The excess burden of tax evasion - An experimental detection-concealment contest*

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Abstract

Tax evasion may cause social welfare losses due to the incentives of taxpayers to invest in the concealment and of tax authorities to invest in the detection of tax evasion. Reducing the investment of both parties at the same time would then lead to a Pareto improvement. Given that concealment and detection costs are hardly measurable in reality, we show in a controlled laboratory experiment that the welfare losses from a concealment-detection contest depend positively on the prevailing tax rate, but not on the penalty which is imposed in case of detected tax evasion. Hence, policy makers who are concerned about socially inefficient concealment and enforcement costs should focus on tax rates rather than penalty rates.

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1 Introduction

The welfare implications of income tax evasion *per se* are unclear. Some authors believe that tax evasion itself constitutes a deadweight loss for society (e.g. Usher, 1986). Some others point out the difficulty to assess the welfare effects of tax evasion, since the state of the economy, the efficiency of the prevailing tax system, and social preferences over income distributions are unknown (see Cowell, 1990a, chapter 7). However, tax evasion implies welfare losses for society by inducing two kinds of socially wasteful activities. First, taxpayers invest effort and money in order to *conceal* tax evasion. For instance, a taxpayer might incur travel expenses or forgo possible interest payments in order to shelter black money abroad (Cowell, 1990b) or he might pay third parties for "laundering" his money and thereby hide the taxable objects from the tax authorities (Yaniv, 1999). Second, tax authorities invest effort and money in order to *detect* tax evasion. Such socially wasteful enforcement costs arise, for example, from hiring more tax administrators to monitor tax reports or from investing into better detection technology (Cebula, 2001). If both parties reduced their investment in such a way that the resulting detection probability remained unchanged then both parties would save some effort cost without changing anything else. Therefore, such a joint reduction in efforts would be a Pareto improvement. Hence, the welfare loss induced by concealment and detection activities gives rise to some extra excess burden of income taxation which has to be added to the well known deadweight losses caused by the distortionary impact of income taxes. The understanding of what determines the size of this extra welfare loss is essential when designing or reforming tax and tax-enforcement law.

In this paper we use experimental techniques to investigate whether and how concealment and detection costs depend on two key parameters of a tax system: the prevailing tax rate and the penalty rate for detected tax evasion. Our experiment is based on a simplified version of the game-theoretic model presented in Bayer (2006), which describes the interaction between taxpayer and tax authority as a concealment-detection contest. Taxpayers decide not only on how much income they declare. They can also invest some of their income in order to conceal evasion, while the tax authority may vary the resources spent on detection effort. The probability of detecting potential tax evasion is modeled by a contest function. It decreases with the taxpayer's concealment investment and increases with the authority's detection effort. By considering both concealment and detection costs we can compare the degree of this social inefficiency for different tax and enforcement regimes.

The model predicts that the waste increases with tax and penalty rates, as both increase the stakes of the contest and therefore the incentives for investment. As long as penalty rates are low - such that they do not reduce evasion behaviour - penalty rates and tax rates are perfect substitutes with respect to wasted resources. Once penalty rates are high enough to reduce evasion their impact on the inefficiency is less strong, but still positive. Our experiment shows that higher tax rates indeed lead to a considerable reduction of efficiency, while penalty rates do not have a significant influence on the social waste. This shows that the main focus of policy makers who are concerned about unproductive concealment and enforcement should focus on tax rates rather than on penalty rates.

It is important to stress that the primary focus of our paper is on the effects of tax rates and penalty rates on the social costs of concealment and detection efforts. Of course, tax rates and penalty rates also have an impact on the frequency of tax evasion (for a recent survey, see Slemrod, 2007). Broadly speaking, tax rates have been found to be a driving force for the frequency of tax evasion (Torgler, 2002; Kirchler, 2007; Maciejovsky et al., 2007), whereas the impact of tax penalties on compliance is ambiguous and often not significant (Baldry, 1987; Fischer et al., 1992; Fortin et al., 2007). Our experimental data yield the same pattern with respect to how tax rates and penalty rates influence the frequency of tax evasion. The novelty of our approach is to consider the social costs of tax evasion through concealment and detection costs. The traditional models of tax evasion - in the spirit of Allingham and Sandmo's (1972) seminal paper - have not been able to address the possible excess burden of tax evasion through concealment and detection costs, because taxpayers had no means of covering their evasion, and audit rates were exogenously fixed in these early models. Only later models have included the social costs of concealment and detection in different ways. Reinganum and Wilde (1985), for instance, have concentrated on detection costs. They endogenised the audit probability by letting the tax authority decide on the level of (costly) investment in the likelihood of a successful audit. Contrary to our model, taxpayers had no means of hiding their tax evasion from the the tax authorities, however. Cremer and Gahvari (1994) have included expenditures on the concealment of tax evasion in their analysis of optimal linear income taxation, but have assumed purely random audits which are independent of the tax authority's efforts (and costs) for detecting tax evasion. Yaniv (1999) has studied the taxpayer's decision on laundering money and its consequences for an optimal deterrence policy, without examining the consequences for social welfare, though. Usher (1986) has been the first one to consider both concealment and detection costs in a general equilibrium model of optimal taxation and enforcement. He shows that costly evasion and detection increase the marginal cost of public funds considerably.[1] The main difference to our approach is Usher's (1986) assumption of homogeneous taxpayers. This

[1] The paper by Kaplow (1990) obtains results that are, basically, analogous to those in Usher (1986). Yet, Kaplow (1990) is less concerned with the cost of public funds, but he examines modifications to the Ramsey-type optimal commodity taxation in the presence of administrative and evasion costs.

homogeneity resolves all uncertainty about the true income of an individual taxpayer. Our taxpayers, however, are heterogeneous with respect to their income (or productivity), implying that the authority does not know which type of taxpayer it faces. Thus, our approach adds an interesting - and in reality highly relevant - strategical dimension to the contest been taxpayer and tax authority.

Besides these differences in the way concealment and detection efforts are integrated in our model as compared to previous papers, our paper is the first to provide an empirical/experimental attempt to measure the concealment and detection costs associated with tax evasion. All previous papers that consider concealment and detection have been purely theoretical. The lack of empirical evidence is not surprising, though, because an empirical test would require (a) to assign different taxpayers randomly to different tax systems and (b) to be able to observe evasion, detection and concealment costs. Unfortunately, the fulfillment of condition (a) would be very expensive and for equity reasons hardly feasible, while the information requirements for (b) are practically prohibitive. Given the limitations of observing the excess burden of tax evasion in the field we have opted for a controlled laboratory experiment. We can (a) assign subjects randomly to different (experimental) tax systems and (b) can induce preferences over efforts by assigning (experimental) cost functions, which enables the measurement of concealment and detection costs through the observed effort.

The remainder of the paper is organized as follows: Section 2 introduces the basic model and provides the main predictions for the parameter settings used in the experiment. Section 3 is devoted to our experimental results. In particular we analyse the influence of tax rates and penalty rates on evasion, detection, concealment, efficiency and revenues. A brief conclusion is offered in Section 4.

2 Model and experimental design

In this section, we explain the timing, information, and payoff structure underlying the experiment. The experimentally implemented environment follows the theoretical model developed in Bayer (2006). This model follows the tradition of non-commitment tax-evasion games initiated by Reinganum and Wilde (1986). We chose a model where the tax authority cannot commit beforehand to a certain audit strategy, but decides on an audit effort only after receiving the tax return. The reason for this choice is our belief that this is the more realistic case. The alternative principal-agent approach pioneered by Border and Sobel (1987) where the tax authority can commit to an audit strategy seems less realistic.[2]

In contrast to Reinganum and Wilde (1986), though, our model allows for the taxpayer exerting concealment effort with the aim to make it more difficult for the tax authority to prove evasion by investigating. This setup leads to a concealment-detection contest between the taxpayer and the authority, where the efforts exerted for concealment and detection decide over the likelihood that tax evasion can be proven.

2.1 Timing, action spaces, and payoffs

In what follows we briefly present the model and its equilibrium predictions for the parameters chosen in our experimental treatments. For a complete treatment of a generalized model and its equilibria see Bayer (2006). We begin with the timing of an experimental period.

1. Nature determines the actual income $Y \in \{0, y\}$, where we parametrised $y = 1000$. The probability that $Y = y$ is earned is given by $\lambda = 0.8$. This probability is common knowledge.
2. The taxpayer privately observes Y.
3. The taxpayer makes an income declaration $D \in \{0, 1000\}$ and exerts a concealment effort $E \in \{0, 1, ..., 10\}$.
4. The authority observes the declaration D but neither the concealment effort E nor the true income Y.
5. The authority chooses a detection effort $A \in \{0, 1, ..., 10\}$, which can not be be observed by the taxpayer.
6. Nature decides whether the actual income is verifiable in court. The verification probability depends on the efforts and is given by $P(A, E)$, which is given by the contest function
$$P(A,E) = \begin{cases} 1 & \text{if} \quad A, E = 0 \\ \frac{A}{A+E} & \text{else} \end{cases} . \tag{1}$$

[2] The reasons are twofold: Firstly, the equilibria for optimal audit and fine schemes are usually somewhat unsettling, as there is no tax evasion and the authority only audits truthfully revealing taxpayers. Secondly, for this optimal audit and fine schemes to work, taxpayers would have to know them and would have to believe that the authority is committed to them. Both is not very realistic. Authorities in some countries even try to keep their strategies secret, as they believe that the resulting uncertainty increases compliance. For a more detailed discussion of different modelling choices see Andreoni et al. (1998) and the references therein.

7. Taxpayer and authority are informed about the outcome of the audit and whether a penalty is due. Taxpayers receive their ex post net income U and the authority receives the revenue R, respectively.

The expected net income of the taxpayer depending on gross income, declaration and concealment effort is given by

$$EU(Y = 1000) := \begin{cases} (1-t)y - c^e \cdot E & \text{for} \quad D = 1000 \\ y - p(A^E, E) \cdot f \cdot t \cdot y - c^e \cdot E & \text{for} \quad D = 0 \end{cases} \tag{2}$$

$$EU(Y = 0) := \begin{cases} -t \cdot y - c^e \cdot E & \text{for} \quad D = 1000 \\ -c^e \cdot E & \text{for} \quad D = 0 \end{cases} \tag{3}$$

This implies a linear tax system with tax rate t. The fine is proportional to the evaded tax, with penalty rate f. The constant unit cost of concealment effort is denoted by c^e and fixed at $c^e = 40$.

The expected revenue for the authority, depending on the observed declaration and the detection effort, is given by

$$ER(A) := \begin{cases} \mu \cdot p(A, E^E) \cdot f \cdot t \cdot y - c^a \cdot A & \text{for} \quad D = 0 \\ t \cdot y - c^a \cdot A & \text{for} \quad D = y \end{cases}, \tag{4}$$

where μ denotes the believed probability of the authority to face an evader conditional on a zero declaration. We fix the authority's constant unit cost of effort at $c^a = 20$ in the experiment. The choices of the cost parameters c^e and c^a are supposed to reflect the fact that initially the marginal cost of detection is relatively low. Cross checking accounts, e.g., is quite easy and cheap with modern computers, while effective initial concealment – e.g. a trip to Liechtenstein with a suitcase full of money – is comparatively expensive. Note also that the marginal detection and concealment costs act as a scaling factor for optimal efforts without changing any qualitative comparative-static results of the model.

We are aware that this model is overly simplistic. Linear tax and fine systems are quite restrictive. This choice was made with the experimental implementation in mind. In experiments there is typically a trade-off between control and realism. We opted for this simplification in order to keep the structure easy enough such that we can safely assume that subjects understand the payoff structure.[3] Restricting the possible levels of income to just two (0 or 1000) follows the same rationale.[4] The choice of the earnings probability parameter ($\lambda = 0.8$) was made for three

[3] See Bayer (2006, Section 5) for model predictions under alternative tax and fine regimes.

[4] Note that in this setting it does not make a lot of sense to allow declarations other than 0 or 1000, as any intermediate declaration is immediately found out to be untruthful by the authority.

reasons. Firstly, the most important real world income source – wages – has a high earnings probability. Secondly, in theory, a source that generated income with a high probability induces high levels of detection and concealment efforts in the case of evasion. Therefore the magnitude of potential welfare effects due to changes in behavior is highest in this case. Thirdly, for experimental design reasons we wanted to keep the variance of the payoff potential across subjects relatively low.[5]

2.2 Treatments and equilibrium predictions

We set up six treatments by varying tax and penalty rates. Tax rates could be either 15% (T_l), 25% (T_m) or 40% (T_h). Penalties were proportional to the evaded tax in case of detected tax evasion, by either adding a surcharge of 25% (P_l), of 100% (P_m) or of 220% (P_h) to the evaded tax.[6] This was implemented by setting the parameter $f = 1.25$, $f = 2$, and $f = 3.2$, respectively. Table 1 depicts our design. The four treatments consisting of the possible combinations between (T_m, T_h) and (P_l, P_m) are our main treatments. The two additional treatments T_lP_m and T_mP_h are designed to provide robustness checks for either very low tax rates or extremely high penalties.

	$t = 0.15$	$t = 0.25$	$t = 0.40$
$f = 1.25$	–	T_mP_l	T_hP_l
$f = 2$	T_lP_m	T_mP_m	T_hP_m
$f = 3.2$	–	T_mP_h	–

Table 1: The design

In addition to the tax revenue, tax authorities received a base payment of 450 Taler (the experimental currency) per period.[7] This was done in order to eliminate large differences in period profits of taxpayers and authorities, and thus to avoid behavioural effects stemming from inequality aversion. In what follows we will present the equilibrium predictions for risk-neutral subjects. Of course, we are aware that we should not expect all subjects to be risk neutral. However, there is no unequivocal alternative to the assumption of risk neutrality. Given the

[5] Note that the variance of the total gross income of a participant is proportional to $\lambda(1 - \lambda)$.

[6] The 25% surcharge e.g. is applied in the United States for the "failure to report or pay taxes". A 100% surcharge e.g. is levied in Switzerland for evasion. Some counties have even higher fines. In Singapore a tax evader has to pay up to 400% of the evaded taxes in fines.

[7] Note that this does not have any impact on the equilibrium prediction.

body of experimental evidence we might have some subjects being risk-averse in the expected utility sense, some subjects might exhibit rank-dependent risk-preferences, while others could have preferences consistent with prospect theory. Risk neutrality seems a straightforward and natural benchmark that may also be supported by Rabin's (2000) well-known calibration theorem. Another rationale for not using risk-averse expected utility maximisation as a predictive benchmark has to do with our results. Risk averse agents in our model tend to exert lower levels of efforts than risk neutral agents (as exerting effort reduces the riskfree payoff).[8] In contrast to this prediction, we find that experimental subjects exert more effort than risk-neutral players would in equilibrium. A short derivation of the Perfect Bayesian Equilibria can be found in the appendix. A comprehensive treatment of the comparative statics for this class of models can be found in Bayer (2006).

We chose the parameters such that evasion, given optimal efforts, always pays for risk neutral taxpayers.[9] Therefore, we might expect that a taxpayer always evades if his income is 1000. In fact the expected declaration should always be 0. The authority's belief to face an evader should therefore be equal to the earnings probability, i.e. $\mu^* = \lambda = 0.8$. Solving for the optimal effort and taking the experiment's discontinuous action space into account gives the following prediction of optimal efforts, as summarized in Table 2.[10] The parameters for the different treatments were chosen in a way to generate pairs of two treatments each that have the same predicted equilibrium efforts. Such a design allows for a clean test of the underlying theory by disentangling the behavioural effects of tax rates and penalty rates.[11]

		treatment(tax/penalty)		
optimal effort of	actual/observed action	$\{T_l P_m, T_m P_l\}$	$\{T_m P_m, T_h P_l\}$	$\{T_m P_h, T_h P_m\}$
taxpayer	- evasion	3	5	8
tax authority	- declare = 0	1	2	3

Table 2: Optimal efforts for risk-neutrality

[8] In the case of treatment $T_m P_m$, for example, the equilibrium efforts – compared to those for risk-neutral subjects – drop by about 0.5 units if both players are assumed to be risk-averse with $U(x) = x^{1/4}$. Increasing the risk-aversion parameter for both players decreases efforts.

[9] In the real world returns to a monetary unit of evaded tax are positive and high. Bernasconi (1998) estimates the return to be between 0.75 and 0.99 units for most countries.

[10] Obviously, declaring zero with zero effort after earning no income is also part of the equilibrium, as zero detection effort of the authority after observing a declaration of 1000 is. Note that our predictions are based on the assumption that tax authorities maximize their revenues. In reality, this need not necessarily be the case. Instead, tax authorities could target specific levels of tax revenues, as one referee correctly noted. As long as the actual or expected revenues are below the target for any feasible tax and penalty rates, then revenue maximization might still serve as a reasonable proxy for a target-minded tax authority.

[11] Note that this equivalence does not require risk neutrality, as long as subjects are not so risk averse that evasion is not optimal anymore.

With these equilibrium efforts we can calculate the expected efficiency. The expected waste per period is given by

$$W := \lambda c_e E^* + c_a A^* = 32E^* + 40A^*. \tag{5}$$

The expected efficiency V in percent is given by one minus the ratio of expected waste to expected income:

$$V := 1 - \frac{W}{\lambda y} = 1 - \frac{W}{800}. \tag{6}$$

The predicted efficiency percentages are calculated by inserting the equilibrium efforts in equation (5) and substituting the result into (6). The predictions for the different treatments are shown in Table 3. We see that higher penalties should decrease efficiency for given tax rates, as higher tax rates do for given penalties.

V pred.	T_l	T_m	T_h
P_l	–	0.89	0.80
P_m	0.89	0.80	0.69
P_h	–	0.69	–

Table 3: Predicted efficiency by treatment

In this simple linear world taxes and penalties are perfect substitutes for the effort choice of taxpayers and authorities as long as evasion always takes place once the income is earned. Higher values of both taxes and penalty rates increase the stakes in the detection-concealment contest in the same way. Such a setting - where taxes and penalty rates have exactly the same impact on efficiency - allows for a crisp experimental test whether the behavioural consequences of different tax and penalty rates are, indeed, perfect substitutes. It is reasonable to expect that tax evasion with certainty will not be observed in the experiment, since in the real world this is not the case despite of relatively low detection probabilities and moderate penalties.[12] If tax evasion is not permanent, taxes and penalties may have different impacts. Taxes increase the incentive to evade, while penalties reduce them. Therefore higher penalties should be expected to have a less strong negative impact on efficiency. If increasing the penalty rate strongly reduces evasion this might - contrary to our prediction - even have a positive effect on efficiency.

[12] Several explanations have been put forward to explain the large degree of tax compliance observed in reality. Besides reasons such as risk-aversion or a taste for social efficiency, psychological traits play a prominent role. For instance, Erard and Feinstein (1994) note that guilt and shame influence tax compliance behaviour. In a similar vein, Myles and Naylor (1996) argue that individuals derive psychic benefits from adhering to a social norm of tax compliance. On social conformity effects see, e.g., Fortin et al. (2007).

2.3 Experimental procedure

The experimental sessions were run with the help of z-Tree (Fischbacher, 2007) at the University of Innsbruck.[13] Two persons, called taxpayer and tax authority were paired for 20 periods. The timing of decisions followed the sequence described in the model. After each period the taxpayers and authorities were informed if the contest had led to proven evasion. Subjects were also told their payoffs in the respective period. No information about the opponent's effort or payoff was revealed.[14] For each treatment, we ran three sessions with 20 participants each, yielding 30 independent observations (pairs of taxpayer and tax authority) per treatment. The average age of our 360 participants was 23 years, with 45% being female. About 68% of participants were enrolled in business or economics, most of the others studied law, medicine or psychology. On average, sessions lasted 45 minutes. At the end of the experiment, 1000 Talers were exchanged for 1.2 Euro. Average earnings were 12.9 Euro.

3 Results

3.1 Descriptive overview

Table 4 presents some fundamental descriptive data of the experiment. Recall that the actual gross income is determined by a random draw (with 80% probability for gross income $Y = 1000$, and 20% probability for $Y = 0$)[15]. Declared income can be either 1000 or zero. If a subject receives $Y = 1000$, but declares zero income, he is classified as evading the tax. The relative frequency of tax evasion ranges from 34% in treatment $T_m P_h$ (with medium taxes, but a high penalty rate) to 68% in treatment $T_h P_l$ (with high taxes, but a low penalty rate). Even though it is optimal for risk-neutral subjects to evade all the time, the large majority of subjects (159 out of 180 taxpayers) mixes in their decision between evasion and truthful declaration.

The effort levels for concealment and detection are both higher than predicted (compare the theoretical predictions from Table 2 with the actual efforts in Table 4 below). We note that the

[13] The experimental instructions are available from the authors on request.

[14] This information structure was chosen for reasons of comparability to reality where the tax authority does not find out whether tax evasion has taken place, unless an audit has successfully detected evasion. We conducted some sessions where the subjects had full information about past effort choices and payoffs of their opponents. This alternative setting did not change the results.

[15] In order to keep the total real income constant across treatments we used the following procedure in each session. Eight out of ten participants in the role of taxpayer were randomly drawn in each round and given an income of $Y = 1000$. The two others received $Y = 0$.

actual efforts are generally increasing in the tax rate, whereas no clear pattern emerges for the penalty rate. Figures 1 and 2 provide further support for the relative importance of the tax rate, compared to the penalty rate. These figures show the distribution of efforts by treatment. The distributions for a given tax rate, but varying penalty rates, are very similar. In fact, the penalty rate does not have a significant impact on the distribution of concealment efforts (judging by a Kolmogorov-Smirnov-test on the concealment efforts of subjects averaged over the 20 periods). Using the same test to compare concealment efforts for pairs of treatments with the same fine rate, but different taxes, shows that in two out of four cases the distributions are significantly different (T_hF_m vs. T_lF_m: $p < 0.01$, and T_hF_l vs. T_mF_l: $p < 0.02$, Kolmogorov-Smirnov-test). Using the same pairwise tests (holding either the penalty rate or the tax rate constant) on the authorities' detection efforts shows that the only highly significant difference between distributions is found when comparing detection efforts between low and medium tax rates for medium fines ($p < 0.04$, Kolmogorov-Smirnov-test). The comparison of effort distributions lends some support for the hypothesis that the tax rate is behaviourally relevant and influences the degree of socially wasteful efforts. This result applies to taxpayers (Figure 1) and to some extent also to tax authorities (Figure 2).

	treatment(tax/penalty)					
Averages per treatment (N=30/60)	T_lP_m	T_mP_l	T_mP_m	T_mP_h	T_hP_l	T_hP_m
Real income (Y)	16,000	16,000	16,000	16,000	16,000	16,000
Declared income (D)	8,867	7,467	7,600	10,467	5,400	6,400
Rel. frequency of evasion (if Y=1000)	0.44	0.54	0.49	0.34	0.68	0.63
Avg. concealment effort (e) after evasion	5.88	6.88	7.23	6.80	7.98	8.01
Avg. detection effort (a) after zero declaration	4.07	4.02	4.88	3.72	6.00	5.03
Absolute frequency of paying a penalty	2.40	2.67	2.83	1.77	4.27	3.23
Sum of recovered taxes and penalties	1,203	833	1,416	1,277	2,133	2,586
Profit taxpayer	12,262	12,159	11,405	11,734	10,096	9,481
Profit tax authority	10,003	9,703	10,123	10,993	9,864	11,281
Student of econ./business (yes=1; N=60)	0.58	0.70	0.77	0.62	0.77	0.67
Gender (1=female) (N=60)	0.48	0.40	0.50	0.53	0.37	0.42
Age (N=60)	22.5	23.3	22.2	22.4	23.6	23.9

Table 4: Descriptive statistics

Figure 1 about here

Figure 2 about here

The figures and Table 4 show that – contrary to our prediction – taxes and fines are not perfect substitutes with regard to their influence on concealment and detection efforts. Comparing average efforts (detection and concealment) pairwise for the treatments that provide the same prediction shows that average detection and concealment efforts in treatments T_mP_h and T_hP_m are significantly different (U-test, $p < 0.03$ for detection and $p < 0.01$ for concealment). The treatment with the high tax rate causes significantly higher efforts. In the other pairwise comparisons the differences are not significant on the five percent level. However, the treatments with the higher tax rates tend to cause higher efforts.[16] In what follows we will investigate the effect of tax rates and penalties on evasion and wasted effort costs in more detail.

3.2 A selection model of the behaviour of taxpayers

A taxpayer with positive income has to make two interdependent choices - one on the declaration of income and one on the concealment effort. The decision whether to evade or not is not independent from the (potentially hypothetical) effort decision, because the evasion decision depends on a comparison of the payoff for truthful declaration and the expected payoff for evasion, given a particular concealment effort and an expected detection effort of the authority.

Therefore we encounter sample selection issues when analysing the determinants of concealment efforts. We do not observe the (hypothetical) effort for a taxpayer who reports truthfully (and consequently chooses a concealment effort of zero). Since some parameters jointly influence the two decisions of the taxpayer, an econometric model that jointly estimates the determinants of evasion and concealment efforts seems warranted. We use a Heckman sample selection model with the following structure:

$$\begin{aligned}
effort_{i,t} &= \beta_1 X_{i,t} + \beta_2 W_{i,t} + u_{i,t} \\
effort_{i,t} \text{ is observed if } &: \\
evade_{i,t} &= \gamma_1 Y_{i,t} + \gamma_2 W_{i,t} + v_{i,t} > 0 \\
u_{i,t} &\sim N(0, \sigma) \\
v_{i,t} &\sim N(0, 1) \\
corr(u_{i,t}, v_{i,t}) &= \rho \\
corr(u_{i,t}, u_{j,t'}) &= 0 \; \forall i \neq j, t, t' \\
corr(v_{i,t}, v_{j,t'}) &= 0 \; \forall i \neq j, t, t'
\end{aligned}$$

[16] The impact of the tax rate becomes stronger if we consider only the last ten periods after the behaviour of subjects has stabilised.

The factors that jointly influence effort (regression equation) and the evasion decision (selection equation) are denoted by $W_{i,t}$, where i stands for the individual and t denotes the period. The independent variables that only influence the effort (evasion) decision are given by $X_{i,t}$ ($Y_{i,t}$). In order to allow for joint determination the error terms for the regression and selection equation - $u_{i,t}$ and $v_{i,t}$ - may be correlated within subjects and periods. The correlation coefficient is denoted by ρ. Additionally, we allow for clustering within subjects, i.e. the errors within subjects can be correlated across periods. However, the errors are assumed to be uncorrelated across subjects. We use maximum-likelihood estimation with robust standard errors.

In order to identify learning effects we only consider evasion and concealment decisions in periods 11 to 20 and include outcomes of earlier periods in our regression to capture learning. This seems justified, since comparing evasion rates across treatments and periods shows that evasion rates are relatively similar across treatments up to period 10, while they differ considerably and consistently in later periods. The relatively sparse feedback is responsible that it takes some periods of learning until evasion behaviour stabilises. Figure 3 shows the evolution of the evasion frequencies.

Figure 3 about here

In order to capture a potential trend between periods 11 and 20 we include period dummies in both equations. We also ran the same regression only based on the last period to check the robustness of our results. We obtained very similar results. Therefore we can conclude that allowing for clustering within subjects and including period dummies is sufficient to capture potential dynamic effects that may have occurred during the second half of the experiment.

3.2.1 Identification and estimation

A potential problem of selection models is identification. If the selection equation does not contain any independent variables which have no influence on the regression equation identification is by functional form only. Our underlying theoretical model predicts that every taxpayer (if risk-neutral) should evade whenever her income is 1000. So selection is not really relevant. However, we observe truthful declarations (see Table 4). The two contending explanations for truthful reporting are risk aversion and some form of moral constraints. Depending on which explanation drives truthful declarations different econometric strategies are warranted. If risk aversion were the only driving force, then it would be hard to find a variable that only influences the evasion decision, because risk aversion simultaneously influences both the evasion and the concealment effort decision.

Fortunately, we can exclude risk aversion as the only (if at all) force for truthful declarations. Recall that a taxpayer who evades with a probability greater than 0 and less than 1 has to be indifferent between evasion and truthful declaration, and note that 88% of subjects (159/180) actually do mix. Then for a risk-averse expected utility maximizer the following indifference condition has to hold:

$$U(Y_h) = [1 - p(A^*, E^*)]\, U(\overline{Y}) + p(A^*, E^*) U(\underline{Y}),$$

where $U' > 0$, $U'' < 0$, $Y_h = (1-t)y$, $\overline{Y} = y$ and $\underline{Y} = (1-ft)y$. Jensen's inequality immediately implies

$$Y_h < [1 - p(A^*, E^*)]\, \overline{Y} + p(A^*, E^*)\underline{Y}.$$

The expected payoff from evasion has to be greater than the safe payoff for truthful declaration. Our data are clearly not in line with this hypothesis. Comparing the payoffs in the experiment with the certainty equivalent we find that on average the taxpayers earned less than they would have if they had always declared truthfully. This is confirmed by a statistical test. The payoffs for the taxpayers are significantly more likely to be smaller than or equal to the hypothetical net income they would have earned by permanent truthful declaration ($p < 0.01$, Sign Test, $N = 180$).

A second candidate for relative evasion frequencies below 1 are moral constraints. Moral constraints may come in different forms: scruples to break rules, aversion against robbing legitimate payoff from the subjects playing the part of the authority, or psychological costs due to fear of getting caught. If we use K as the black box variable of non-monetary psychological cost of evasion the indifference condition for partial evasion becomes

$$U(Y_h) = [1 - p(A^*, E^*)]\, U(\overline{Y}) + p(A^*, E^*) U(\underline{Y}) - K.$$

Combining loss aversion ($U' > 0$, $U'' > 0$) and moral constraints can explain the observed payoffs (and efforts). Note that K has a negative influence on the equilibrium evasion probability but does **not** influence the effort choice for a given evasion probability. Therefore we have to find instruments that are correlated with K, but not with the effort choice in order to properly identify our selection model. We use age and gender, since both variables have been shown to have a significant influence on evasion behaviour (Andreoni et al., 1998).

The tax rate and penalty rate in the different treatments are clearly variables that influence both evasion and effort choices.[17] Additionally, we have considered period dummies and a variable that captures the experience of being caught evading in the past. The variable *caught_ 1-10* measures the relative frequency of being caught conditional on evasion in the first 10 periods (prior to the periods analysed in our selection model). Since this variable turns out to have a very strong effect on the evasion decision, we can use this variable - in addition to age and gender - to identify our model.[18] Table 5 shows the regression results.

[17] Note that Yitzhaki (1974) has shown that there is no substitution effect of tax-rate changes in the Allingham and Sandmo (1972)-model with a linear tax system if the fine for evasion is proportional to the evaded tax (rather than the evaded income). Consequently, higher tax rates lead to unchanged (less) evasion if taxpayers are risk-neutral (risk-averse). In fact, our model uses the Yitzhaki (1974) framework for fines. Thus, it might seem that the evasion decision were independent of the tax rate (see equation 13 in the appendix). However, in the experiments we observe that there are differences in evasion behavior if we vary the tax rate. Here we use moral constraints (as a fixed evasion cost) as a construct to explain why we observe truthful declarations and to identify the evasion decision in the selection model. Bayer (2006, Proposition 2) has shown that the addition of moral costs to the model leads to a positive relationship between tax rate and the equilibrium probability of evasion, which is found in the data, but not explained in Yitzhaki's (1974) framework without moral constraints.

[18] In model 1 of Table 5 we dropped 24 subjects who never evaded in periods 1 to 10. In model 2 of Table 5 we excluded the variable *caught_ 1-10* in order to be able to keep these observations. Note that the results for the remaining variables do not change significantly.

Sample selection model with robust standard errors for clustering on id		
	Model 1 (with caught_1-10)	**Model 2 (without caught_1-10)**
N	1299	1440
Log pseudo-likelihood	−2447.65	−2671.84
$Prob > \chi^2$	(0.00)	(0.00)
effort		
tax rate (base=medium)		
– low	−1.50**	−1.67**
	(0.02)	(0.01)
– high	1.45**	1.38**
	(0.00)	(0.00)
penalty (base=medium)		
– low	−0.08	−0.05
	(0.84)	(0.91)
– high	−0.59	−0.51
	(0.33)	(0.37)
period dummies	*not sign.*	*not sign.*
constant	6.15**	6.19**
	(0.00)	(0.00)
evade		
tax rate (base=medium)		
– low	−0.22	−0.03
	(0.33)	(0.87)
– high	0.43**	0.58**
	(0.00)	(0.00)
penalty (base=medium)		
– low	0.26	−0.29
	(0.08)	(0.06)
– high	−0.26	−0.24
	(0.25)	(0.23)
caught_ 1-10	−1.69**	
	(0.00)	
female	0.29**	0.34**
	(0.02)	(0.01)
constant	−0.42	−0.83
	(0.56)	(0.22)
period dummies, age	*not sign.*	*not sign.*
ρ	0.52**	0.38**
Wald test (H_0: $\sigma_u = 0$)	(0.00)	(0.01)

p-values in parentheses; ** sign. on 2.5%-level; * sign. on 5%-level

Table 5: Regression results for taxpayers

3.2.2 Marginal effects

The parameter estimates in selection models can be misleading sometimes. Since such a model allows for correlation in the error terms of the regression and selection equation, the sign and significance of the marginal effects can be different from those of the coefficients. In what follows we report the marginal effects on (a) the expected effort unconditional on evasion, (b) the effort given that evasion takes place, and (c) the evasion decision itself. Here (a) shows the influence on the expected waste due to concealment and evasion, (b) reports the influence on the effort of evaders, and (c) isolates the influence on the likelihood of evasion. For dummy variables the marginal effect is measured as the change in the dependent variable due to a discrete switch from 0 to 1. The marginal effects of the relative frequency of previous detection (*caught_ 1-10*) is given as the elasticity at the sample average. The effect of age is measured at the sample average as the effect of an increase by one year. Table 6 reports only the marginal effects for the model that includes the history of detection, as the marginal effects are very similar if model 2 of Table 5 were used.

	Marginal effects for model 1 of Table 5		
	(a)	**(b)**	**(c)**
	expected effort	**effort if evasion**	**prob. of evasion**
tax rate (base=medium)			
– *low*	-1.27^{*}	-1.31^{*}	-0.09
	(0.04)	(0.03)	(0.33)
– *high*	1.88^{**}	1.10^{**}	0.17^{**}
	(0.00)	(0.01)	(0.00)
penalty(base=medium)			
– *low*	0.57	-0.30	0.10
	(0.18)	(0.51)	(0.07)
– *high*	-0.92	-0.37	-0.10
	(0.16)	(0.53)	(0.25)
caught_ 1-10	-1.01^{**}	0.20^{**}	-0.67^{**}
	(0.00)	(0.01)	(0.00)
age	0.09	-0.03	0.01
	(0.20)	(0.26)	(0.21)
female	0.70^{**}	-0.25	0.12^{**}
	(0.02)	(0.08)	(0.02)

p-values in parentheses; ** sign. on 2.5%-level; * sign. on 5%-level

Table 6: Marginal effects for taxpayers

Concerning the influence of tax rates we see that high tax rates have a very strong positive influence on evasion probabilities and concealment efforts. Switching from the medium tax treatment (with a 25% tax rate) to the high tax treatment (with a 40% tax rate) increases the relative evasion frequency by 17 percentage points. Effort conditional on evasion increases by 1.10, while the compounding effect on ex-ante expected effort is even stronger (1.88). Very high tax rates lead to significantly more tax evasion and more resources wasted for concealment. Lowering tax rates from a medium level to a low level (of 15%) has no significant effect on tax evasion. However, lowering the tax rate below the medium level still has some sizeable benefits. It reduces the concealment efforts of evaders by 1.31 units. As a consequence, lowering the tax rate below the medium level still reduces the ex-ante expected concealment effort significantly (by 1.17 units) despite the failure to reduce tax-evasion frequencies significantly.

Turning to penalty rates we note that their impact is very weak. The only significant impact is the reduction of evasion generated by a switch from the low fine rate to the high fine rate. Recall that this is a very large shift in the fine regime (from a surcharge of 25% of evaded taxes to a surcharge or 220%). This switch from a very lenient to a very drastic punishment regime reduces the evasion frequency by 20 percentage points. Evasion rates do not differ significantly for pairwise comparisons between low and medium and between medium and high fine treatments, though. Different penalty rates have no significant impact on the concealment effort exerted by evaders. However, switching from low fines to high fines reduces the ex ante expected concealment effort (by about 1.47 units). This is driven by the reduction of evasion probabilities

The experience of having been caught in the past (*caught_ 1-10*) has a strong effect. For instance, an increase of the relative frequency of being caught in periods 1 to 10 by 10 percentage points decreases the relative evasion frequency by 6.7 percentage points. Getting caught more often increases the concealment effort significantly, given that a taxpayer still evades. However, by looking at the waste due to concealment this effect is dominated by the decreased evasion frequency. Overall, more cases of detected evasion in the past considerably reduce the welfare loss due to taxpayers' concealment efforts. The ex ante expected concealment effort declines with the relative frequency of previously detected tax evasion with an elasticity of -1.01.

Looking at the influence of demographic characteristics we find that the relative evasion frequency of females exceeds that of males by 12 percentage points. Consequently, the ex ante expected welfare loss due to concealment is higher for females, even though female taxpayers exert slightly lower efforts than male taxpayers if they evade. Age has no significant influence on evasion and ex-ante expected waste.

In sum, high tax rates increase evasion substantially. Lowering tax rates to a medium level decreases the tax evasion frequency considerably, which also reduces the ex ante expected concealment efforts. Lowering the tax rate further does not reduce evasion further, but still reduces the ex ante expected concealment efforts, as taxpayers reduce their effort if they evade. Fines have a less strong influence on evasion and concealment behaviour. Only the switch from a lenient to a very harsh penalty regime reduces evasion and ex ante expected concealment efforts.

3.3 A panel Tobit model of the behaviour of tax authorities

In order to analyse the behaviour of tax authorities we estimate a panel data Tobit model, where the detection effort after a zero-declaration is the dependent variable. The model allows for correlation within a subject and takes into account that the detection effort is truncated at zero from below and at ten from above. We use again only periods 11 to 20 in order to add a variable capturing past experience. The variable *detect_ 1-10* captures the fraction of periods with successful detection in periods 1 to 10, given that a zero declaration was observed. This variable is influenced by two important variables that are unobservable by the authority, though, i.e. the taxpayer's true income in case of a zero declaration and the effort of the taxpayer. The variable *detect_ 1-10* basically captures the information an authority can use when forming beliefs about the evasion and concealment behaviour in later periods. We also estimated a model without *detect_ 1-10.* The effects of tax and fine rates were very similar. We prefer the model with *detect_ 1-10*, as its over-all fit is much better.[19] Table 7 reports the coefficients and the marginal effects (both unconditional and conditional on the effort being positive) of our proffered model.

We find that only two variables have a significant influence on the tax authorities' detection efforts if they observe zero declarations – tax rates and relative past detection rates. Wasteful detection effort increases considerably if we switch from a medium to a high tax regime (by about 1.77 units). This effect can be decomposed in two subeffects. (a) Conditionally on exerting a positive effort, the switch in the regime increases the effort by 1.25 units, while (b) the fraction of tax authorities that exert positive efforts is raised by about 14 percentage

[19] Dropping *detect_ 1-10* reduces the explanatory power of the Tobit model significantly ($Prob > \chi^2$ falls below significance).

points. However, a switch from a medium to a low tax rate does not have any significant influence on the detection effort choices of the tax authorities. Previous experience of successful detection has also a strong positive impact, meaning that tax authorities increase their detection efforts if they have been successful in the past. An increase in the past detection rate by ten percentage points increases the detection effort by about 0.52 units. Conditional on exerting positive effort a rise in the past detection rate increases the effort by about 0.37 units, while the probability of exerting positive effort rises by 4.4 percentage points. Similar to the findings in the analysis of taxpayers' behaviour, penalty rates have no significant influence on the effort choices. Demographic variables do also not influence the efforts exerted by the authorities. Moreover, we do not observe any time effects. Effort choices are stable over periods 11 to 20.

Panel-Tobit estimation of the detection effort				
	Coefficients	Marginal effects		
		unconditional	cond. on effort>0	prob{eff>0}
N	1104			
Log pseudo-likelihood	−2272.25			
$Prob > \chi^2$	(0.00)			
tax rate (base=medium)				
– low	1.08	0.76	0.57	0.06
	(0.33)	(0.34)	(0.35)	(0.31)
– high	2.55**	1.77**	1.25**	0.14**
	(0.00)	(0.00)	(0.00)	(0.00)
penalty (base=medium)				
– low	0.01	0.01	0.01	0.00
	(0.99)	(0.99)	(0.99)	(0.99)
– high	0.31	0.22	0.15	0.02
	(0.78)	(0.78)	(0.78)	(0.78)
period dummies	*not sign.*	*not sign.*	*not sign.*	*not sign.*
detect_ 1-10	7.70**	5.23**	3.68**	0.44**
	(0.00)	(0.00)	(0.00)	(0.00)
age	−0.05	−0.04	−0.03	0.00
	(0.68)	(0.68)	(0.68)	(0.68)
female	−0.79	−0.54	−0.38	−0.05
	(0.24)	(0.24)	(0.24)	(0.24)
econ-student	−0.92	−0.63	−0.44	−0.05
	(0.20)	(0.20)	(0.20)	(0.20)
constant	2.44			
	(0.45)			
residual correlation ρ	0.35**			
Wald test (H_0: $\sigma_u = 0$)	(0.00)			

p-values in parentheses; ** sign. on 2.5%-level; * sign. on 5%-level

Table 7: Regression results for tax authorities

Combining our findings on taxpayers' and tax authorities' behaviour from Tables 6 and 7 reveals a clear pattern. High tax rates, as opposed to medium and low tax rates increase the evasion probability considerably. This in turn prompts the authorities to raise their efforts, which is countered by high concealment efforts of taxpayers. Low tax rates compared to medium tax rates have no influence on the evasion frequencies. So evading taxpayers only slightly decrease their efforts (compared to the efforts exerted under a medium tax rate), as the gap between the payoff after a successful contest and a failure is reduced under a lower tax rate. However, this effort reducing effect is not observed for tax authorities. Both parties (taxpayers and authorities) do not react strongly to the incentives provided by the size of potential fines. Taxpayers neither reduce evasion frequencies nor increase their effort levels. Tax authorities also do not change their effort levels when fines are higher.

3.4 Efficiency and tax revenue

We now turn to the analysis of efficiency levels across different treatments. For each pair of taxpayer and tax authority we calculate as a measure of efficiency the percentage of income that is not invested into wasteful detection and concealment. Considering again only the last 10 periods, Figure 4 shows the fraction of pairs with an efficiency measure in a particular interval (of 10 percentage points width) and Table 8 shows the overall averages. While in the low and medium-tax treatments 45 to 50 percent of pairs achieved at least 90 percent efficiency, less than 10 percent of pairs were able to sustain such a high efficiency level in the high-tax treatments.

Figure 4 about here

V	T_l	T_m	T_h
P_l	–	0.89(0.89)	0.79(0.80)
P_m	0.91(0.89)	0.89(0.80)	0.83(0.69)
P_h	–	0.92(0.69)	–

values predicted by theory in parentheses

Table 8: Efficiency in the last 10 rounds by treatment (in percent)

Testing for pairwise differences with a Mann-Whitney U-test shows that low and medium taxes lead to higher efficiency than high taxes ($p < 0.01$, Mann-Whitney U-tests for given penalty rates). The influence of penalty rates is not significant ($p > 0.14$ for low versus medium penalties, given high taxes; $p > 0.98$ for low versus medium penalties, given medium taxes; $p > 0.10$ for high penalties versus medium and low penalties, given medium taxes). An additional observation is that the efficiency is higher than predicted for the treatments with high and medium penalty rates, while it is basically as predicted in the treatments with low penalty rates. We can observe two main deviations from our predictions in all treatments: less evasion, but higher efforts. In the case of the low penalty rate-treatments these two effects (which are countervailing as far as efficiency is concerned) just cancel each other out. However, as higher penalty rates do not have the predicted effect of increasing efforts, these treatments generate a higher efficiency than predicted. Note that higher penalty rates do not significantly reduce evasion activity. So varied penalty rates have hardly any influence on efficiency, while taxes drive efficiency differences.

Although higher taxes are associated with a loss of efficiency they might at least generate higher revenues for the government. However, this is not necessarily the case if one takes the detection costs into account. Table 9 summarizes the average revenue (summed over the last 10 periods) by pair and treatments. Higher tax rates lead to slightly higher tax revenues, significantly higher taxes recovered by audits, and higher revenues from penalties. However, if the detection costs of the authority are taken into account, then the differences in total net revenue across treatments are small, with the following exception. The total net revenue in the two treatments where the product of fines and tax rates is highest (T_mP_h and T_hP_m) is significantly higher than in all other treatments ($p < 0.05$ in any pairwise comparison to the other treatments; Mann-Whitney U-tests), indicating that a combination of relatively high tax rates and high fines are suitable for raising revenue. In the case of high fines this result is driven by healthy tax payments, while in the case of high taxes the collected fines and repaid taxes are responsible. If high taxes are combined with low penalty rates, net revenues are not significantly different from net revenues with medium tax rates. So just raising taxes is not necessarily sufficient for higher net revenues.

Revenue (averages per pair)	treatment(tax/fine)					
	T_lP_m	T_mP_l	T_mP_m	T_mP_h	T_hP_l	T_hP_m
(1) Tax revenue from declared income	480	908	1042	1317	933	1200
(2) Taxes recovered by audits	239	258	267	183	947	733
(3) Penalties	238	64	267	320	237	733
(4) Detection costs	−787	−785	−939	−681	−1683	−1339
Total net revenue, i.e. (1) + (2) + (3) + (4)	170	445	637	1139	434	1327
Net revenue in percent of income	2.1	5.6	8.0	14.2	5.4	16.6
Rel. cost of recovered revenue: (4)/[(2) + (3)]	1.7	2.4	1.8	1.4	1.4	0.9

Table 9: Revenue of tax authorities in the last 10 periods by treatment

The bottom row in Table 9 reports a measure for the efficiency loss (through detection costs) per unit of net revenue generated from detected tax evasion. Treatment T_hP_m has the only ratio below unity, indicating that the recovered taxes and penalties exceed the detection costs only in this treatment. In all other treatments the attempt to detect tax evasion leaves tax authorities with lower total net revenues than those received from declared income.

4 Conclusion

Though tax evasion is a pervasive phenomenon in many countries, the excess burden through the costs of concealing or detecting tax evasion has only been examined in purely theoretical models so far (like, e.g., in Usher, 1986, or Cremer and Ghavari, 1994). In this paper we have provided a first empirical examination of the influence of tax rates and penalty rates on the concealment and detection costs associated with tax evasion. Given the problems of observability and measurability of concealment and detection costs in the field we have run a controlled laboratory experiment to test the behavioural incentives of different tax regimes.

Based on the model by Bayer (2006) our experiment has shown that tax rates are the driving force for the amount of concealment and detection costs wasted in the contest between taxpayers and tax authorities. Penalty rates, however, have been found to have no systematic impact on the excess burden of tax evasion. Hence, higher taxes lead to a higher excess burden through a strong increase in socially wasteful investments into concealment and detection, but higher penalties do not. Therefore, our results suggest that policy makers who are concerned about unproductive concealment and enforcement should focus on tax rates rather than on penalty rates.

Besides adding the novel findings on the excess burden of tax evasion to the empirical literature on tax evasion, our paper is also a contribution to some previously addressed issues. Several earlier papers have examined the influence of tax rates and penalty rates on the amount of tax evasion, and our results with respect to tax evasion are basically in line with the earlier experimental findings. Tax rates have been shown to be the main factor for explaining the frequency of tax evasion (Friedland et al., 1978; Baldry, 1987; Alm et al., 1992), whereas the impact of penalty rates is small at best (Witte and Woodbury, 1985; Dubin and Wilde, 1988; Kirchler, 2007). The same effects of taxes and penalties on the frequency of tax evasion have been observed in our experiment. The econometric evidence from field studies on the effect of taxes on evasion is less clear, though. Clotfelter(1983), Christian and Gupta (1993), and Joulfaian and Rider (1996), for instance, find a positive relationship. However, Alm et al. (1990) and Feinstein (1991) find the opposite. The different methodological approaches of measuring tax evasion in the various field studies might explain the partly contradictory econometric evidence. In the laboratory the measurement of the impact of tax rates on evasion is simple and standardised across studies. Therefore, the consistency of experimental results might reflect one of the advantages of laboratory methods in the research on tax evasion.

We have also addressed another aspect in the tax evasion literature where experimental and econometric field studies have come to opposite conclusions. This is the deterrence effect of past audits. In experimental studies usually the experience of being audited and/or caught has a strong deterrence effect for the future, while in econometric studies hardly any deterrence effect is found (see Andreoni et al., 1998, pp. 843f. for a review of the literature concerning this point). Our design allows for a further investigation into this puzzle. In earlier experiments subjects did not have the possibility to invest in concealment, so their only possible reaction to detected evasion was to keep evading or to switch to truthful declaration. Many subjects chose the latter in order to avoid getting caught again. In our experiment, as in reality, caught evaders had two ways of avoiding future detection. They could either report truthfully or they could reduce the detection probability with a higher investment in concealment. Many subjects kept evading but stepped up their efforts. The concealment efforts of subjects who still evaded increased with the frequency of detected evasion in the past. However, despite of this second option, honesty as a response to previous penalties still featured prominently in our data. Having been caught in the past reduced the expected concealment effort through this channel. This might suggest at first sight that successful audits are a good method of reducing wasteful investments in the detection-concealment contest. Yet, this is not the case. Authorities that caught a subject in the past considerably increased their effort. This effect dominates the deterrence effect. It also shows that prior detection can lead to an escalation of the contest, thereby increasing waste. In fact, the efforts of taxpayers in later periods (eleven to twenty) and those of tax authorities in earlier periods (one to ten) have been highly positively correlated[20], meaning that there is an upward trend of social waste once evasion takes place and gets detected. This observation is no surprise in the light of the standard literature on contests (Lazear and Rosen, 1981) which have been shown to increase the efforts of competitors. However, the observation is novel in the literature on tax evasion as this literature has not yet addressed the welfare implications of the contest between taxpayers and tax authorities.

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Appendix - Model predictions

In this appendix we derive the Perfect Bayesian Nash Equilibrium in our model. An equilibrium consists of a declaration and concealment effort for the taxpayer for $y = 0$ and $y = 1000$, the authority's detection efforts for the declarations $D = 0$ and $D = 1000$ and an equilibrium belief μ, which gives the authority's believed probability of facing an evader after observing $D = 0$. Obviously $E^* = 0$, $D^* = 0$ if $y = 0$ and $A^* = 0$ if $D = 1000$ are part of any equilibrium.

The first-order condition for an optimal detection effort choice of the authority observing a zero declaration (and given the expected concealment effort E^E of the taxpayer) is given by

$$\frac{\partial ER(A, D=0)}{\partial A} = \frac{\mu \cdot E^E \cdot f \cdot t \cdot y}{(E^E + A)^2} - c_a = 0 \tag{7}$$

$$E^E, A \geq 0 \tag{8}$$

The first-order condition for an evading taxpayer with respect to her concealment effort (given the expected detection effort A^E of the tax authority) is given by

$$\frac{\partial EU(E, D=0, Y=y)}{\partial E} = \frac{A^E \cdot f \cdot t \cdot y}{(E + A^E)^2} - c_e = 0 \tag{9}$$

$$E^E, A \geq 0 \tag{10}$$

Solving (7) and (9) simultaneously and imposing the non-negativity constraint on efforts gives positive optimal efforts which depend through μ on the declaration strategy:

$$A^*(D = 0) = \mu \cdot c^e \cdot \phi \tag{11}$$

$$E^*(Y = y,\ D = 0) = c^a \cdot \phi, \tag{12}$$

where

$$\phi := \frac{\mu \cdot f \cdot t \cdot y}{(\mu c^e + c^a)^2}.$$

We now look for a pure strategy evasion equilibrium. In such an equilibrium a taxpayer always evades whenever she earned the income. Then in equilibrium the authority's belief μ that a zero declaration comes from an evader has to be equal to the prior probability λ that the income was earned:

$$\mu^* = \lambda.$$

The taxpayer's expected payoff from evasion has to be weakly greater than the payoff for truthful declaration for such an equilibrium to exist:

$$EU(D = 0, E^*, A^*) \geq (1 - t)\, y$$

which leads to the following condition on parameters:

$$f \leq \frac{(c^a + c^e\lambda)^2}{c^e\lambda(2c^a + c^e\lambda)}. \tag{13}$$

Note that this equilibrium is the unique Perfect Bayesian Nash equilibrium for all parameter configurations that satisfy (13). For parameter values violating the condition above the marginal concealment cost and the penalty are too high for always evading to be profitable. Taxpayers then choose to mix between evasion and truthful declaration. It can be shown that the equilibrium evasion probability α^* conditional on having earned the income y and on violating condition (13) can be written as:[21]

$$\alpha^* = \frac{\eta(1-\lambda)\left(\sqrt{f} - \sqrt{f-1}\right)}{\lambda\left((1-\eta)\sqrt{f-1} - \eta\sqrt{f}\right)}$$

where $\eta = c^a/c^e$ is the comparative advantage in concealment over detection. It is possible to show that lower fines increase the probability that an actually earned income is evaded in the case that always evading does not pay.[22] Note, that here equilibrium efforts A^* and E^* decrease if the equilibrium evasion probability α^* decreases. This is driven by the feature that the equilibrium beliefs for evasion μ^* decrease if α^* decreases. In this formulation the tax rate should have no influence on the evasion probability. Note, however, that taxpayers with a fixed evasion cost (maybe due some moral constraints) will evade with higher probability when the tax rate is higher.

[21] For the derivation see Bayer (2006).

[22] This is true, since $\partial\alpha^*/\partial f < 0$ for $\alpha^* \in [0, 1]$.

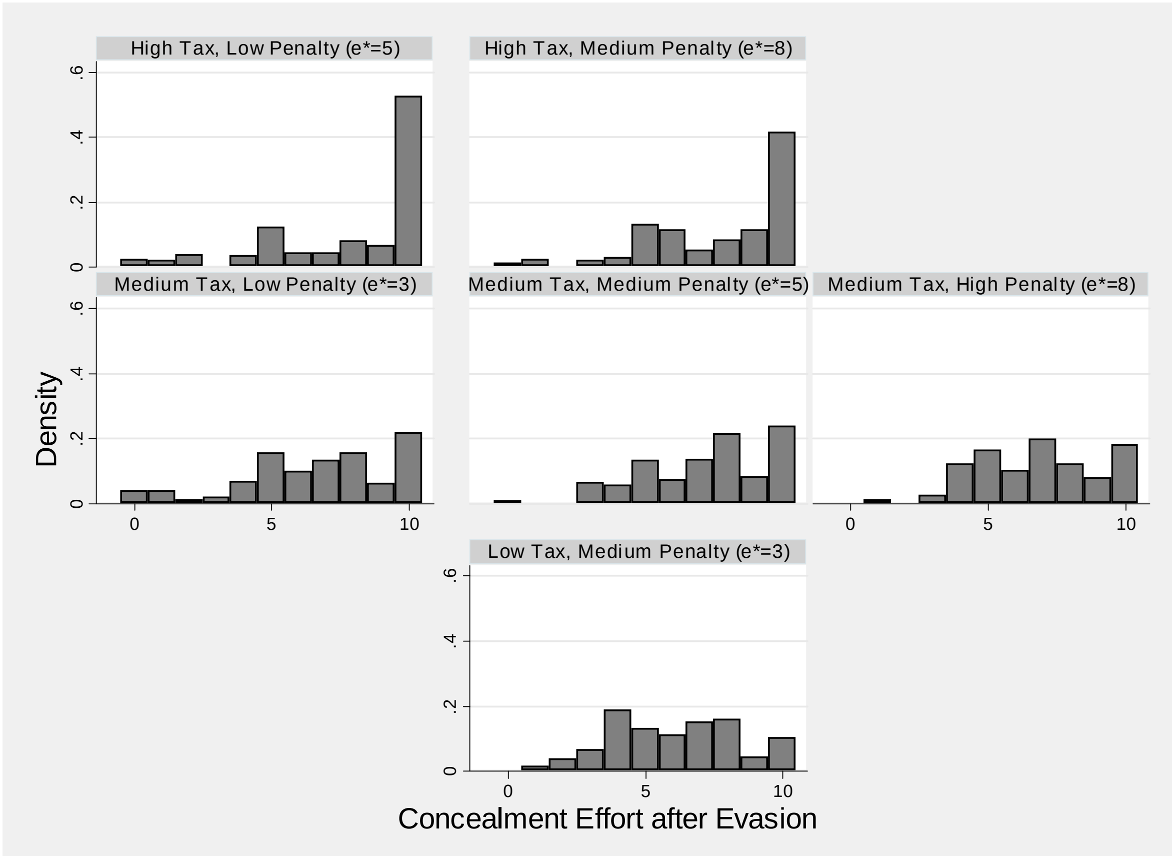

Figure 1: Distribution of concealment efforts by treatment

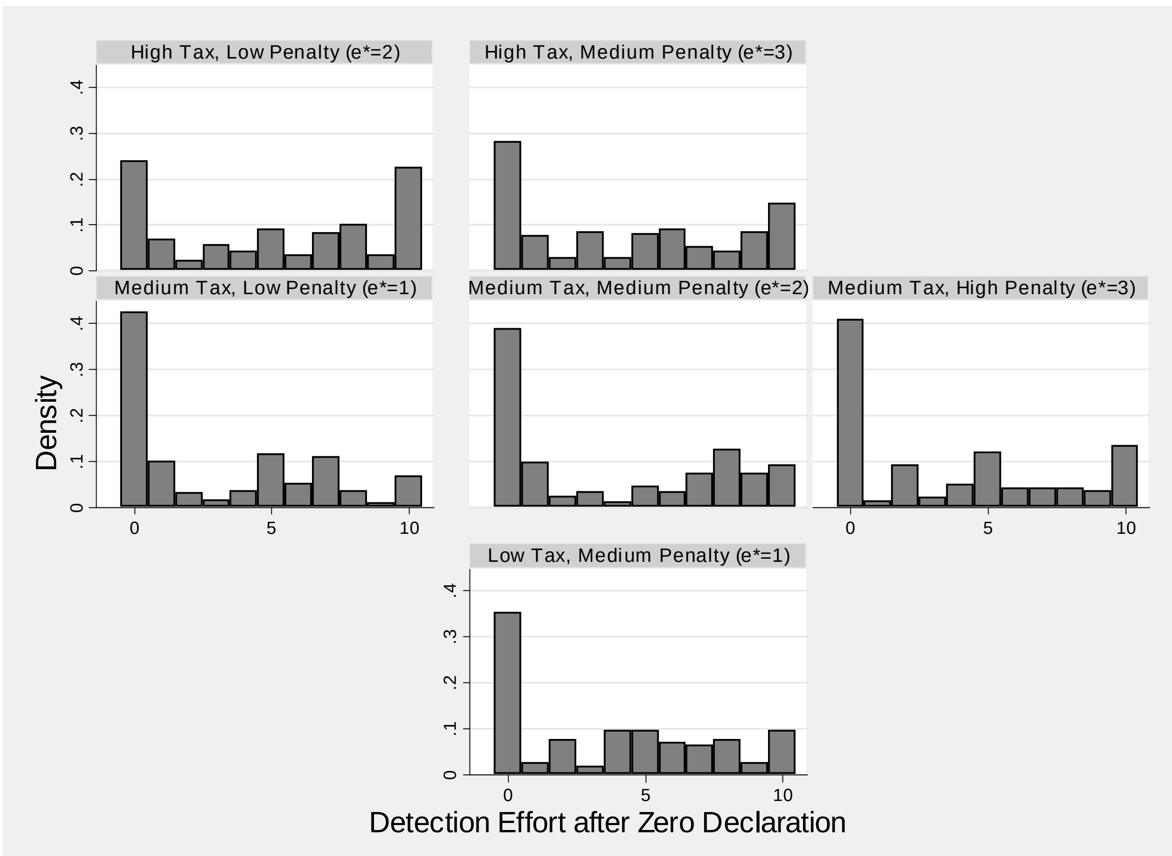

Figure 2: Distribution of detection efforts by treatment

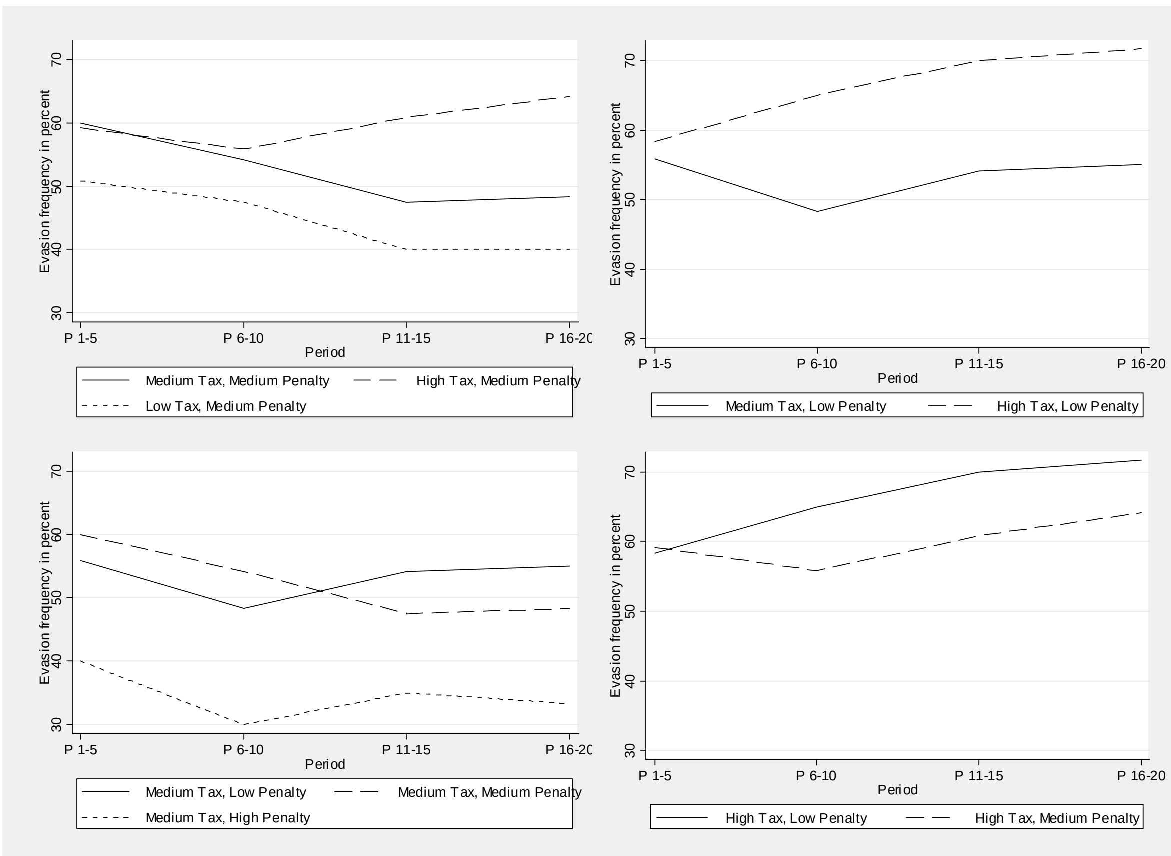

Figure 3: Evolution of evasion frequencies

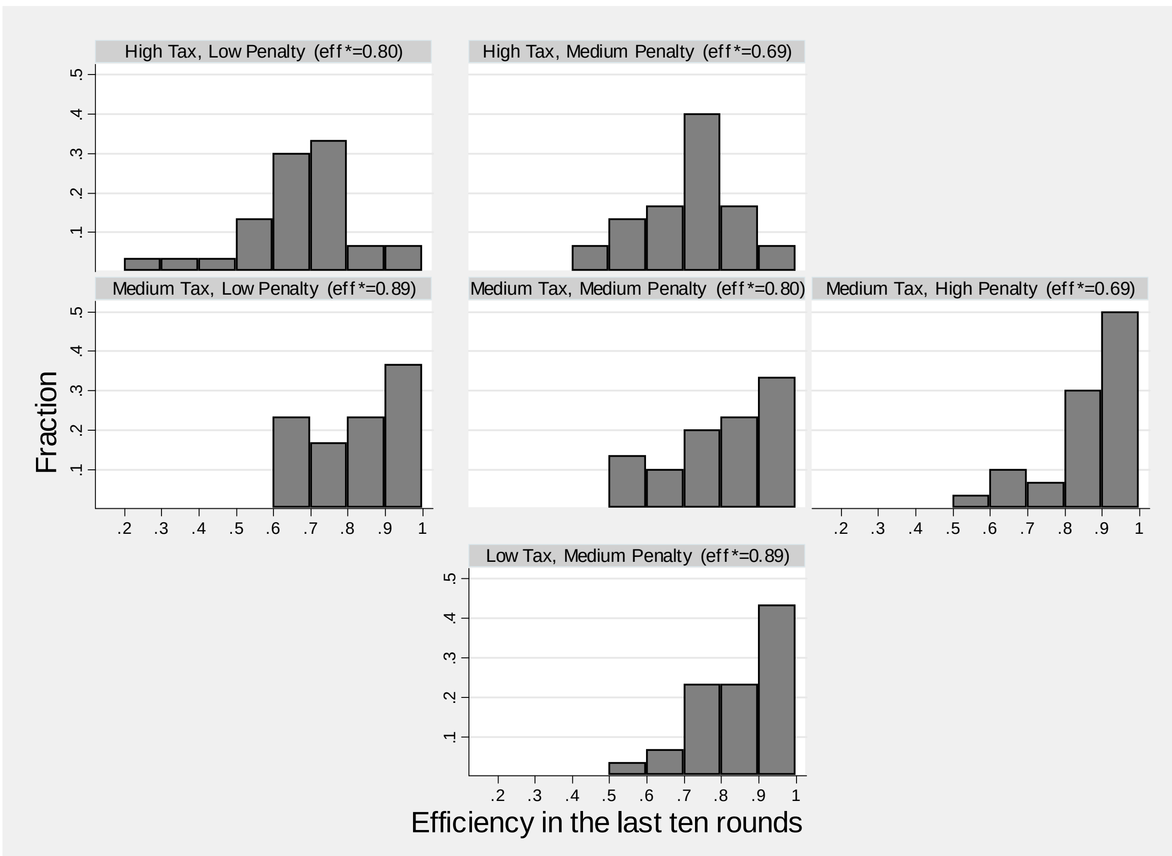

Figure 4: Efficiency of pairs by treatment in rounds 11 to 20