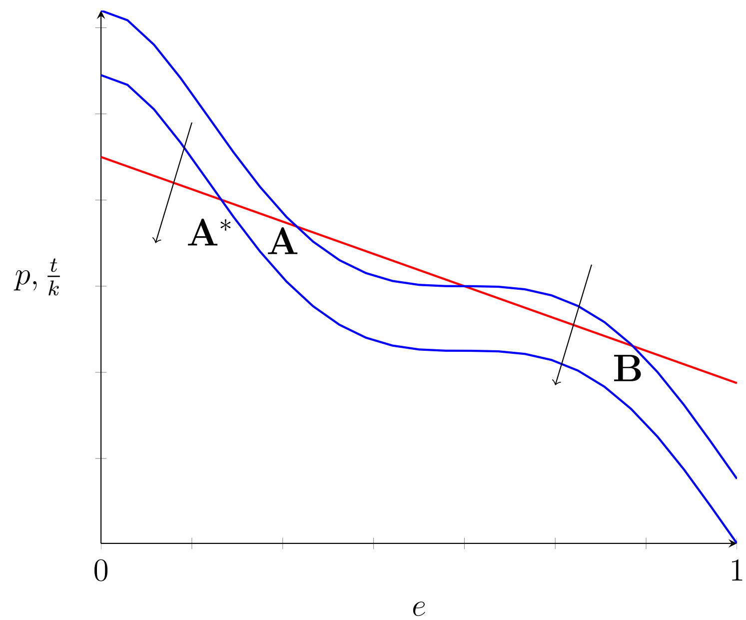


Figure 5: One good interior equilibrium

not evading. Suppose that each person pays $\bar{t}$ if not evading and 0 otherwise. The authority conducts a audits and recovers $\bar{t}aP(e|a)$ dollars. The taxes paid by the non evaders are $\bar{t}(1-e)$. We therefore have

$$m = \frac{aP(e|a)}{aP(e|a) + 1 - e}. \tag{2}$$

From the latter it is straightforward that if audits a and effectiveness $P(e|a)$ are fixed, m is positively correlated with e. Later we identify e with data on the VAT gap and find that the correlation with m is indeed positive. This is an initial indication that the probability of being caught $P(a|e)$ is decreasing in the number of evaders.[15] However, m positively correlated with e is necessary but not sufficient for $aP(e|a)$ fixed. So more work follows to construct an empirical counterpart for $P(a|e)$ and see if it is actually decreasing in the number of evaders.

From (2), we have $P(e|a) = \frac{m(1-e)}{a(1-m)}$ and substituting we get $P(a|e) = \frac{P(a \cap e)}{P(e)} = \frac{P(e|a)P(a)}{P(e)} = \frac{m(1-e)P(a)}{a(1-m)P(e)}$. If we assume that $P(a) = a$ and $P(e) = e$ this simplifies to $P(a|e) = \frac{m(1-e)}{(1-m)e}$. So we have that the equilibrium probability of being caught when evading is

$$p(e) = P(a|e) = \frac{m(1-e)}{(1-m)e}.$$

Holding m constant, p is decreasing with the share of evaders e. However, m itself could be a function of e, meaning that $p'(e) < 0$ is not implied by our construction. For

[15]This is because a higher number of evaders implies a higher $P(e)$ and from Equation (1), if the effectiveness of the tax authorities $P(e|a)$ and the audits they conduct $P(a)$ stay the same, a higher $P(e)$ implies a lower $P(a|e)$.

example, consider the case where the tax authorities do not perform targeted audits, but just choose a random sample of the population. Then, $P(a|e) = P(a)$ and the probability $p(e)$ of being caught is independent of how many evade, so that $p'(e) = 0$ is allowed by our construction. In that case, $P(a|e) = P(a) = a$ and $m = \frac{ae}{ae+1-e}$. Mechanically, in this case the increase in e is countered by an increase in m such that $p(e) = P(a|e) = \frac{m(1-e)}{(1-m)e}$ remains the same.

In Section 3.3, we estimate $p(e)$ using an IV approach. We find that $p'(e) < 0$, which is the main assumption implying that the game is supermodular.

3 Empirical Evidence

In this section we present the empirical evidence that is needed to assess our theory and, in particular, the empirical relevance of the case of multiple equilibria which leads to multiple LCs. We first provide a short description of the data we use. In Section 3.2, we map tax evasion and tax rates, which we take as suggestive of the presence of multiple equilibria. However, in subsequent sections we provide a more thorough analysis, first by testing our key assumption of supermodularity, a decreasing p, using an IV method (Section 3.3), and then by testing explicitly whether our data is consistent with a unique equilibrium (Section 3.4). Finally, in Section 4 we perform a structural estimation of our model. We find that multiplicity is pervasive and quantitatively important.

3.1 Data

We use data from the European Commission (Barbone et al. [2013], Poniatowski et al. [2016] and European Commission [2016]) on VAT rates and on the VAT gap, which is an estimate of the revenue loss due to "fraud and evasion, tax avoidance, bankruptcies, financial insolvencies, as well as miscalculations". It is defined as the ratio of the VAT collected and the VAT Total Tax Liability (VTTL). These data are available for a sensible time span (from 2000 to 2014) and for 27 EU countries.

Using the VAT gap as a measure of tax evasion has several advantages. First, although it is a common tax across all EU countries, there is considerable heterogeneity in tax evasion and tax rates, both across countries and across years. Second, it is fairly straightforward to measure it, because the VAT is essentially a flat tax on the value of transactions, for which there are several measurements. As a comparison, to measure evasion on income tax would be more difficult because it is not a flat tax, so for each individual one would need to measure his true income, compute his tax rate, and then subtract his declared taxes. Since the VAT is a flat tax, one does not need individual measures of what is owed, as the distribution does not matter.

In order to construct our estimate of the probability p of being caught while evading, we use data on tax effectiveness by OECD [2015], as we describe in Section 2.1. Table 6.9 provides data on the value of taxes recovered due to explicit verification efforts or audits by the tax authorities, divided by the total number of taxes earned. These data come from a survey of tax administration systems, practices and performance of the revenue bodies of 56 countries, including all EU countries for which we have VAT evasion data. It covers the period from 2007 to 2013.

Finally, in order to construct our instrument for the IV method of Section 3.3, we use migration inflows to the EU countries, taken from the OECD.[16]

3.2 A First Look at the Data

Figure 6 shows the scatter diagram between the VAT rate and tax evasion: each dot shows the tax evasion and tax rate of a country in a year. The figure suggests a threshold VAT tax rate at 18% below which, both the level and the variance of tax evasion are much lower. In particular, below the threshold of 18%, all observations but 2 are below the average tax evasion, denoted by the horizontal red line. The only two observations well above the mean are Spain in 2008 and 2009. Research by the Spanish Tax administration shows that the increase in the gap was heightened by changes in the filing and refund procedures implemented in those years (Barbone et al. [2013]). So these two observations may be considered outliers. That the data appear so much more concentrated could simply be because there are more observations above the 18% threshold (339 equal or above and 51 below the threshold), but a Bartlett test, that takes this into account, strongly rejects the null of same variance (with a p-value of 0.00).[17]

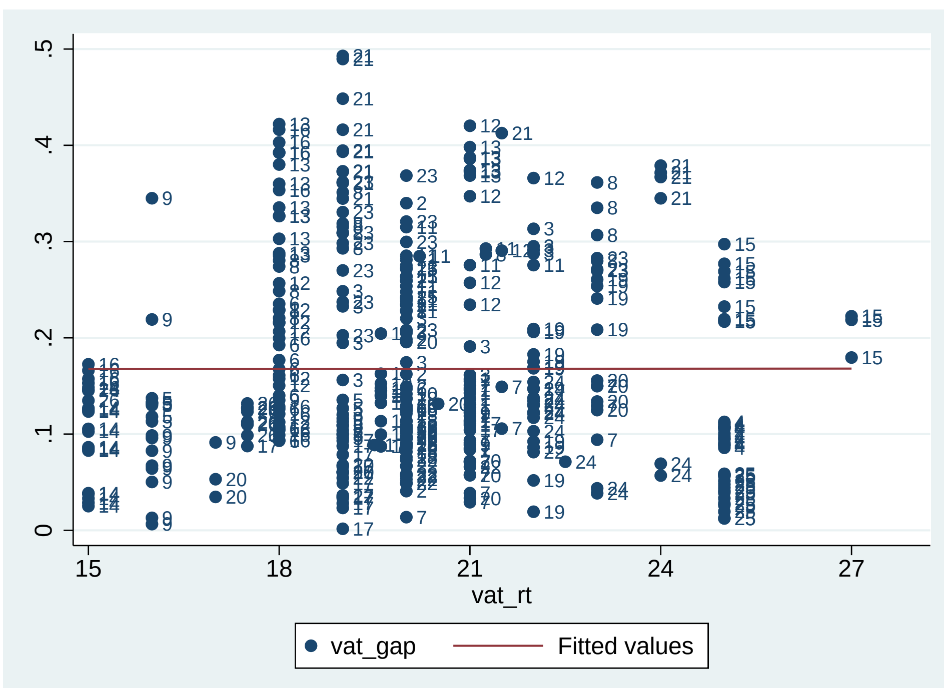


Figure 6: Tax evasion and VAT rate for EU27

The fact that above the 18% tax rate the variance in tax evasion is higher is consistent with multiple equilibria above the low threshold. An alternative theory that

[16]https://stats.oecd.org/Index.aspx?DataSetCode=MIG

[17]This was done including the data for Spain in 2008 and 2009. The difference in variance is even larger when excluding the two observations.

explains the variance simply as across country heterogeneity would not be able to explain why the heterogeneity is much higher above the threshold.[18]

Besides the change in variance, the figure suggests that there is a clear discontinuity in the average tax evasion at the 18% threshold. A t test strongly rejects the null of same average tax evasion for tax rates above and below 18% (with p-value of 0.00). Our theory predicts such a discontinuity because of the multiplicity of equilibria, which allows for the sudden emergence of equilibria of high tax evasion above the threshold. However, An alternative explanation may be that the means in the 2 samples differ not because of a discontinuous change at the threshold due to the sudden emergence of bad equilibria, but because there is a unique equilibrium where tax evasion increases smoothly with the tax rate and we have included many observations for tax rates well above 18%. Yet another explanation could be that countries that are prone to having high tax evasion also tend to have high tax rates, but with the causality not being that high tax rates induce tax evasion. In these two cases the change in the mean would not be sudden around the threshold so we restrict attention to smaller sets to the left and to the right of the threshold ([17-18%) and [18-19%]. This exercise confirms strongly significant differences in the mean. Furthermore, the variance as well is much higher in the [18-19%] sample.

In what follows we complement this analysis with an approach that more directly tests the key assumptions and implications of the model. First, we examine whether our main assumption that implies supermodularity, $p' < 0$, is supported by the data, using an IV approach. Second, we derive a test that can reject the hypothesis of a unique equilibrium, which is necessary and sufficient for multiple LCs.

3.3 Testing for supermodularity

We test our key assumption, that the probability of detection p is decreasing with evasion e, using an IV approach. As mentioned before, we measure tax evasion e as the ratio of the VAT gap and the total amount of VAT taxes due, using data by the European Commission. The probability of being caught p is constructed as detailed in Section 2.1, using data on tax effectiveness by OECD [2015]. These data come from a survey of tax administration systems, practices and performance of the revenue bodies of 56 countries, including all EU countries for which we have VAT evasion. It covers the period from 2007 to 2013.

With these two variables it is in principle possible to run a panel in which we regress p on tax evasion e. One problem is that evasion e may be endogenous to changes in the left hand side variable: if p increases, perhaps people react by reducing tax evasion. This would bias the regression, possibly suggesting a negative relationship even if the effects of an exogenous increase in e may not make p decline. We attempt to isolate changes in e that are not due to changes in p by instrumenting e with migration, using

[18]Of course, the threshold could be country specific (e.g. because of different monitoring and punishment policies). Thus 18% may be interpreted as the minimum threshold among the countries in the sample. Unfortunately we cannot estimate country specific thresholds because there is not enough variation of VAT rates for each country, so it is very unlikely that a country varies its tax rate enough to be below and above its threshold at different time periods: the standard deviation of VAT rates within country is 1.25.

data from OECD [2017]. The idea is that migrants from different countries may have different attitudes toward evasion. Therefore, migration can affect the overall evasion rate, for a given p. On the other hand, migration could itself be endogenous if p is a driving factor in the decision to migrate to a given country. However, migrating to another country is a life changing decision that depends on a multitude of factors, some of which are even beyond the immigrant's control, and we believe that it is unlikely that one of them is the probability of being caught if tax evading. Furthermore, our measure is the total migration inflow to each country. We do not observe that countries with low p attract more migrants.

Results are reported in Table 1. We find that the square of the migration inflow with 2 lags is a strong instrument for tax evasion. Intuitively, lags give time to immigrants to participate to economic activity and make a contribution to the evasion rate. The square may capture the fact that larger masses of immigrants have stronger effects than a marginal increase in the number of immigrants.

The first stage regression suggests that the instrument is valid and strong. The coefficient of immigration of tax evasion is strongly positively significant with the 1st stage F statistic ranging between 32.75 and 41.572 depending on the controls.

Consistent with our assumption, the second stage regression finds the effect of evasion on p to be negative and strongly significant. This is robust to adding or removing GDP growth, m, which is a measure of tax effectiveness (see Section 2.1), and time dummies. For comparison, in the last column we also report the OLS estimate which is a bit lower in absolute value but it would not change the conclusion that the p function is strongly significantly downward sloping.

Table 1: Regression estimates – p function

	(1)	(2)	(3)	(4)
		TSLS		OLS
e	-1.873	-1.852	-1.729	-1.472
	(0.308)	(0.300)	(0.265)	(0.350)
Lagged GDP Growth		-1.429	0.004	-0.034
		(0.237)	(0.274)	(0.294)
Lagged log m			0.096	0.081
			(0.053)	(0.019)
Time dummies	yes	yes	yes	yes
F-stat first stage	32.75	40.98	41.572	
N	97	97	94	108

3.4 Testing for uniqueness of equilibrium

The result in the previous section supports our key assumption for supermodular games, $p' < 0$, which can give rise to multiple equilibria. However, a decreasing p function is necessary but not sufficient for multiplicity. As explained earlier, in order to have multiple equilibria, the $\frac{t}{k}$ function must be S-shaped and cross the p function from above at least two times. Second, even in the presence of multiple equilibria, in practice it may be that only one is played, so in the data we may not be able distinguish from a model with a unique equilibrium.

Fortunately, the special structure of supermodular games provides some testable implications for the existence of a unique equilibrium, which we are able to bring to the data. As we show in the following Proposition, a unique equilibrium implies that whenever the total payable taxes (weakly) increase for everyone, whereas the probability of being caught (weakly) decreases for everyone, then the probability of evasion (weakly) increases for everyone.

Lemma 1. *Suppose that the game has a unique Nash equilibrium and that function p is indexed by parameter p_0, so that $\frac{\partial p}{\partial p_0} > 0$. If $t' \geq t$ and $p'_0 \leq p_0$ then $s' \geq s$.*

Proof. Since there is a unique equilibrium, it is both good and bad. From property 3 of Proposition 1, $t' \geq t$ implies $s' \geq s$. As in the proof of that Proposition, we can use Theorem 6 in Milgrom and Roberts [1990] to show that there is strategic complementarity between s_i and $-p_0$ because $\frac{\partial^2 U_i}{\partial s_i \partial p_0} > 0$. Hence, $p'_0 \leq p_0$ implies $s' \geq s$. □

To show what are the empirical implications of this Lemma, suppose that the game is characterised by two straight lines, $\frac{t}{k} = g_0 + ae$ and $p = p_0 + ce$, where e is evasion, p is the probability of being caught and $\frac{t}{k}(e)$ is e-th highest ratio. The unique equilibrium is given by the intersection of these two lines, where $a < b < 0$ implies that the equilibrium is stable. Solving with respect to e we have $e = \frac{g_0}{b-a} - \frac{p_0}{b-a} = cg_0 + dp_0$, where $c > 0, d < 0$.

Note that $cov(g_0, e) = cov(g_0, cg_0 + dp_0) = ccov(g_0, g_0) + dcov(g_0, p_0)$. If we have data on the two intercepts, g_0 and p_0, and on the amount of evasion e, then our testable implication under the hypothesis of a unique equilibrium specifies that $cov(g_0, p_0) < 0$ implies $cov(g_0, e) > 0$.

Corollary 1. *Suppose the game has a unique Nash equilibrium with $\frac{t}{k} = g_0 + ae$ and $p = p_0 + ce$. Then, $cov(g_0, p_0) < 0$ implies $cov(g_0, e) > 0$.*

In the data, we identify changes in g_0 first using GDP growth. This is tantamount to assuming that if GDP increases, then (holding k fixed for all), we have $t' \geq t$.[19] However, an argument against such a causation is that the average tax rate may decrease but GDP increases, hence driving down the due taxes. For robustness, we perform the same analysis below using VAT Total Tax Liability (VTTL), which computes the total estimated VAT taxes and is independent of total income. The results are the same. We identify shifts in the intercept p_0 using the residuals of the estimated function p from the previous section.

Using either GDP or VTTL growth, we find that $cov(g_0, p_0) < 0$ at the 5% significance level (p value 0.045). Since we also find that $cov(g_0, e) < 0$ at the 5% significance level (p value 0.040), we conclude that the data reject the hypothesis of a unique equilibrium.

[19] This does not mean that taxes must increase for each individual, only that the k-th highest agent (in terms of $\frac{t}{k}$), will now pay more taxes with t' than the k-th highest agent pays with t. This is because function $\frac{t}{k}$ is constructed by sorting agents in decreasing order, so some agents could swap with others in the ranking. An increase in GDP implies $t' \geq t$ if, for instance, taxation is increasing in income and an income distribution in a period with higher GDP has first order stochastic dominance over the distribution in a period with lower GDP.

We should be clear that our test condition can only reject uniqueness in favour of multiplicity, not the other way around, as the latter is the more general specification.[20] Moreover, our test may be inconclusive if either $cov(g_0, p_0) \geq 0$ or $cov(g_0, p_0) < 0$ but $cov(g_0, e) \geq 0$, meaning that the data is not inconsistent with our model with a unique equilibrium, where p and $\frac{t}{k}$ are straight lines.

To put our model to further scrutiny, we test individually each country. This is an interesting exercise for two reasons. First, since we find that for some countries uniqueness is not rejected, we argue that our test is not somehow geared to always reject uniqueness. Second, as we explain in the introduction, our assumption of a decreasing cost of evading as more people evade is more relevant for countries with weak institutions and ineffective governance. If we interpret not rejecting uniqueness of equilibrium as a proxy for good institutions and effective governance, then it is interesting to check whether our model's classification of countries with good institutions using VAT tax evasion is consistent with the classification derived from other sources.

Our results show that this is true. The countries for which we fail to reject uniqueness, even though the first condition $cov(g_0, p_0) < 0$ is satisfied, are Finland (1st), Sweden (4th), Denmark (8th) and Germany (12th). In parentheses are the their ranking, among 149 countries, in terms of Governance (consisting of effective governance, democracy and political participation, rule of law) according to the Legatum Institute [2017]. The countries that we cannot test because $cov(g_0, p_0) > 0$ are Netherlands (6th), Luxemburg (7th), Belgium (15th), Austria (16th), France (23rd), Portugal (25th) and Italy (46th). Finally, the countries for which we can test and reject uniqueness are UK (10th), Ireland (13th), Estonia (21st), Spain (30th), Czech Republic (31st), Slovenia (36th), Poland (37th), Latvia (40th), Slovakia (42nd), Greece (53rd) and Hungary (56th).

4 Structural estimation

In Section 3.3, we showed using an IV method that a necessary condition for multiplicity of equilibria, a negatively sloped p function, is satisfied. However, we did not identify $\frac{t}{k}$, which needs to be sufficiently S-shaped for multiplicity.[21] In order to identify the shape of the $\frac{t}{k}$ function, we structurally estimate our model. Using the same data as in the previous sections, we performed the estimation for 21 European countries and 7 years, from 2007 to 2013.

The shape of the $\frac{t}{k}$ function depends on the distribution of taxes and k over the population, or equivalently, the distribution of $\frac{t}{k}$. We cannot make a distributional assumption for this unobserved variable so we estimate its distribution non-parametrically. We first note that $\frac{t}{k}$ has to be above the maximum data point for p for some agents (those that always evade) and below the minimum observed p for the agents that never evade. To achieve this we assume that $\frac{t}{k}$ is distributed between 0 and 1. We then estimate the histogram for the $\frac{t}{k}$ distribution as follows. Let the $\frac{t}{k}$ distribution be approximated by

[20] Note, however, that if we were to find a flat p function in Section 3.3, we would reject multiplicity.

[21] Recall that in Section 3.4 we devised a test aimed at rejecting uniqueness of equilibrium, and this was the case for several countries.

n bins $\frac{t}{k}(i), p(i)$ where $p(i)$ is the share of people with $\frac{t}{k}$ between $\frac{t}{k}(i)$ and $\frac{t}{k}(i+1)$. It is then possible to estimate either $p(i)$ given a grid on $\frac{t}{k}$, or conversely, estimate $\frac{t}{k}$, given a grid on $p(i)$. We do the latter, so that we estimate this distribution by fixing a grid for $p(i)$ and estimating the points $\frac{t}{k}(i)$.[22]

Similarly to Fu and Wolpin [2017], we estimate this $\frac{t}{k}$ distribution for all countries and time periods, so that all countries have the same $\frac{t}{k}$ function, except for the country-specific shocks which shift the intercept (however later we control for demographic factors which allow the $\frac{t}{k}$ to differ across countries). We match each observation by assuming a multiplicative shock by country and time that shifts $\frac{t}{k}$ up or down. We assume these shocks to be normal and i.i.d over time and across countries. We also estimate the p function, which also has country fix effects and shocks that are normal and i.i.d over time.

Concluding, we have data for p and e by country and time, and 2 shocks that move the $\frac{t}{k}$ and the p function respectively, by country and time. We are then able to construct a likelihood function that we maximize for the parameters which determine $\frac{t}{k}$, the slope and fix effects for the p function.

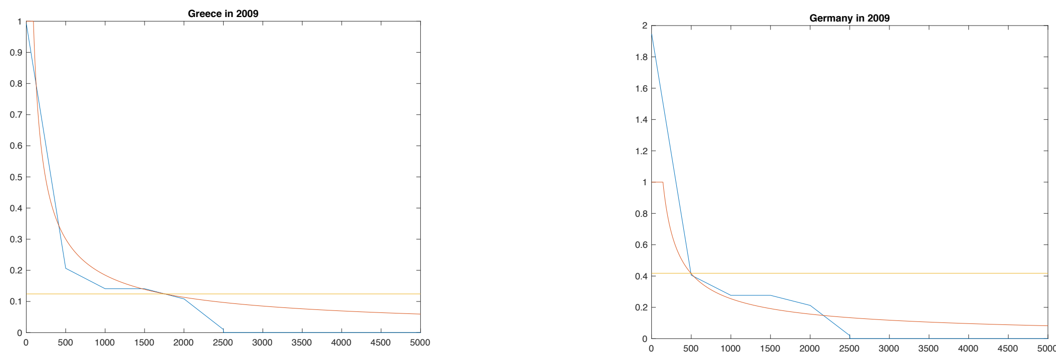
4.1 Identification

As discussed in Cooper [2002], multiplicity of equilibria is logically distinct from and does not imply an identification problem. However, identification issues can arise in models with multiple equilibria, when there are multiple parameter values that match the data with the same likelihood.

In our model, different parameterisations imply different S-shaped $\frac{t}{k}$ and p functions. Without restrictions, their intersection could go through all points given appropriate shocks that have the same likelihood. However, this is not possible in our estimation because of the way we parameterise the $\frac{t}{k}$ function. In particular, we require that it is linear within each bin, with the slope (determining the mass of people in that bin) being a parameter to be estimated and the shock specifying the intercept. An added restriction, stemming from the continuity of $\frac{t}{k}$, is that the end point of the $\frac{t}{k}$ function in the previous bin is the starting point in the next bin. Then, it is not possible that two different slopes within a bin can match 2 or more points within that bin with the same set of shocks or intercepts. Hence, with enough data within each bin, it is not possible to match the same data with different parameterisations and similar shocks.

To test our algorithm, we run the estimation on model simulated data given some parameter values and we estimated parameters that are very close to the ones assumed in the simulation. In particular, the $\frac{t}{k}$ and the p functions look visually identical to the ones assumed. The only case in which the method has failed is when there are no observations within a bin. In the estimation with empirical data we assume 5 bins. This guarantees multiple observations within each bin (on average 157/5 observation per bin) and enables the $\frac{t}{k}$ function to have a fairly flexible shape (up to 5 different

[22]We chose this because it is much faster, as we can exploit the property that $\frac{t}{k}(i) \geq \frac{t}{k}(i+1)$, which implies that for a given $\frac{t}{k}(i)$, the search for $\frac{t}{k}(i+1)$ is on a smaller set.



(a) Greece in 2009 (b) Germany in 2009

Figure 7: Coordinating on the bad and on the good equilibrium

slopes).[23]

4.2 Results

Figure 7 depicts two examples of the estimated p (red line) and $\frac{t}{k}$ (blue line) functions, for Greece and Germany in 2009. Note that $\frac{t}{k}$ is S-shaped. The yellow horizontal line denotes the equilibrium probability of detection. Although there are multiple equilibria for both countries, Greece coordinates on an equilibrium with high evasion (a bad one), whereas Germany coordinates on an equilibrium with lower evasion (a good one). In particular, in the figure for Greece there is an better equilibrium with lower evasion, that would be very similar to the equilibrium in the figure for Germany. And in the figure for Germany, there is an equilibrium with high tax evasion, which is very similar to the equilibrium in Greece.

We find that multiplicity is pervasive. However, we do not observe jumping between good and bad equilibria in all countries. For instance, we find that for Finland, Sweden, Denmark and Germany, we only observe equilibria which are very close to the best equilibrium in terms of tax evasion. These are the countries for which we were not able to reject uniqueness of equilibrium in the previous section and that have strong institutions according to the Legatum Institute [2017].

On the other hand, for countries with weak institutions, like Greece, Latvia and Czech Republic, we find that they coordinate mostly on bad equilibria. To provide a general picture, we calculated, for each country, how close the observed equilibrium is on average from the best equilibrium. Formally, we calculated, for each year, the λ such that $e = \lambda b + (1 - \lambda)w$, where e is the observed equilibrium tax evasion, b is the best possible equilibrium and and w is the worst. We then took the average of all λ, for each country, so that a λ close to one shows that this country coordinates on the good equilibria on average.

[23] Note that it is not possible to estimate the mass of people in a bin (i.e. its slope) independently from the ones of the other bins. This is because for a given shock, the mass of people in a bin determine the intercept for the next bin.

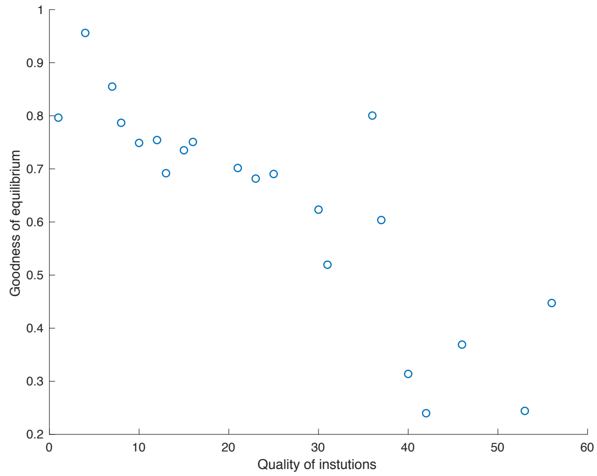


Figure 8: Goodness of equilibria (λ) vs. quality of institutions

We plot the average λ for each country on the vertical axis of Figure 8, against the ranking, in terms of strong institutions, on the horizontal axis. We find that as institutions become stronger, there is more coordination on the good equilibrium. Note that this is different from saying that stronger institutions lead to lower tax evasion. It is possible in our estimation that a country has low observed tax evasion, but coordinates on the bad equilibrium that is also low evasion. Such an example is Finland in 2010, depicted in Figure 9. There are two low tax evasion equilibria, however Finland coordinates on the bad one, so that $\lambda = 0$ for that year, even though Finland is ranked first in the institutions ranking.

5 Example

Our test in Section 3 showed that the data are consistent only with multiple equilibria, which are generated in the model only with an S-shaped (or more generally a wiggly) $\frac{t}{k}$ function that crosses the p function more than once. Is it easy to derive such an S-shaped $\frac{t}{k}$ in practice? The answer is yes. To explain why, recall that the $\frac{t}{k}$ function is generated by ordering t_i/k_i from highest to lowest, so that as i increases, t_i/k_i decreases. The $\frac{t}{k}$ function will be relatively flat for a mass of agents who have very similar t_i/k_i, whereas it will be relatively steep if they have very different t_i/k_i. For instance, any bell-shaped distribution of t_i/k_i will generate an S-shaped $\frac{t}{k}$ function, where the mass around the peak specifies the flat region, whereas the left and the right of the peak generate the steep regions. More generally, a multiple-peaks distribution will generate a wiggly $\frac{t}{k}$ and possibly more than two equilibria.

In the presence of multiple equilibria, our model generates multiple LCs, as in Figure 2. Is it then possible that an increase in tax rates cause a jump from a high LC to a low LC and reduce revenues? To investigate this possibility, we calibrate a $\frac{t}{k}$ function for Greece in 2008, using the VAT Gap data from Section 3.3.

First, since evasion (VAT Gap) ranges between 0.28 and 0.36 we assume that 28%

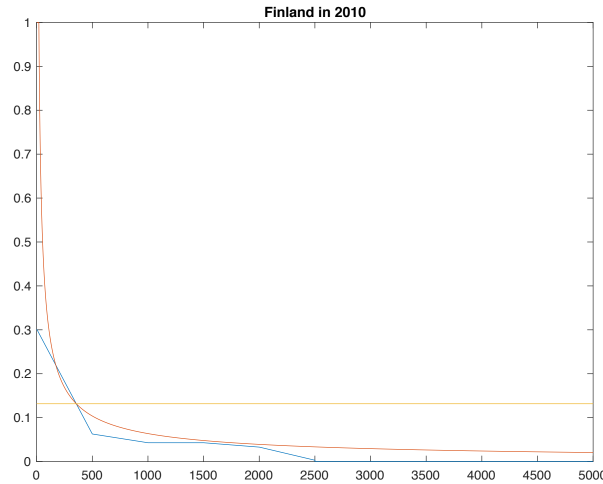


Figure 9: Finland in 2010

of the agents always evade, due to a very high t_i/k_i, whereas (1-0.36)% of the agents never evade, due to a very low t_i/k_i. We are interested in the remaining 8% who change their behavior over time.

Since we do not have real data about the distribution of k_i, we keep it as a constant. To get an S-shaped $\frac{t}{k}$ function, we assume that t has a bell-shaped distribution with fat tails.[24] But it would be possible to get the same $\frac{t}{k}$ function by assuming a non degenerate distribution for k and finding an appropriate distribution for t. We can then move the $\frac{t}{k}$ function up or down by changing k to match any data point on our figure (tax evasion and detection probability). In particular, we construct a $\frac{t}{k}$ function to match the evasion rate and p in 2008. As we explain above, we choose this date because it preceded the financial crisis, and the VAT rate and the evasion rate were much lower than in the following years. So we can see if we can predict the spike in evasion given the increase in the VAT rate, which moved to 21.25 in 2010 and to 23 from 2011 onward.

The results are summarised in Figure 10, which shows the LC associated with the $\frac{t}{k}$ function and p function for 2008, when the VAT rate was 19%. The figure shows that for VAT rates over 20%, there is only a bad equilibrium. The data point for 2008 sits on the higher LC as it is accounted as a good equilibrium. The increase in the VAT rate caused a jump to the equilibrium with a much higher evasion rate. According to the

[24] Fat tails make sure that the S-shape is not such that the stable equilibria are too much at the extremes. We generate a fat tail distribution by assuming that a share λ of agents has t lognormally distributed, whereas the remaining $1-\lambda$ is uniformly distributed over the support given by the min and max t sampled for the λ individuals. This way you essentially get a lognormal that sits on top of a uniform, which gives low curtosis and high tails. We are clear that we do not have any direct evidence for the distribution of $\frac{t}{k}$, so we calibrate it to get the S-shape that is needed to generate equilibria with tax evasion in the observed range. However, there is evidence that consumption is roughly lognormal, so t equal to the VAT rate times consumption should also be lognormal. The actual shape of $\frac{t}{k}$ also depends on the distribution of k, which we do not observe. But we experimented with a lognormal for t and with k either uniform or lognormal and we found that it is very hard not to get an S-shaped $\frac{t}{k}$ distribution.

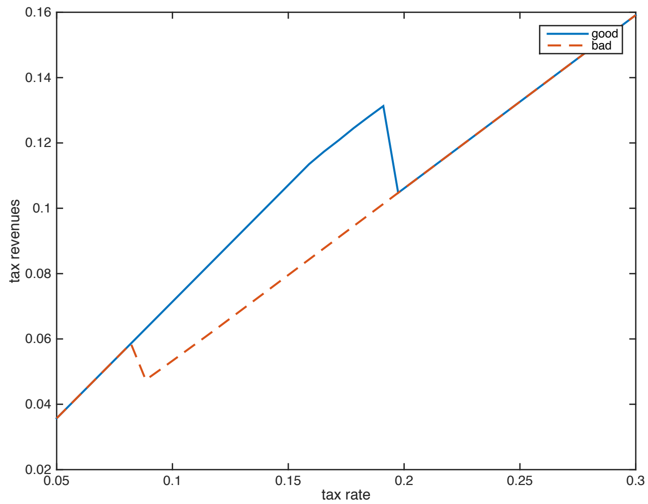


Figure 10: LC for Greece, 2008

model, the evasion rate with a VAT rate of 23% is 36%, whereas the average evasion rate in the data from 2011 to 2013, when the VAT rate was 23%, ranged between 31% and 36%. As a result of the increased evasion, the increase in the VAT rate actually decreased tax revenues over GDP from 13.1% with a VAT rate of 19%, to 12.08% with a VAT rate of 23%. The maximum VAT rate that allows for a good equilibrium is 20%, with tax revenues over GDP equal to 13.4%.

Figure 10 also shows that a VAT rate of around 19% is equivalent to a rate of 25%, in terms of tax revenues. However, this calculation does not take into account that income is fixed in this exercise and only tax evasion can reduce revenues. If we were to make the labour decision endogenous, as in the standard LC, an even higher VAT rate would be needed to compensate for the decrease in income. This story is consistent with the huge decrease of Greece's GDP between 2008-2016.

How robust are these findings? The LC in Figure 10 depends on our calibration which is not entirely pinned down by the data: it would be possible to change the bell distribution on t and still satisfy the points above. For example, we could change the variance of the lognormal, or the share of agents who are uniformly distributed. However, we found that, as long as this is done so that there is an s shape in the range, the results are robust to these changes. In particular, the LC always tops the good equilibrium at about 20%. It is also very hard if not impossible to account for the data point in 2008 as a bad equilibrium. The reason is that the evasion rate was well below average, so to match such a data point with a $\frac{t}{k}$ function that also allows for other equilibria in the observed range (evasion between 28% and 36%), the one observed has to be a good one. It would be possible to consider a wider range, e.g. evasion between 0 and 0.4, in this case the data point in 2008 would be matched as an intermediate and unstable equilibrium and stable equilibria would be outside the range observed in the data (with either too low or too high evasion relative to the data).[25]

[25] Of course there is a range for which the data in 2008 are accounted as a bad equilibrium, but an evasion

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