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Narrowing time windows to study effects of tax policies on GDP and the underground economy: Italy 1982 to 2006

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Abstract

Studies of the effect of tax changes on GDP and the underground economy, UGE, give ambiguous results when correlation techniques are applied to long, observed time series. Here, we apply a novel technique that identifies time windows in linearly detrended tax rate time series where tax changes are leading variables to GDP and to UGE and thereby candidate causes. With the raw series for GDP and UGE in Italy, 1982 to 2006 linear regression showed that increasing taxes increased GDP whereas the effects on UGE were ambiguous. With restricted time windows, the net effect of increased personal and corporate tax rates was decreased GDP, and increased UGE. In 10 out of these time windows major tax shocks coincide with the leading relation. Tax shocks set up 3 to 6 years long cycles in tax rates that precede corresponding cycles in UGE and GDP with 1 to 4 quarters. We also added insights into 3 conjectures related to taxation and UGE; the existence of multiple equilibriums in UGE, delayed response to tax evasion control and the Yitzhaki tax evasion puzzle. For the two last conjectures, a delayed economic response to tax policies that is greater than ¼ of the common cycle length seems to be important.

Keywords: Tax policy, GDP, Underground economy, tax evasion, delayed response, Yitzhaki tax evasion puzzle, repeated games

JEL: O17, C63, E52, H26

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1. INTRODUCTION

The idea is very simple, we propose four steps in narrowing time windows to increase the probability that tax policies affect GDP and the underground economy, UGE. The first step include the full time series under study, the second step is to detrend the full time series, the third step is to use only time windows where tax rate is a leading variable to the economies. The last step includes only time windows where the windows are associated with a tax shock.

The presence of underground economy is widespread in almost all countries, although there are substantial differences between countries (Buehn and Schneider 2012 p. 160). Economists and policy makers investigate the causes of the shadow economy and try to propose ways to reduce their importance. According the Eurobarometer survey in 2007, the most frequently answers of respondents were of two different kinds: “too low salaries” and “too high taxes”. As for Italy and for some other countries, the two reasons relate to each other, since net wages are low because taxes on wages are high. So, ultimately, the tax system seems to play a major role in deciding, for an economic agent, whether to operate on the legal market or not.

According the World Bank (2012) report, the high taxes on labor, mostly at low earnings, are among the principal causes of the shadow economy; mainly due to the high contribution for social insurance. When a tax rate is perceived as too high, both firms and workers often face the trade-off between compliance and the possibility to move into the shadow market.

There are also other reasons that contribute to swell the informal economy. Among these should be considered the situation in which the effective tax burden is lower for the self-employed than the dependent workers, in which case workers move from employee to self-employed. Furthermore, the tax treatment of families can foster secondary family earners to work informally, because, in general, the additional family income is taxed at a higher marginal rate. Thirdly, the tax burden may feel differently in poor areas of Italy than in rich areas.

In Italy the tax burden has shown an increasing trend over the period 1982 -2006 along with the rise in public spending, the budget deficit and public debt. Personal taxes rose from about 25% in 1982 to about 46 % in 2006. The greatest growth in the tax burden was in the period 1982-1993, and in particular the 1992-93 biennium corresponds to the peak of the whole period considered. (See Figure 1c, detrended values). The different governments in office during the period 1981 to 2006 have tried to promote the return policies of public spending and tax burden, getting mixed results. Italy has experienced periods of decline in UGE around 1995, and in the period 2002-2005. Therefore, in the period 1982 to 2006, there are elements that should allow empirically analysis of the supposed relationship between tax burden, growth and level of underground economy. For comparison, the weighted average shadow economy for high income OECD countries are estimated to 13.4 % % in 2005, with a minimum of 11% and a maximum of 28.0%, (Buehn and Schneider 2012).

Factors that potentially affect GDP. An overview of the effects of tax changes on GDP is given by Mountford and Uhlig (2009) and Romer and Romer (2010). Reaction to tax changes is assumed to be particularly strong shortly after considerable tax changes, or tax shocks, have been announced or implemented. However, empirical evidence on the effects on fiscal policy on economic growth is scant and mixed, (Arin et al. 2013). This is partly because data are few, the time series are serial correlated, there are problems with reverser causations, (Romer and Romer 2009). Furthermore, the effects may be confounded with other policy measures than taxation.

There are also studies that address behavioral dynamics, e.g., Piolatto and Rablen (2017), Pickhardt and Prinz (2014), and morale, both in the government and among the taxpayers, Alm (2012), Torgler et al. (2010).

Factors that potentially affect the underground economy are discussed by Orsi et al. (2014). The canonical model on tax evasion proposed by Allingham and Sandmo (1972), which also applies to the shadow economy analysis, states that the choice of agents depends on the probability of being caught, that is, the number of investigations, and the extent of the potential penalty. According to this model, operating on these two levels, evasion, and therefore also the shadow economy, could be reduced significantly. Some authors also include additional factors, as income or per capita, real GDP, unemployment rate and nominal interest rate, (Muehlbacher et al. 2011; Cebula and Feige 2012). A third set of studies morale, both in the government and among the tax payers, (Torgler et al. 2010; Barone and Mocetti 2011).

Causality. Since most economic variables show cycles, causality can be interpreted to say that a causal variable to UGE has to peak before UGE peaks, and a trough has to come in advance of a trough in UGE. Similar arguments hold for tax effects on GDP. However, the leading lagging, LL-method used here does not only identify peaks and troughs, but identify LL- relations for 3 running consecutive observations in paired time series. Estimate of significance can be established after 10 consecutive observations.

Underground economy. As a candidate cause for decrease in the UGE, we examine the effect of reducing tax rates on the tendency to avoid compliance with taxation, social security, labor and administrative legislation. In the present study we examine the UGE, but not the informal and the illegal economy, see Orsi et al. (2014). We then compare the effects on UGE to the effects on GDP.

Long term and decadal variable movements. We detrend the time series for tax rates and economies and study the long term trends in the economy, 1982 to 2006 separately from annual and decadal movements. The long term trends will most probably be affected by a variety of factors in addition to tax related measures, like technology changes and changes in social norms (Acemoglu and Jackson 2017). For the annual and decadal movements we restrict our estimates of the relationship between tax rates and the economies to time windows where tax rate series are shown to be leading variable to the economy series. A subgroup consists of time windows where the windows are preceded by tax shocks or shocks in GDP - health. Such shocks may potentially change attitudes towards tax evasions.

1.2 Hypotheses

The leading- lagging, LL –method we adopt are used to test *five* hypotheses. *Firstly,* H1, we hypothesize that tax shocks initiate the leading relation for taxes to the economies. However, tax shocks may also have been announced before the shock is detected in tax level changes, and thus anticipated. *Secondly*, H2, we hypothesize that tax shocks will set up an oscillating pattern with increasing and decreasing taxes, and corresponding changes in the economies. The rationale is that there will be opposing interests between fiscal and monetary policies over decadal time scale; tax changes beget tax changes. If the leading relation for tax policy to GDP or UGE lasts for one full cycle, then the policy variable has to be changed two times with accompanying and consistent response in GDP or UGE. *Thirdly,* H3, we hypothesize that reductions in personal and corporate tax rates during periods where the tax rate leads the economy, the GDP will increase and the underground economy will decrease over decadal time. One rationale for the effect on GDP is that tax reductions are mediated by a transfer of money to the private sector where it partly will increase buying power for consumer goods and partly contribute to investments and innovations. However, Gechert (2015) suggest that the multiplier effect on GDP of public spending (taxes) is larger than that of private spending. With lower taxes, the gain by cheating on taxes becomes less and the tradeoff between gain and the risk of being caught gets in favor of complying with the tax law and other regulations. The social security tax rate may have a less strong effect on the underground economy because it is a direct investment in own welfare. It may also affect the economy differently from other taxes, Romer and Romer (2016). *Fourthly,* H4, we hypothesize that the time windows where tax rate significantly lead the economies are related to exogenous factors and that these factors again can be related to political events in Italy during the period 1982 to 2006.Lastly, H5, we hypothesize that our data will enable us to add insights into three current conjectures related to taxation: multiple equilibrium in UGE, delayed response for the economies and the Yitzhaki puzzle that states that as the tax rate increases the income evaded decreases.

We use a novel technique that identifies windows in the time series where taxes are leading variables to the economies, that is, time windows where a causal relation between taxes and the economies is probable. We find that changing personal and corporate taxes in Italy sets up cycles where taxes become leading variables to the underground economy. Increasing taxes decrease GDP and increase the underground economy, UGE, during the time windows where taxes are leading variables to the underground economy.

The rest of the paper is organized as follows. We first present the material in section 2. In section 3 we describe the methods used, in particular the leading – lagging, LL- method and the method for identification of tax shocks. Results are presented separately for multidecadal trends, and for annual and decadal cyclic movements in section 4. In section 5 the results are then discussed relative to five hypotheses. In the final section 6 we conclude.

2. MATERIALS

Our target variable is GDP and the underground economy, UGE during the period 1982 to 2006**.** In the present study, we use as candidate causal variable for changes in the two economies, GDP and the UGE i) corporate and ii) personal tax rate, and the average of these rates, the iv) tax evasion control efforts and v) economic health formulated as running average volatility in GDP. A high volatility would signify bad economic times. Bad economy may cause people to comply with tax laws, because tax evasion enforcement may be intensified during such times, and some tax evaders may not have resources to combat or pay tax fines. The three first variables are included as variables in a DSGE model for the underground economy, UGE, whereas the last variable would be external to the model. The variables are depicted in raw format in Figure 1a, as strongly smoothed and normalized series in Figure 1b, and as detrended and normalized series in Figure 1c. Figure 1d will be discussed below.

Underground economy. In a recent study, Orsi et al. (2015), taking a cue from Allingham and Sandmo (1972) model, have proposed a dynamic stochastic general equilibrium model, DSGE, that allows an estimate for the underground economy of Italy for the period 1982 to 2006. The time series for UGE compares fairly well with a series for undeclared value added taxes, VAT, discussed by Chiarini et al. (2013). However, the latter series shows much greater volatility.

Data for consumption, investment, wages and fiscal revenues were provided by the Italian Institute of statistics, (ISTAT 2007).

Tax compliance enforcement, probability. The proportion of fiscal controls, Cp, is the ratio between the number of inspections and the number of companies susceptible to inspection on an annual basis. The time series was provided by the Agenzia delle Entrate (the Italian revenue agency) and was disintegrated to quarterly frequency by Orsi et al. (2014).

Figure 1 in here. Data and power spectral density graphs

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3. METHOD

First, we apply multiple linear regression to raw variables to obtain an expressions for the influence of the variables on UGE and GDP over the whole multidecadal period. Since the variables are given in different units, we first normalize the variables to unit standard deviation. Secondly, we use principal component analysis, PCA, on the detrended data series to obtain expressions for the influence of the variables on decadal or shorter time scales. We thereafter show how the time series are pretreated, we show the application of the power density spectral algorithm, PSD, to the data, and lastly the Leading lagging, LL- method.

3.1 Principal component analysis, PCA.

The PCA produces two plots, the score plot that shows how samples are related (here observations for each quarter, not to be shown) and the loading plot that shows how variables are related (here our seven variables). Variables that are in the same direction from the origin are associated. Cyclic variables that are at a right angel relative to the origin are either unrelated, or shifted ≈ ¼ cycle length in time. Generally, with cyclic time series there is a relation between the shift between the cycle series and the angles between lines connecting points in the PCA score plot to the origin. We use the PCA to obtain an overview of the relationships between variables, and in guiding an outline of stylized relations.

3.2 Detrending, normalizing and smoothing.

Smoothing. The form of the noise on the observed data is not known (uniform or Gaussian, additive or multiplicative). Since the DSGE modelling studies included added stochastic elements, we smoothed both the observed and the modelled series. However, apart from that, no parameters are included in the algorithm that defines leading or lagging relations between paired series.

Secondly, to help see the medium term trends for the resulting variables, we smooth the results series. For smoothing, we used the 2D smoothing algorithm of SigmaPlot©. The algorithm is a locally weighted polynomial smoothing function. We use the parameter f = 0.2, f = 0.4 and f = 0.6 to define local domains (20 %, 40 % and 60% of the full series respectively) and a second order polynomial function, p = 2, to interpolate.

3.3 Power density spectra.

The version we use for the power spectral density algorithm, PSD, assumes that the series are stationary. However, moving average methods for PDS methods exist, Kestin et al. (1998). By using the PSD, we identify cycles in the single series that can be compared to common cycles for paired series that we identify with the LL- method. We take the log of the power spectral density because cycles shorter than about 5 time steps are frequent in leading – lagging series generated by random numbers, and may therefore not be significant (Seip and Grøn 2016). Furthermore, densities for longer cycles becomes clearer.

3.4 Shocks

We estimate tax shocks by taking the 1st derivative of the corporate, personal, and social security tax rates. By normalizing the rates to unit standard deviation and making histograms for the normalized rates, we identified tax shocks by comparing their distribution to a fitted Gaussian curve. Outliers were identified as rates at the tails of the distribution. Rate changes > ± 3, for tax changes were used to find the dates where changes had been appreciable. The procedure was similar for control probability, but inspecting the tails of the histogram of the derivatives we found that a reasonable cut off value was ± 1.3. We also estimated if there were shocks in UGE. We estimated tax shocks in "GDP-health" by calculating running average volatility as standard deviation over 9 consecutive quarters. Then we estimated shocks as the first derivative of volatility, and by inspecting the histogram for the distribution of derivatives we found ± 2.3 as a reasonable cut off value. The shock identified in this way was subsequently compared to events, or time windows, where tax rates were leading variables to GDP or UGE. The histograms are shown in Supplementary material 1.

3.5 Leading and lagging LL - relations.

The LL- method is relatively novel (Seip and McNown 2007). The first part where paired time series are depicted as phase portraits is related to the Lissajous curves in electrical engineering, (Wikipedia 2015). The second part where we calculate rotational properties is related to the calculation of magnetic fields around an electric wire. The method is simple and is implemented in one Excel sheet and is available from the authors. Other methods are available for identifying LL-relations, e.g., Granger (1989), but to our knowledge, the LL-method is the only one that does not require stationary time series and that work for short, n < 10, series.

To illustrate the method, we use two sine functions that are displaced 1/8 of a cycle length relative to each other. The two sine functions are shown in a dual representation, as time series along a time axis, Figure 2a, and in a phase plot representation with one series depicted on the x-axis and the other variable on the y -axes. The two sine functions shown can be thought of as representing tax reductions (peaking first) and GDP (peaking closely after), but less than ½ cycle length, λ after tax reductions.

3.5.1 Explaining LL- relations

If the variables show cyclic patterns that are shifted in time relative to each other, like the stylized tax reductions and GDP in this example, the trajectories for the (x,y) pairs will rotate in a clock-wise direction as suggested in Figure 2b. Pairs of ideal cyclic time series that are centered and normalized to unit standard deviation will show an elliptic form with center in the origin and with the long axis along the x = y axis (phase shift, PS < ¼ Cycle length, λ) or along the x = -y axis. (1/2 λ< PS < ¼ λ). If the trajectory rotate positively (counter-clockwise per definition) then the y-axis variable lags the x-axis variable. The two lower panels show a similar example with two uniformly random series. The lower bar chart in Figure 2c shows the angles V; positive angels show counter clock - wise rotations and negative angles show clock wise rotations.

Figure 2 in here, method

We quantify the rotational patterns in phase plot by the function:[3]

$$(1) \qquad V = sign(\bar{v}_1 \times \bar{v}_2) \cdot A\cos\left(\frac{\bar{v}_1 \cdot \bar{v}_2}{|\bar{v}_1| \cdot |\bar{v}_2|}\right)$$

where $\bar{v}_1$ and $\bar{v}_2$ are two vectors formed by two sequential trajectories between three sequential points in the phase plots. From these angles, we identify a leading – lagging, LL- strength. It can be formulated as a function of the number of positive angle, N_{pos} minus the number of negative angles, N_{neg} divided by the sum of the absolute values of both positive and negative angles over a certain time span, n.

[3]With x- coordinates in A1 to A3 and y-coordinates in B1 to B3 the angle is calculated by pasting the following Excel expression into C2: =SIGN((A2-A1)*(B3-B2)-(B2-B1)*(A3-A2))*ACOS(((A2-A1)*(A3-A2) + (B2-B1)*(B3-B2))/(SQRT((A2-A1)^2+(B2-B1)^2)*SQRT((A3-A2)^2+(B3-B2)^2))).

$$(2) \quad LL= (N_{pos} - N_{neg})/(N_{pos}+N_{neg})$$

The variable LL range between -1 (y- variable leads x- variable) to +1 (y-variable lags x- variable). With LL = 0, there is no leading- lagging relationship. With time on the x- axis and LL –strength on the y – axis there are no significant LL –relations in the phase plot in a band around LL = 0, corresponding to no significant cyclic variations in the time series plots.

3.5.2 Cycle lengths.

We calculate running averages for cycle lengths, CL (n ≥ 3) according to Eq. (3):

$$(3) \qquad CL = 2\pi n / |\sum V|$$

Since one full rotation of the trajectories in phase space corresponds to one full cycle for the paired time series, we are interested in the average cycle length for the set of observations that completes one cycle in phase space. We plot significant cycle lengths for n = 3, for n = 9.

3.5.3 Phase shifts between paired series.

Lead and lag times, or phase shifts, PS, are estimated from the correlation coefficient, r, for sequences of 5 observations, PS (5). If the two series co-vary exactly, their regression coefficient will be 1, and the time lag will be zero. If they are displaced half a cycle length, the correlation coefficient is r = -1 and the series are counter cyclic. An expression for the phase shift between two cyclic series can be approximated by:

$$(4) \qquad PS \approx \lambda/2 \times (\pi/2 - \text{Arcsine}(r))$$

Phase shifts can also be calculated by cross correlation or by cross spectral analysis where the phase is calculated as $\tan^{-1}$ to the ratio between the imaginary and the real part of the coherence (essentially the square of the correlation coefficient between frequency components x and y, Granger (1969)).

3.5.4 Uncertainty estimates.

Using Monte Carlo technique, we identified 95% confidence interval as LL < - 0.32 or LL > +0.32. The relationships are significant for these values if n > 9, (Seip and McNown 2015). The running average of LL is calculated over 9 successive observations (quarters in this study). We also found that a persistent LL –relations for n > 5 consecutive paired observations occurred in less than 5 % of 100 random trials, suggesting that such series would be significant at the p = 0.05 level. This result can be compared to the card shuffle dilemma: How many times should you shuffle a deck of cards? While our task is to find patterns, the shuffling card task is to destroy patterns, both are stochastic processes based on uniform random distributions. See Seip and Grøn (2017).

4. RESULTS

We present the results according to the four steps in narrowing the time windows: i) the whole series 1982 to 2008 normalized to unit standard deviation, ii) the whole series detrended and normalized, iii) time windows restricted to sections where tax policies lead the economies and lastly to iv) the sections where there also is a tax policy shock included in the time window. Since all series are cyclic, ordinary linear regression statistics will not always apply, but the regression, or β- coefficient may still express the decadal trend. However, we here report on the β- coefficients that are significant at the p = 0.05 level.

It is reasonable to assume that the multidecadal trends in GDP and the UGE, 1982-2006, are affected by many factors, whereas the decadal and shorter movements to a larger extent are affected by shocks in single variables.

We first discuss the results for the two first steps, 1 and 2, then the LL –method, and lastly the steps 3 and 4 that depend upon the LL- method.

4.1 Long, multidecadal series

We first report the results for steps 1 and 2 where the full time series 1998 to 2006 are used.

Step 1. Variables showing multidecadal trends. We applied multiple linear regression to the series shown in Figure 1a. The results are shown in time window 1 in Table 2. (GDP) and Table 3 (UGE). We examined if we would get similar results if multiple regression was applied to the strongly smoothed series in Figure 1b. For the GDP, Tp pair we got a β –coefficient of -1.60 instead of +0.58, but apart from this result, the numbers for the significant β - coefficients were similar for both GDP and UGE.

Step 2. Detrended variables showing decadal or shorter variations. The series used were shown in Figure 1c. We applied PCA to the detrended and normalized variables. We obtained six relationships between tax variables and economies. The results are shown as a loading plot in Figure 3a. For clarity in the graphs, we shortened GDP to G and UGE to U. The score plot of the PCA supports, and partially quantifies, our intuitions. Figure 3a shows that when personal and corporate taxes are increased (following positive arrows for Tp and Tc), the underground economy, U also tend to increase, but probably with a time lag, since the legends lie on lines from the origin that shows an angle between them. However, U also increases with increasing control probability effort, Cp, which is contrary to expectations. With reduced taxes (going in the opposite direction of the arrows for Tp and Tc), G increases, consistent with expectations. Increasing social security taxes, Ts, however, appears to decrease U. Economic volatility, V, is close to the line connecting U to the origin.

Figure 3 in here, PCA plots

Table 1 in here, Tax shocks

4.2. Leading – lagging, LL- relations and tax rate shocks

We compare the LL- relations with tax shocks in three Figures, each with 6 panels arranged in two columns. Each column gives key information for the LL- relations between one pair of time series. In these figures the policy variables are defined so that a peak in the policy variable is followed by a peak in the response variable, assuming that our hypotheses on cause and effect are correct. (E.g., a peak in tax reduction is followed by a peak in GDP, that is, for the tax/ GDP pairs the tax series are inverted.) LL-relations and tax shocks are shown in panels c and d and cycle times and phase shifts in panels e and f.

A fourth figure shows selected phase plots for the time series. In this figure both the policy variable and the response variables have their "natural" sign, that is, positive for taxes and control probability and positive for UGE and GDP. In the text below, time windows that are shown as phase plots are marked in bold letters.

Underground economy, UGE, and personal and corporate taxes, Figure 4. Personal taxes were leading UGE during three time windows: around 1986, from **1995 to 2000** and from 2004 to 2005, Figure 4c. Corporate taxes were leading UGE around 1985, from 1988 to 1989 and from **1996 to 1999**, and around 2005, Figure 4d. For both personal and corporate taxes there were positive tax –rate shocks (increases in tax rates) in 1992:4 and 1997:4. The tax – rate shocks in 1992:4 came as an increase in the personal and corporate tax rates, but the positive shock in personal taxes was followed by a negative shock the year after, 1993:4. Figure numbers in figures c and d refer to detailed graphs in Figure 7. Overall common cycle times for personal taxes are 13.62 ± 5.82 quarters and the phase shifts are 2.81 ± 1.48 quarters. The corresponding numbers for corporate taxes and phase shifts are 20.48 ± 13.92 quarters and 5.74 ± 4.09 quarters, Figure 4e and f. The time windows in Table 2 may be longer than the significant time windows, because the windows have been extended with observations that are almost significant. The significant time windows are reported in Supplementary material 2, Table S2- 1.

UGE and social security taxes and control probability, Figure 5. With a large negative shock in social security taxes in 1997:4 the social security tax became a leading variable to UGE from about **1997 to 1998**. (The shock occurred simultaneously with positive shocks in personal and corporate taxes, Figure 4a). The corresponding results for UGE versus tax control efforts are shown in Figure 5 right column. There are two time windows where control probability leads UGE: **1990:3 to 1993:1** and around 1997. The first period is associated with a small increase and then a small decrease in control probability. There are also short periods at the beginning and at the end of our study period where control probability leads UGE. Overall common cycle times for social security taxes are 27.37 ± 29.56 quarters and the phase shifts are 5.85 ± 6.86 quarters. The corresponding numbers for control probability are 16.78 ± 7.50 and for phase shifts 4.04 ± 2.14 quarters, Figure 5e and f.

GDP and personal and corporate taxes, Figure 6. There is a long period from **1990 to 1995** where personal taxes lead GDP. In addition there are three shorter periods: around 1987, 1998 to 1999 and 2002 to 2004. The first long period is associated with two increases in personal taxes and then a decrease. The second short period starts with an increase in personal taxes 1997:4, Figure 6c. Corporate taxes lead GDP during a period from **1995 to 1998**. The period ends with an increase in corporate taxes. One short period occurred around 1987 and another around 2000. The latter was associated with three changes in corporate taxes, Figure 6d. Overall common cycle times for personal taxes are 10.91± 3.08 quarters and for phase shift 2.37 ± 0.50 quarters. The corresponding numbers for corporate taxes are 22.31 ± 17.98 quarters and 5.96 ± 4.91 quarters, Figure 6e and f.

Figure 4, 5, 6 and 7 in here, leading – lagging relations

Phase plots. Figure 7 shows a selection of phase plots where the policy variables are plotted on the x-axes and the response variables on the y - axes. In these plots the paired time series are detrended and normalized to unit standard deviation. The number of quarters included corresponds to the number of quarters where the policy variable is leading the response variable. In addition to the trajectories for the paired time series we show regression slopes between the policy variable and the response variable for four quarters after a shock in the policy variable (dashed lines) and for the full time window (full lines). The actual β – values are reported in Table 2 (GDP) and 3 (UGE) for the significant values. Figure 7a and b for the personal and corporate taxes show that an increase in taxes causes an overall increase in UGE. However, changes in taxes set up partial cycles, so that on parts of the cycles there will be the opposite relations. A full rotation in phase space corresponds to a full cycle in the time series graph. Figures 7c and d show results for social security taxes and control probability on UGE. Increasing social security taxes decreases UGE and increasing control probability decreases UGE. Both results comply with anticipations, but results are not independently robust because the data are part of cycles. The curve “shifted 3Q” will be discussed below. Figure 7e and f show corresponding graphs for taxes versus GDP. For both personal and corporate taxes the overall result for time windows where taxes leads GDP is that increasing taxes decrease GDP. However, effects closely after tax changes give mixed results. All β- values are shown in Supplementary material 3 Tables S3-1 and S3-2.

Tax rate shocks. All tax rate shocks as well as the shock in control probability occur in the last quarter of the years, Table 1. The shocks in bold letters correspond to events where tax rate series are leading variables to the economies GDP and UGE. As an example, all three types of taxes get a shock in the last quarter of 1997 and there is also a shock in control probability.

Table 2 in here, time windows

We first examined the results of the LL- relation in a PCA loading plot to see if interactions between two or more variables are similar. Thereafter, we calculate OLR for time windows where taxes lead the economies.

PCA loading plot. From Figure 3b it is seen that the LL- relations between U and personal and corporate taxes are similar. (UTp and UTc pointing in the same direction.) It is interesting that the LL- relation for G and the average personal and corporate taxes, GDPT p+c, are either unrelated or ¼ cycle length out of phase with the LL-relations UTp and UTc. However, the LL- relations for G and social security taxes, UTs, are similar to the LL- relations GDPT p+c. The LL-relation for U and control probability, UCp, is opposite to GDPTp+c.

4.3. Short, decadal time windows

In this section we report results for step 3 and 4 where short, decadal time windows are examined.

Step 3. Policy variables lead economies. There are 23 windows where taxes or control probability are leading variables to the economies. In 14 of these windows regressions between taxes or control probability as x- variable and GDP or UGE as y-variables were significant, Tables 2 and 3, windows 3 and 4. For 10 of them there were no tax shock associated with the time windows (3 for GDP, 7 for

UGE). Results for the 5 parameters: β – coefficients, p – values, number of quarters for the regression, cycle length and phase shifts are shown as window 3 and 4 in Table 2 (GDP) and 3 (UGE). We included a tax window if either the regression over 4 quarters, over the policy leading window, or both, were significant. We found that taxes are leading GDP for 4 to 9 quarters and UGE between 9 and 25 quarters (average 13 quarters). Supplementary material 4, Table S4-1 shows regression for all time windows where taxes lead the economies.

Step 4. Policy variables lead economies with a policy shock. Following the beginning of a significant "tax- leading" period, cycles may be set up where tax rates become a leading variables to UGE or GDP. For 4 time windows a major tax shock is preceding, or close to, the beginning of a time window (1 for GDP, 3 for UGE).

If we pool the values for windows 3 and 4 we find that increasing taxes decreases GDP (β – coefficient is -1.85 on the average, Table 2). Increasing taxes increases UGE (β – coefficient is 0.74 on the average, Table 3) The cycle times for tax rate versus GDP are about 11 quarters and normally smaller than the cycle times for tax rates versus UGE. (About 17 quarters, Table 3). However, there are great variations in the data. The average phase shifts are 3 and 4 quarters respectively. The number of significant observations are 4 to 6 quarters on the average, but the period where the smoothed tax rates lead the economy may be twice or three times as long. During the period where the smoothed tax rate lead the economies (not necessarily significantly), about one cycle is completed. Supplementary material 5 shows detailed results.

Table 3 in here , Underground economy

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5 DISCUSSION

The economy acts on different time scales. Economic trends over multidecadal scales may be caused by technical or social innovations (partly dependent on tax level) and improvements in infrastructures (tax dependent). Shorter, decadal events, may be caused by tax policy changes. For the trends, ordinary least squares techniques, OLR, may be applied, but for short series, cyclic behavior may be dominant. OLR may still be applied to show the net effect of a policy action and its response, but statistical measures do not apply since the data are not close to a normal distribution.

The discussion addresses two major results. The first is the effects of narrowing the time windows for estimating tax policies on the economies. The second addresses three conjectures that are frequently discussed in the tax evasion literature. We believe that by narrowing the time windows to sections of the full time series where tax policies are leading the economies, details in the interaction between the policy variable and the economy can be found that add insights into the tax policy conjectures.

5.1 Narrowing time windows.

In this section, we first discuss relations between multidecadal trends in tax policy variables and UGE and GDP. Thereafter we discuss relations on interannual and decadal time scales when tax- rates leads the economies.

5.1.1 Long, multidecadal series

In this section we discuss step 1 and step 2.

Step 1: Trends 1982 – 2006. We calculate a regression between the trend in the 3 tax types, control probability and GDP-volatility (x –variables) and the trend in GDP, and the underground economy, UGE (y-variables). Our results showed that an increase in personal taxes increased GDP and UGE whereas an increase in corporate taxes increased GDP, but decreased UGE. However, trends in tax rate and trends in GDP over multidecadal period (25 years) may be due to several other factors than tax policies intended to modify GDP or UGE. Brosio et al. (2002) show how the use of central and local taxes are perceived in terms of confidence and trust in government, and Sanyal et al. (2000) and Barone and Mocetti (2011) in terms of efficiency. Thus, results based on aggregating taxes and GDPs across regions may be biased.

Step 2 Detrended variables 1982-2006. The results for the detrended series showed that increasing personal and corporate taxes increased GDP consistent with anticipation. Increasing personal and corporate taxes increased UGE, but probably with a long delay since there is an angle between the lines that connect the legends to the origin. (delay ≈ ¼ λ). However, it was surprising that both control probability, Cp, and economic volatility, V, were positively associated with UGE. The reason may be that in bad economic times, that is, times showing high volatility, UGE increases and tougher Cp measures are enacted, Alm (2012 p. 71 on marginal income).

There are conflicting evidence whether increasing tax rates increase tax evasion or not, and a summary is given in Ali et al. (2001). Empirical studies reported in the literature normally address long time series and they do not detrend the series. Ali et al. (2001) use annual US data from 1980 to 1995, Cebula and Feige (2012) use US data from 1960 to 2008, but examine different time windows of the data, the smallest time window being 28 years. These authors find a significant positive correlation ($p < 0.05$) between compliance and tax rate and between compliance and penalty rate, although for some results these variables have to interact with screening variables (like actual income, Ali et al. (2001), Cebula and Feige (2012). However, literature studies are rather different in their assumptions, so direct comparisons are complicated.

Since interpretations are difficult, the results on multidecadal trends are presented as a backdrop and a rationale for the selection of time windows where the probability is greater that it is tax policies that affect GDP and UGE.

5.1.2 LL- relations and shocks

The method for identifying LL –relations also identify common cycle length for the policy variable and the economy. Furthermore, it identifies phase shift between the policy variable (assumed to come first) and the economy variables.

The *cycle lengths* can be compared to the cycle lengths identified for each of the series by power spectral density, PSD. We would expect that common cycles for paired series are among the PSD cycles. The cycles we obtain for the paired tax and economy series are 11 quarters (GDP, Table 2) and 17 quarters (UGE, Table 3). The cycle lengths found for GDP and UGE with PSD were 7, 11 and 17 quarters, Figure 1d. Thus, it appears that taxes extract 11 quarters cycles from GDP and 17 quarters cycles from UGE. (Supplementary material 5 shows the original power spectral densities before log transformation.) Cycles shorter than, say, 7 time steps may be caused by uniform random movements in the two variables, Seip and Grøn (2016 supplementary information)

Phase shifts. The phase shift between series that involve UGE is found to be the average longer than those that involve GDP (4.1 quarters versus 3.2 quarters, not significantly different).

Cycle closure. On the average, time windows including UGE accommodated fewer cycles than those including GDP (0.86 versus 1.36 cycles). If a full cycle is completed, the tax shock initiates both positive and a negative movements in the taxes and accompanying responses in either GDP or UGE or both.

H1. Our first hypothesis was only partially supported. Although 10 tax policy shocks were followed by a period where the tax policy became a leading variable to the economies, there were also three cases were tax shocks had no such consequences.

The differences in cycle lengths, phase shifts, and number of cycles completed by taxes versus GDP and versus UGE may be due to the time it takes for taxes to affect the two economies. If this interpretation is correct, GDP reacts more rapidly to changes in taxes than UGE, and the interaction between taxes and GDP is more consistent, and initiate more policy decisions (one cycle corresponds to at least two tax policy decisions and two economy responses.) H2: Thus, our second hypothesis was supported. Within the time window where a tax policy were leading the economy, new tax changes were created showing that tax changes beget tax changes.

5.1.3 Leaders and followers in tax evasion" games"

We decided to define the length of the time windows as the number of quarters where the smoothed LL- series showed an overall consistent sign, accepting that noise and quarterly movements may occasionally give non-leading signatures for the tax - economy relations. About 15 % to 40 % of the time series show significant leading lagging relations and about half of them are periods where taxes are leading the economies. In a leader – follower repeated game context, the tax authorities and the people shift about equally in being leader and follower, xxx (Seip and Gron 2016).

Shocks There were a total of 13 events related to taxation where the changes could be characterized as "tax shocks", Table 1. There were 3 events where control probability and GDP volatility had shock characteristics. In addition, there were 1 event where UGE showed shock. The UGE shock occurred simultaneously with a positive shock in corporate taxes. To our knowledge tax shocks have not been identified as outliers compared to a Gaussian distribution before.

Several authors suggest that the effect of rapid changes in tax levels has typical time horizons of 4 to 6 years, e.g., Mountford and Uhlig (2009)**.** We found that the time horizon varied between 2 and 6 years with an average of 13 quarters. Thus, the LL-method identifies potential causal relations between tax policy changes and the economies of similar lengths as found in the literature.

5.1.4 Short, decadal time windows

In this section we discuss step 3 and step 4.

Step 3. Policy variables lead economies.

The result for time windows where taxes were leading variables to the economies, GDP and UGE showed that increasing corporate and social security taxes decreased GDP and increasing personal and social security taxes increased UGE (Table 2, window 3). However, increasing corporate taxes and control probability decreased UGE, (Table 3, and window 3.) Thus, the results for UGE are ambiguous with respect to the effects of tax policies.

Step 4. Policy variables lead economies with a policy shock.

To support the interpretation that taxes have an effect on the economy, we examine the relations during time windows where taxes were leading the economies and also associated with tax shocks. The OLR shows that a positive tax shock in social security taxes would decrease GDP, (Table 2, window 4). However, the observed shock occurred in 1997:4, was negative, and increased GDP over 9 quarters, (Figure 1c, start of shaded period.) Increases in personal and corporate taxes and control probability all increased UGE.

An important question is whether the net result of a cyclic movement between taxes and economies is so that an increase in taxes decrease GDP and increase UGE over time. Using long series (≈ 100 quarters) may give more strength to a result in terms of statistical measures, but will also give a larger potential role for confounding factors. For the full series, the results for GDP contrasted with our hypothesis that increasing taxes would decrease GDP.

For UGE the results changed with tax types (Tables 2 and 3, window 1). Detrending the time series and thus emphasizing decadal movements showed that increasing taxes decreased GDP and increased UGE. However, the results are qualitative (window 2). Using only sections of time series where tax policy variables lead the economies, increase the probability that the policy factors affect the economy. This restriction, and the added restriction that the time window should be associated with tax shocks, showed that GDP generally decreased with increasing taxes and UGE increased with increasing taxes (Tables 2 and 3, averages windows 3 and 4).

H3. Thus, our third hypothesis was supported; increasing taxes decreased GDP and increased UGE. However, contrary to our expectation, we did not find any time window where increasing personal taxes would decrease GDP. Time windows associated with tax shocks showed that increases in personal and corporate taxes increased UGE. In the time windows not preceded by shocks, the results were ambiguous. In particular, control probability both increased and decreased UGE. This issue will be discussed in the section on the third tax evasion conjecture.

5.1.5 Endogenous factors.

The period studied, 1982 to 2006 is short, and we only register a total of 21 time windows where tax rate changes are leading variables to changes in GDP or UGE. The first half of the 1990s showed high political instability whereas the period 1996 to 2000 gave a more stable framework for tax collection. However, in 1997:4 there were tax shocks in all tax variables. Personal and corporate taxes were increased whereas the social security tax and control probability were reduced. The events in 1997:4 may be due to the reorganization of the fiscal authority that started in 1997. See e.g., Chiarini et al. (2013) for a summary of fiscal policies in Italy 1980 to 2006. These authors also found a break in 1998:1 (and two breaks in 1983:4). H4. Our fourth hypothesis was partly supported. For some tax shocks that were followed by a leading role for tax rates, there were political events that could explain changes in tax policies, e.g., 1997. However, we believe that also other major tax changes could be associated with policy situation, but this will be outside the scope of the present article.

5.2. Three tax conjectures.

We comment on three tax current conjectures that relate to tax rate changes and UGE: the multiple equilibrium conjecture, the UGE delayed response conjecture and the Yitzhaiki tax evasion puzzle, (Yitzhaki 1974)

The multiple equilibrium conjecture states that UGE may have multiple stable equilibria corresponding to different tax levels and enforcement regimes according to Acemoglu and Jackson (2015) and Varvarigos (2017) These studies explain this by an increasing amount of tax-evading individuals. We transfer this conjecture into the proposition that a tax shock may cause an abrupt change in the size of UGE. In the theory the changes in tax rates may be "tiny" (Acemoglu and Jackson 2017) and the change in UGE should be stable. We find that a there is a relation between tax shocks and shocks in UGE, but UGE do not become stable indicating that there is not a second stable equilibrium. This is in agreement with Chiarini et al. (2013) that suggest that value added tax evasion do not start a "vicious" circle in Italy.

Chiarini et al. (2013) suggest that there exists a long – run strategy for taxpayers. The present results suggest that the tax policies rather can be seen as a repeated leader - follower game where the tax policy makers and the taxpayers change in being leaders and followers with 10 to 30 quarters cycle times.

Delayed response conjecture states that it will take time for tax audits to have an effect on tax compliance. In addition Kogler et al. (2016), in a game theory study, found that delayed response results in higher tax compliance. In our empirical study, we found that a shock increase in corporate taxes in 2005:4 caused a shock decrease in UGE in the same quarter. For Cp the average phase shift relative to UGE is close to λ/4, suggesting that the response to Cp is delayed. Figure 7d also suggests a long delay. Supplementary material S4, Table 4, shows delays.

The Yitzhaiki tax evasion conjecture states that UGE may increase with increasing marginal tax rate, in contrast to intuition, Yitzhaki (1974) and Piolatto and Rablen (2017). The authors state that the puzzle reverses with tax audit probability. Since both Cp and UGE are normalized to unit standard deviation (they are measured in different units), control probability, Cp, and UGE may show a section of circular pattern in phase space (Cp on the x-axis and UGE on the y-axis). The choice of time window for observing the two variables is thus crucial. Figure 7d. Furthermore, the size of the phase shift, PS, between Cp and UGE is important. A phase shift greater than a quarter of a cycle length, λ/4 will cause a 45^{o} β – coefficient to turn into a - 45^{o} β – coefficient. In our analysis the ratio PS/λ between UGE and personal taxes varies between 0.08 and 0.35 and for UGE and corporate taxes between 0.15

and 0.42. Thus, since the largest value is greater than 0.25, we obtain both positive and negative associations between taxes and UGE for combinations of taxes and UGE. Long phase shifts for the reaction to Cp may be due to slow growth, or decline, of tax evading individuals (Varvarigos 2017 p. 977)

H5. Our identification of cycle times, phase relations, the ratio between them, and the phase plot representation of time series sections give some insights into the tax conjectures discussed. In particular, the Yitzhaki puzzle (assuming that the taxpayer has an absolute risk aversion which decreases with income), is transformed into a question of delayed response to tax evasion control efforts. Thus, our fifth hypothesis was supported.

Cross correlation. In economy time series representing a candidate cause and a response are often shifted relative to each other to obtain better statistics, e.g. Enders (2010). In the present case, if control probability is shifted forward with 3 quarters, corresponding to the calculated phase shifts between the two series from 1990:3 to 1993:1, then the banana shaped curve in Figure 7d represents the phase plot. The β –coefficient and explained variance then changes from –β = -0.77, p = 0.367 to β = -2.01, p= 0.001, However, shifting time series to compensate for delayed effects is more meaningful if the series are stationary and several cycles can be included.

Since the tax series and the economies are normalized to unit standard deviation, we can calculate a multiplication factor directly for the effects of tax changes on the economies. We find that a 1% increase in corporate tax reduces GDP with 0.75 % and increases UGE with 1.49%. There is no effect of personal taxes on GDP, but an increase of 1 % in personal taxes increases UGE with 1.08 %.

6. CONCLUSION

There are several ways in which tax changes can impact the economy, and both positive and negative effects may be envisaged. Empirical result applying ordinary linear regressions to observed series for tax policies and economic responses show ambiguous results. The present study strengthen the search for a direct test on the effects based on empirical data. It does so by i) removing multi decadal trends, ii) restricting the study to time windows where tax changes are leading the economies, iii) identify subsets of the time windows where tax shocks are closely associated with a leading relation for tax series, iv) examine both GDP and the underground economy, UGE. There were complete cycles where taxes were leading GDP, suggesting that tax increases reduced GDP and vice versa. The results for UGE showed that increased personal and corporate taxes increased UGE significantly. Results for social security taxes and control probability were ambiguous. Tax policies were leading GDP and UGE for 2 to 6 years corresponding with literature values for the effects of tax policy variables.

We added insights into three tax related conjectures. i) We found no evidence for multiple equilibrium states in the underground economy, ii) we found that there was a delayed response to tax evasion control probability and iii) this delayed response could be responsible for the unanticipated finding that increased control probability increased UGE, the Yitzhaki tax evasion puzzle.

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Appendix

Tables and Figures

Table 1 Tax and economy shocks.

Numbers in parentheses show tax shock size relative to normalized values. Numbers in bold show tax shocks that are followed by a time window where the tax leads the economy variable.

Time window	Shock type					
	Personal tax	Corporate tax	Social security tax	Tax control probability	GDP volatility	UGE
1	**1989:4 (+3.2)**	1991:4 (-2.8)	**1989:4(2.9)**	**1990:4 (1.56)**	**1988:1(2.33)**	
2	**1992:4 (+-3,6)**	1992: 4 (+3.3),		**1991:4 (-1.38)**	**1999:4 (2.54)**	
3	**1993: 4 (-3.7)**				**2000:1 (2.58)**	
4	**1997: 4 (+3.8)**	**1997:4 (+3.2)**	**1997:4 (-7.5).**	**1997:4 (-1.38)**		
		1999:4(+2.5)				
		2000:4 (+4.1).				
		2001:4 (-2.5)				
		2005:4 (2.4)				2005:4 (-3.5)

Table 2 GDP. Narrowing time windows for the effects of tax policy variables. Time windows 3 and 4 include only significant regressions at the 0.05 level. Tp = personal taxes, Tc = corporate taxes, Tss = social security taxes, CP = control probability. Volatility is volatility in GDP, with high volatility signifying bad economic times.

Time window	Variable	β –coefficient	p- values	# quarters	Cycle length quarters	Phase shift quarters
1. 1982-2008 Normalized multidecadal trends, **MLR**	Tp	0.58	<0.001	92	12, 14, 17	NA
	Tc	0.31	0.003			
	Tss	0.03	0.42			
	Cp	-0.05	0.14			
	Volatility	-0.04	0.29			
2. 1982-2008 detrended decadal trends, **PCA**	Tp	- (minus)	NA	NA	NA	NA
	Tc	- (minus)	NA	NA	NA	NA
3. Tax policy leading GDP	87-89 Tc	-0.75	<0.05	4	36.20 (1)	11.53 (1)
	82-85 Tss	-1.70	<0.001	4	8.96	2.44
	02-06Tss	-7.95	<0.05	4	9.31	2.52
4.Tax policy leading GDP and tax shock	96-98 Tss	-0.23	<0.05	9	12.5	3.87
Average W3 taxes p and c		-3.47± 3.91	0.03±0.03	4±0	9.14±0.25	2.48±0.06
AverageW 4 taxes p and c		-0.23	<0.05	9	12.5	3.87

(1) Treated as an outlier an exempted

Table 3 Underground economy. Narrowing time windows for the effects of tax policy variables. Time windows 3 and 4 include only significant regressions at the 0.05 level. Tp = personal taxes, Tc = corporate taxes, Tss = social security taxes, CP = control probability. Volatility is volatility in GDP, with high volatility signifying bad economic times.

Time window	Variable	β –coefficient	p- values	# quarters	Cycle length quarters	Phase shift quarters
1.1982-2008 normalized multidecadal trends, **MLR**	Tp	1.24	<0.001	92	12,14,17	
	Tc	-0.21	0.004			
	Tss	-0.21	<0.001			
	Cp	-0.02	0.50			
	Volatility	-0.04	0.09			
2. 1982-2008 detrended decadal trends, **PCA**	Cp	+ (plus)	NA	NA	NA	NA
	Volatility	+ (plus)	NA	NA	NA	NA
	Tss	- (minus)	NA	NA	NA	NA
3. Tax policy leading UGE	85-87 Tp	0.45	<0.05	9n	21.31	4.10
	04-06 Tp	1.92	<0.001	4	16.24	4.41
	83-86 Tc	-0.92	<0.001	10	42.49 (1)	14.09 (1)
	88-90 Tc	-0.66	<0.05	10	9.52	3.17
	00-02 Tss	4.74	<0.05	9	17.90	2.69
	83-86 Cp	-2.00	<0.001	12	24.42	6.05
	88-90 Cp	1.30	<0.05	10	10.60	2.41
4. Tax policy leading UGE and tax shocks	95-01 Tp	1.08	<0.001	25	16.21	3.06
	96-99 Tc	1.49	<0.001	13	20.36	5.66
	96-99 Cp	0.83	<0.001	13	26.19	6.56
Average W3 taxes p and c		0.20 ± 1.29	0.03±0.03	7±5.20	15.69±5.91	3.89±0.65
Average W4 taxes p and c		1.29±0.29	0.001±0.0	19±8.49	18.29±2.93	4.36±1.84

(1) Treated as an outlier and exempted

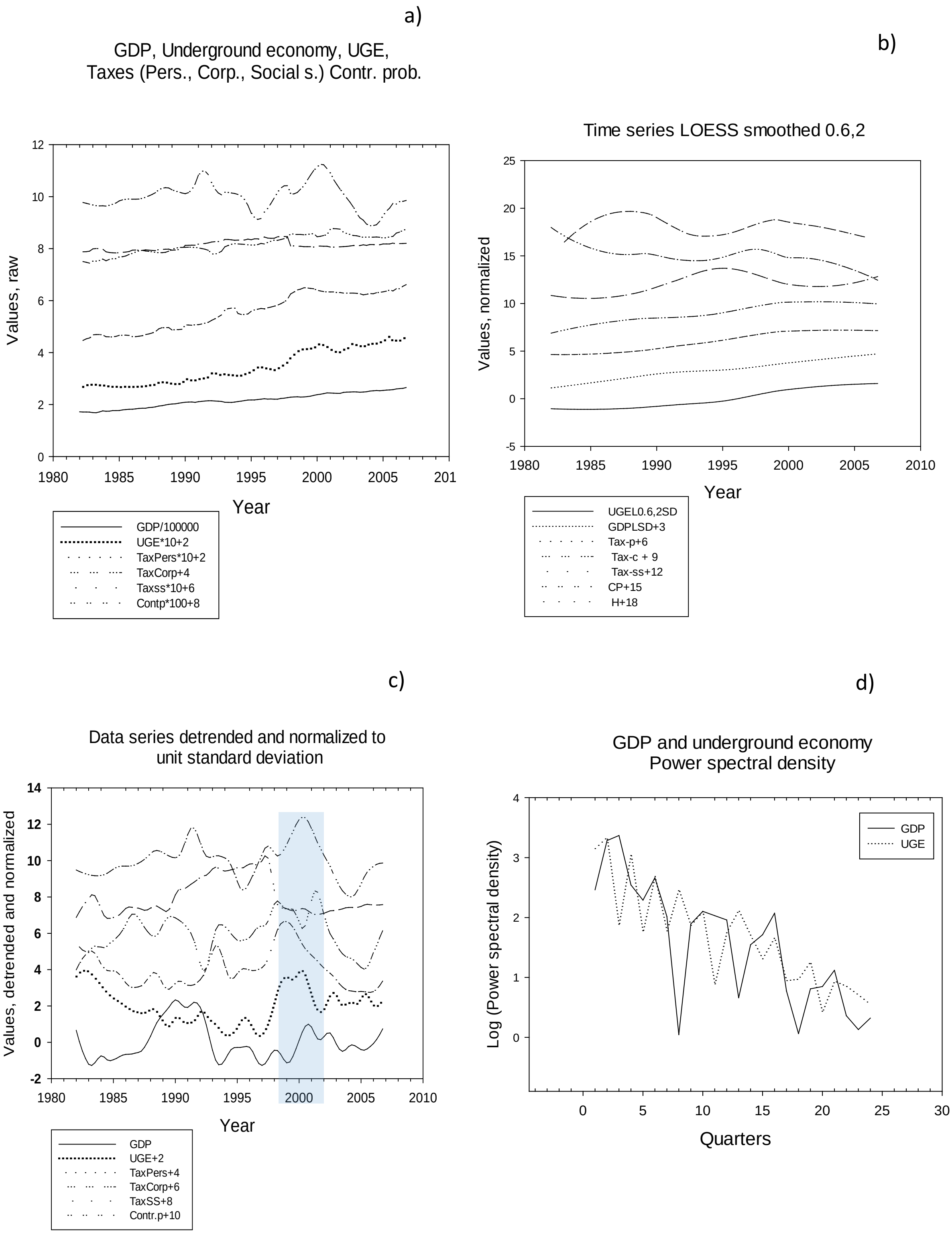


Figure 1 Time series used in the present study. a) Raw time series normalized and shifted vertically. b). Strongly LOESS smoothed time series (L0.6, 2), normalized and shifted vertically. c) Series detrended and normalized to unit standard deviation. The colored rectangle outline portions of the time series that starts with major tax shocks in both personal and corporate taxes in 1997:4 d) Power spectral density for GDP and the underground economy, UGE. The series have common cycles at 7, 11 and 17 quarters. GDP = gross domestic product, UGE = underground economy, TaxPers = Personal taxes, Tax Corp = corporate taxes, Tax ss = social security taxes, Contpr = control probability.

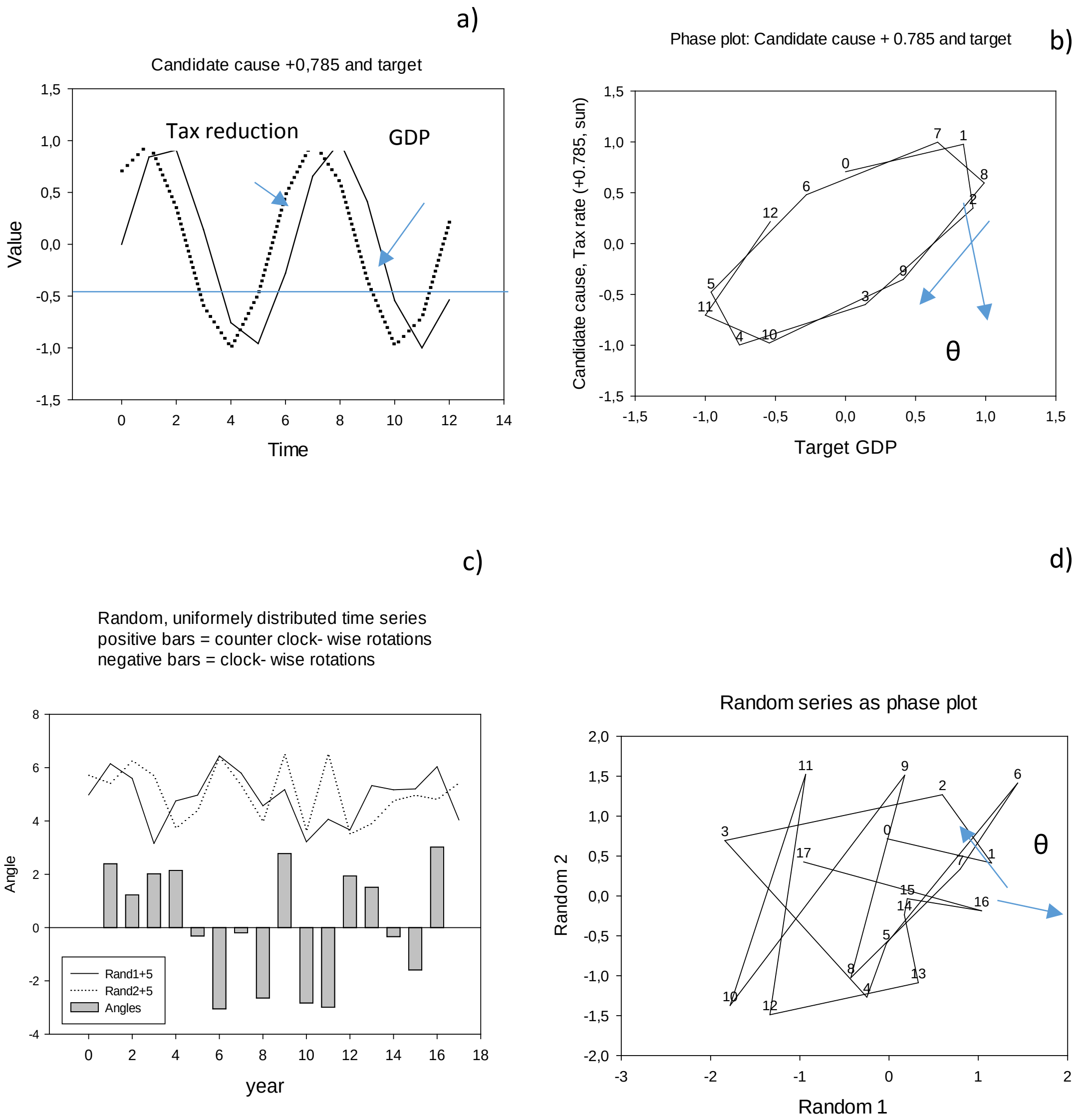


Figure 2. Relation between time series and phase plot. a) The candidate cause, the tax reductions, peaks before, and close to the target, GDP. b) Phase plot for Tax rate and GDP (target, GDP, on x – axis); c) Two uniformly random time series (upper series); bars (lower series) showing the angles between consecutive trajectories. d) Phase plot for the two random time series in c. An angle θ between trajectory 0-1 and 1-2 is shown. The Figure is redrawn after Seip and Grøn (2017)

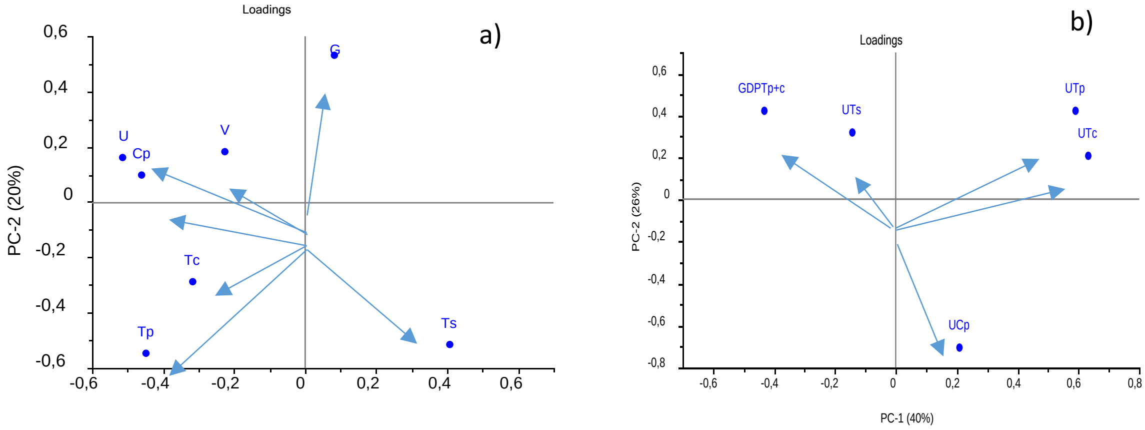


Figure 3 Principal component analysis, PCA. Loading plots. a) Time series linearly detrended and normalized to unit standard deviation; b) LL- relations. U = Underground economy, GDP = gross domestic product, T_P, T_C and T_S are personal, corporate and social security taxes respectively, Cp is tax evasion control probability. T p+c is average personal and corporate taxes*, V* is volatility, high volatility, bad economy

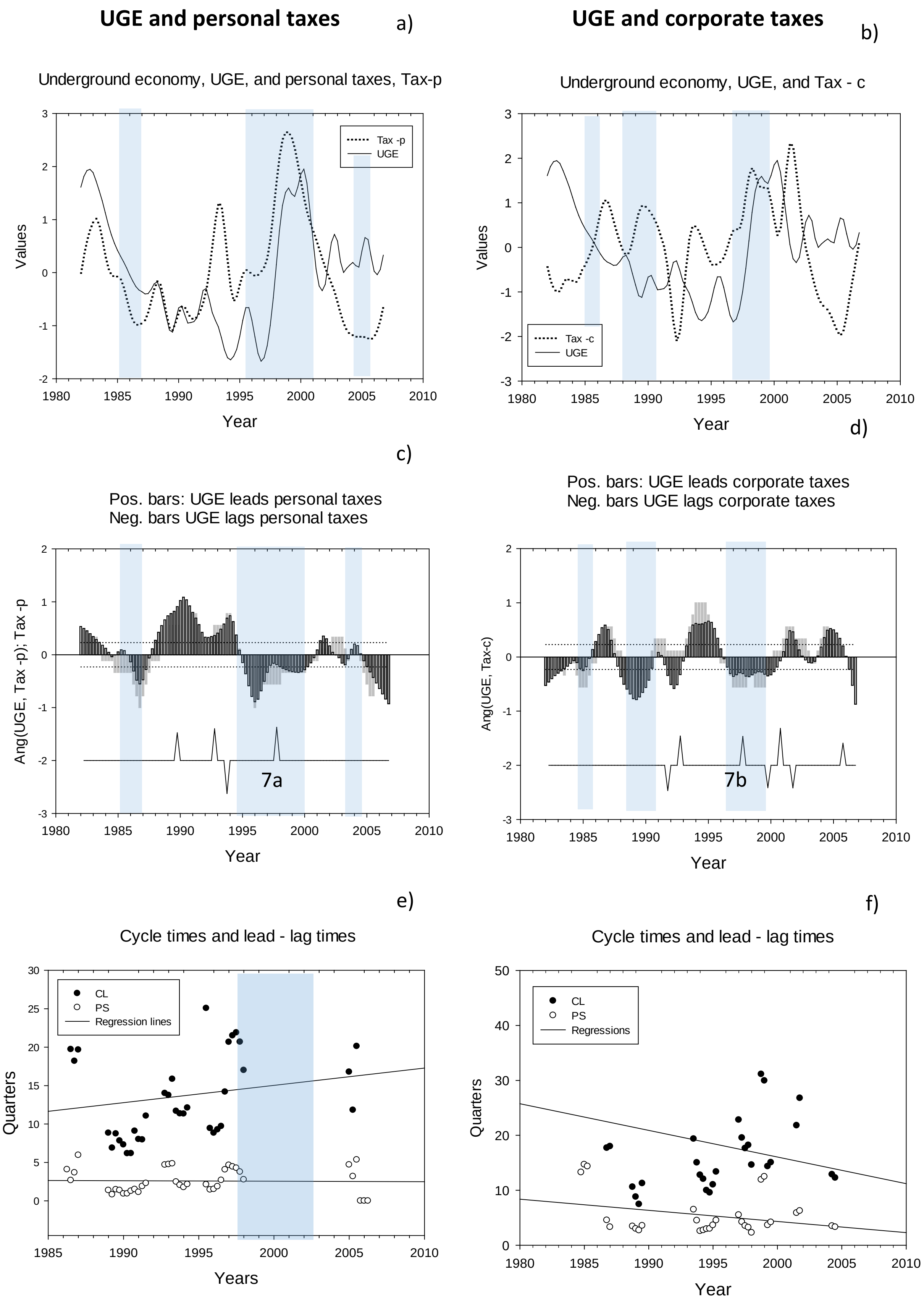


Figure 4. Leading lagging relations between the underground economy, UGE and personal and corporate taxes. a) Personal taxes and underground economy, UGE. Black dots indicate common cycle

lengths for the paired variables. b) Corporate taxes and underground economy, UGE. c) Leading –lagging, LL- relations between UGE and Tax –p. Lower line shows shocks in personal taxes. d) Leading – lagging, LL- relations between UGE and Tax – c. Lower line shows shocks in corporate taxes. e) Cycle times and lead – lag times between UGE and tax –p. Saw -tooth shaped line counts time steps until a closed circle is completed in the phase plot for UGE and tax –p. f). Cycle times and lead – lag times between UGE and control probability. Saw -tooth shaped line counts time steps until a closed circle is completed in the phase plot for UGE and tax -c.

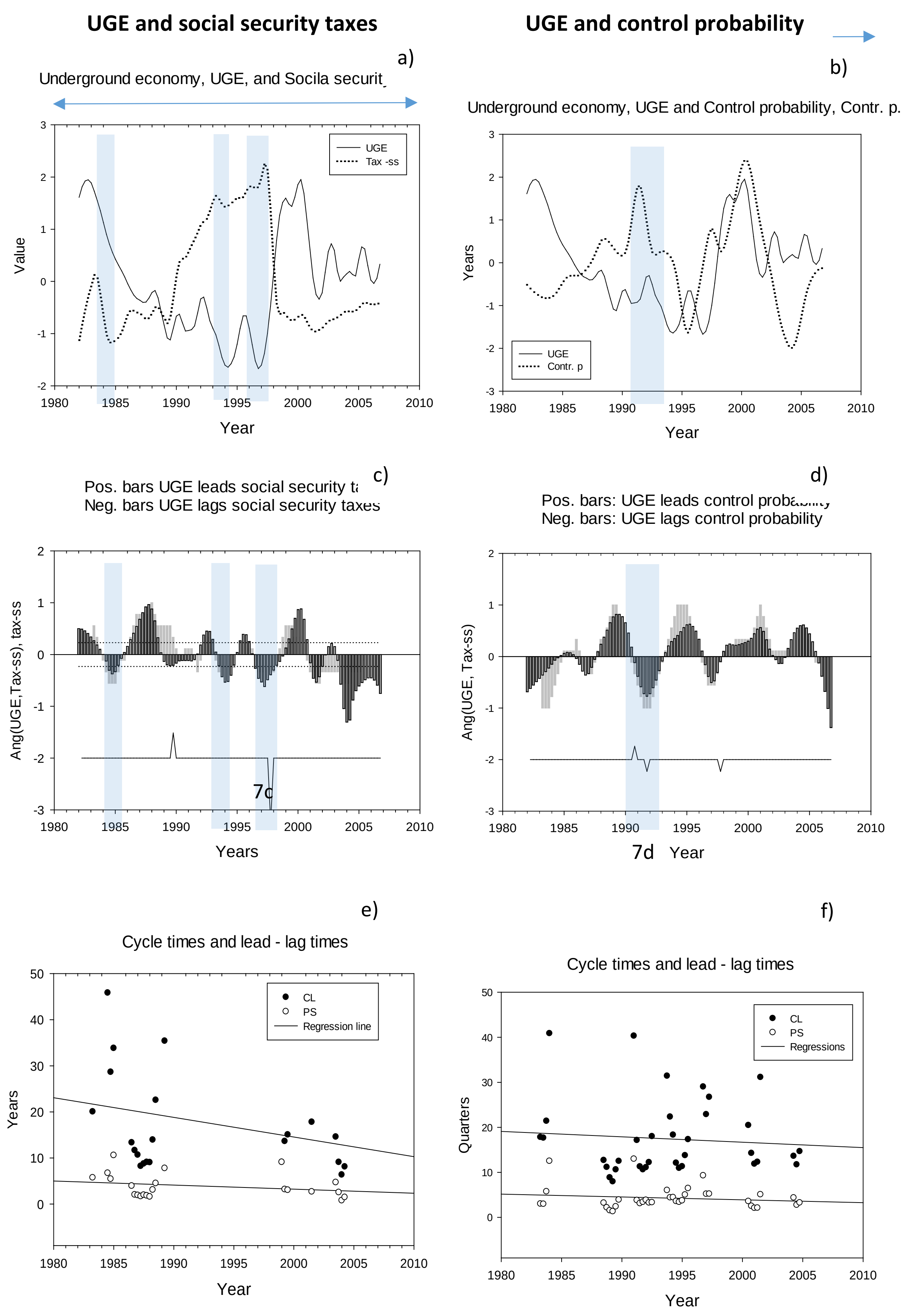


Figure 5 Leading lagging relations between the underground economy, UGE social security taxes and control probability. a) Social security taxes and underground economy, UGE. b) Control probability and underground economy, UGE. c) Leading –lagging, LL- relations between UGE and Tax –ss. Lower

line shows shocks in Social security taxes. d) Leading –lagging, LL- relations between UGE and control probability. Lower line shows shocks in control probability. e) Cycle times and lead – lag times between UGE and tax -ss. Saw -tooth shaped line counts time steps until a closed circle is completed in the phase plot for UGE and tax –ss. f). Cycle times and lead – lag times between UGE and control probability. Saw -tooth shaped line counts time steps until a closed circle is completed in the phase plot for UGE and control probability.

Fig 6

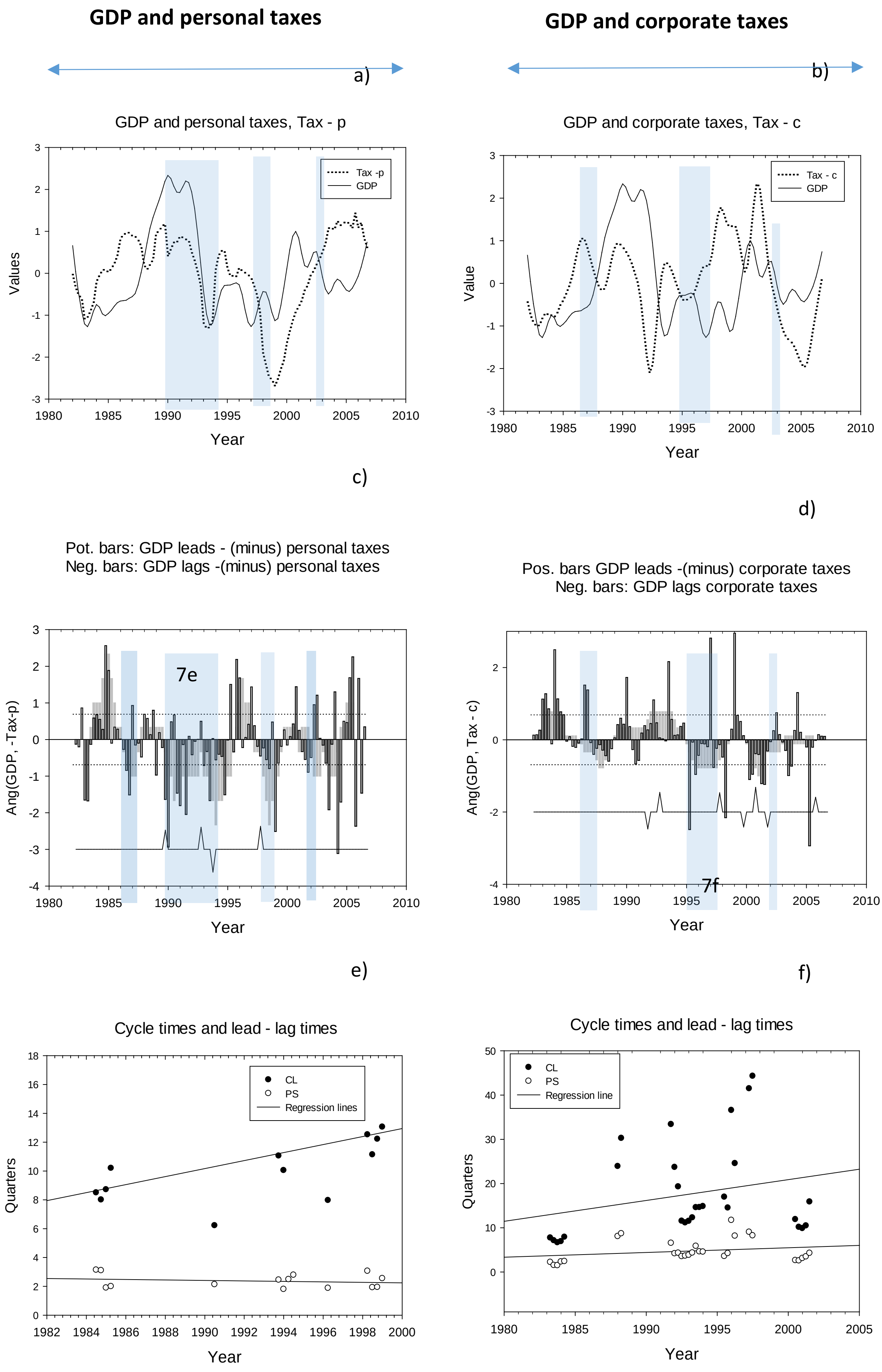
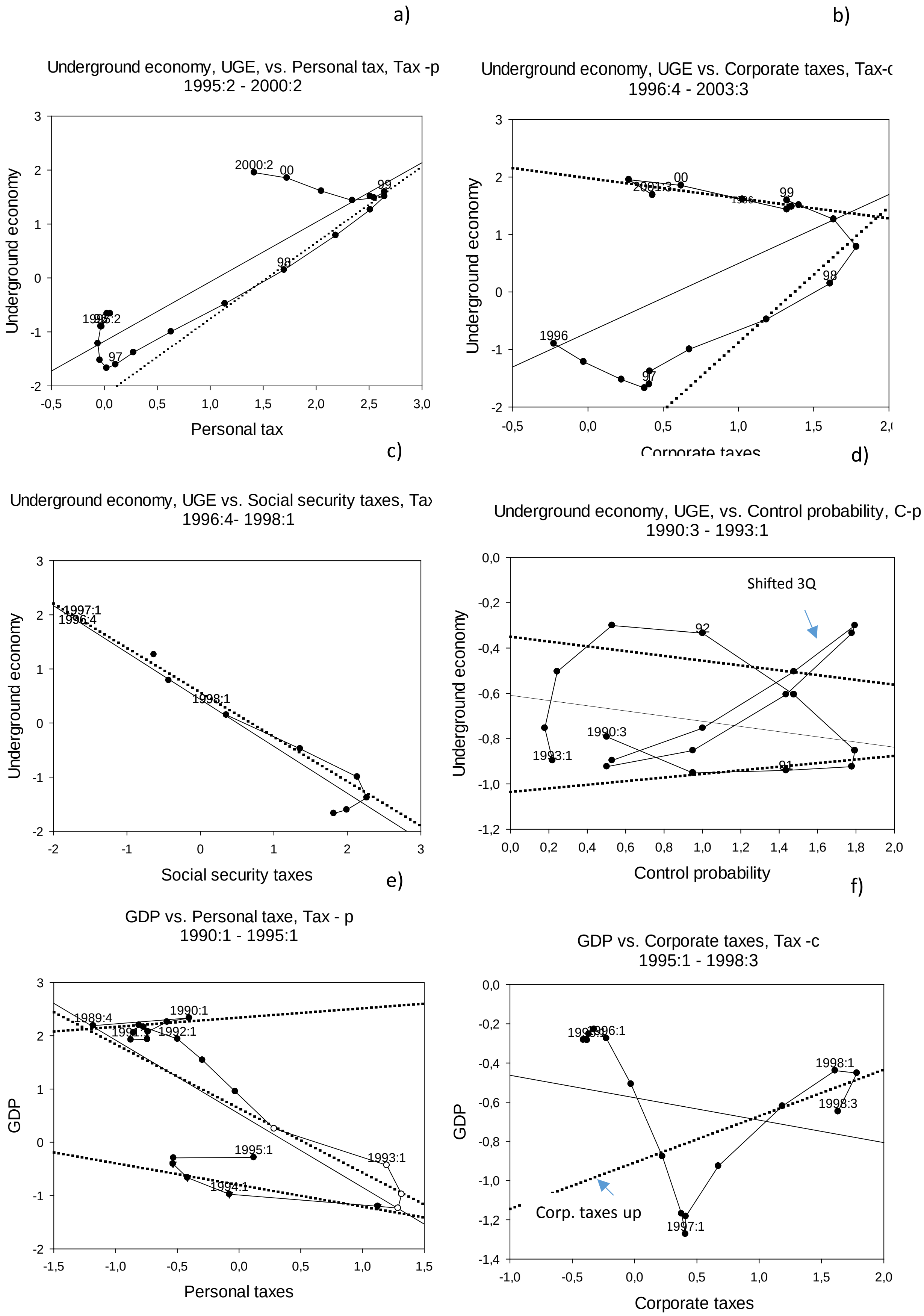

GDP and personal taxes
GDP and corporate taxes
a)
b)
GDP and personal taxes, Tax - p
Tax -p
GDP
Values
Year
GDP and corporate taxes, Tax - c
Tax - c
GDP
Value
Year
c)
d)
Pot. bars: GDP leads - (minus) personal taxes
Neg. bars: GDP lags -(minus) personal taxes
7e
Ang(GDP, -Tax-p)
Year
Pos. bars GDP leads -(minus) corporate taxes
Neg. bars: GDP lags corporate taxes
7f
Ang(GDP, Tax - c)
Year
e)
f)
Cycle times and lead - lag times
CL
PS
Regression lines
Quarters
Year
Cycle times and lead - lag times
CL
PS
Regression line
Quarters
Year

Figure 6 Leading lagging relations between the gross domestic product, GDP, and personal and corporate taxes. a) Personal taxes and gross domestic product, GDP Black dots as in Figure 5.. b) Corporate taxes and GDP. c) Leading –lagging, LL- relations between GDP and Tax –p. Lower line shows shocks in personal taxes. d) Leading –lagging, LL- relations between GDP and Tax –c. Lower line shows shocks in corporate taxes. e) Cycle times and lead – lag times between GDP and tax –p. Saw -tooth shaped line counts time steps until a closed circle is completed in the phase plot for GDP and tax –p. f) Cycle times and lead – lag times between GDP and tax -c. Saw -tooth shaped line counts time steps until a closed circle is completed in the phase plot for GDP and tax -c.

Phase plots



Figı

sponse variable on the y- axis. a) Underground economy, UGE, versus personal taxes, Tax – p; b) UGE versus Corporate taxes, C – p; c) UGE versus Social security taxes, Tax –ss. d) UGE versus Control probability, C –p. The curve designated “shifted 3Q” shows the phase plot when Tax-c is shifted 3 Q forward. . e) GDP versus Personal taxes, Tax – p. f) GDP versus Corporate taxes, Tax –c.

Supplementary material 1: Identifying tax shocks.

Tax changes have been normalized to unit standard deviation. We identify tax shocks by finding years that corresponds to values at the tails of the distribution.

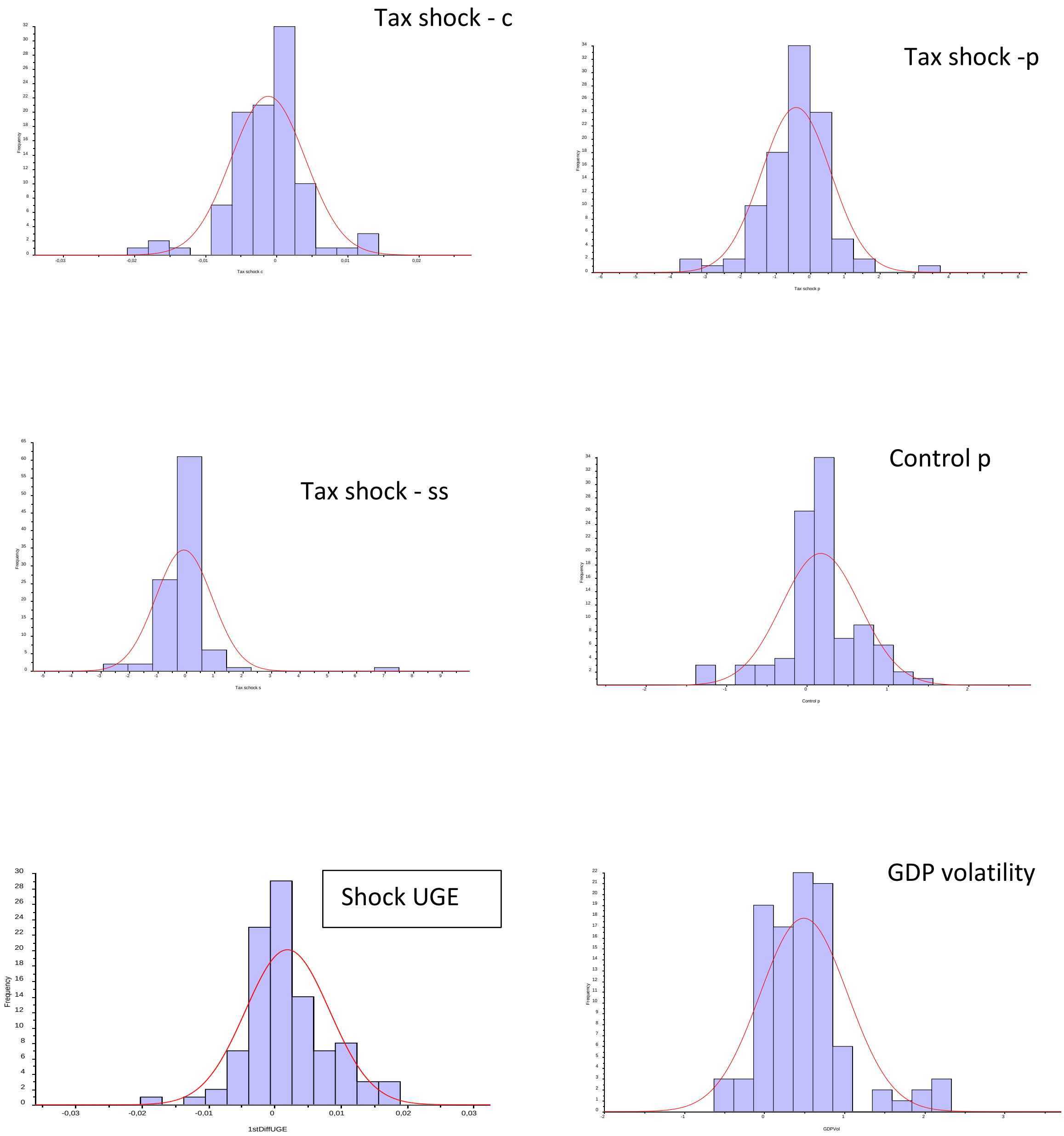


Figure S1-1 Histograms for tax- shocks and GDP volatility

Supplementary material 2. Time windows where tax changes strictly lead UGE or GDP.

Table S2-1 Significant time windows where taxes lead economies.

Significant time windows have LL –strength < 0.32. Bold numbers show dates where tax shock occurred within 4 quarters of the date.

Economy	Time window	Tax type							
Under ground economy, UGE		Personal		Corporate		Social security		Control	
		from	to	from	to	from	to	From	to
	1	1986:2	1987:2	1983:4	1986:1	1984:3	1985:1	1983:2	1984:2
	2	**1995:3**	**1998:1**	1988:4	1989:3	2001:3	2001:4	**1991:1**	**1992:3**
	3	2004:1	2005:3	**1997:1**	**1998:1**	2003:2	2004:2	**1996:4**	**1997:2**
				1998:4	1999:1				
Gross domestic product, GDP	1	**1990:3**	**1990:3**	1987:3	1988:2	1983:2	1984:3		
	2	**1993:4**	**1994:3**	**1995:3**	**1997:4**	**1997:1**	**1998:1**		
	3	1998:2	1999:1	2000:3	2001:3	2000:4	2001:2		
	4					2003:2	2005:2		
	5								

Supplementary information 3 Time windows where taxes lead economies

Table S3-1 Time windows where taxes lead economies. B – values, that is the regression coefficient between x (taxes) and economy

Bold numbers show dates where tax shock occurred within 4 quarters of the date. In this table we have allowed the time windows to be interrupted or extended by sections where there are one or two observations where taxes do not lead the economies. Star show significant regressions * = $p < 0.05$, ** = $p < 0.01$; *** = $p < 0.001$.

Economy	Tax- type									
Gross domestic product	Personal					Corporate				
	From	To	β, 1 yr	β, long	n	From	top	β, 1 yr	β -long	n
	1989:3	**1991:3**	0.47	0.47	10	1987:1	1989:1	-0.75*	-1.05	9
	1993:1	**1995:3**	-0.18	-0.39	11	**1995:1**	**1998:3**	0.68	-0.11	15
	1997:3	**2000:2**	0.31	-0.28	12	**2001:1**	**2002:1**	-0.10	-0.04	7
	2003:1	2004:3	0.66	0.28	15					
Average significant			none	none				-0.75	none	
Underground economy	1985:4	1987:4	0.70	0.45*	9	1983:4	1986:1	-2.06	-0.92***	10
	1995:1	**2001:1**	2.08***	1.08***	25	1988:1	1990:2	-1.25***	-0.66*	10
	2004:2	2006:3	1.92***	-1.10	10	**1996:1**	**1999:1**	-1.28***	1.49***	13
Average significant			2.01± 0.13	0.77± 0.46				-1.25± 0.02	-0.03± 1,32	

Table S3-1 continued

Economy	Tax- type									
Gross domestic product, GDP	Social security					Tax control probability				
	from	to	β, 1 yr	β, long	n	From	top	β, 1 yr	β, long	n
	1982:2	1985:1	-1.7***	-0.26	12					
	1996:3	**1998:3**	-0.41	-0.23*	9					
	1999:4	2001:4	10.68	0.27	9					
	2002:4	2006:2	-7.95*	-0.34	15					
Average significant			-4.83± 4.42	0.23						
Underground economy	1984:1	1985:2	0.98	1.20	6	1983:4	1986:1	-4.16	-2.0***	10
	2000:4	2002:3	7.10*	4.74*	9	1988:1	1990:2	-0.86	1.30*	10
	2003:2	2004:4	-0.32	0.00*	7	**1996:1**	**1999:1**	-0.70*	0.83***	13
Average significant			7.10	4.74				-0.70	0.04± 1.79	

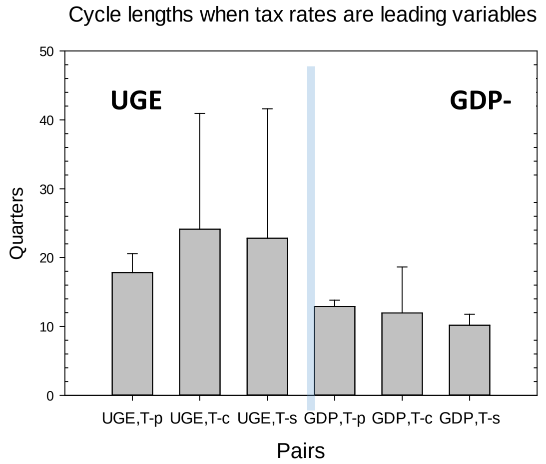
Table S3-2. Cycle length and phase shifts for control probability, Cp, and the Underground economy, UGE, where Cp leads UGE . From Table 3 in main text

Time window	Cycle time	Phase shift	Cycle time /4
83-86	24.42	6.05	6.11
88-90	10.60	2.41	2.65
96-99	20.36	5.66	5.09

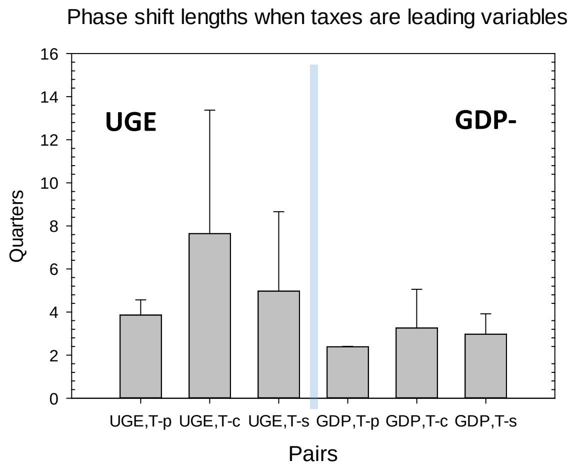
Supplementary material 4 Cycle lengths, phase shifts, number of observations and cycle closure

Following the beginning of a significant “tax- leading” period, cycles may be set up where tax rates become a leading variables to in UGE or GDP. Table 2 show 23 such windows. For 10 time windows a major tax shock is preceding, or close to, the beginning of a time window. Figure S6a show that the cycle times for tax rate versus UGE are about 20 quarters and normally greater than the cycle times for tax rates versus GDP. (About 12 quarters). However, there are great variations in the data. The average phase shifts are 2 to 8 quarters, Figure S6b. The number of significant observations are 4 to 6 quarters on the average, but the period where the smoothed tax rates lead the economy may be twice or three times as long, Figure S6c. During the period where the smoothed tax rate leads the economies (not necessarily significantly), about one cycle is completed, Figure S&d.

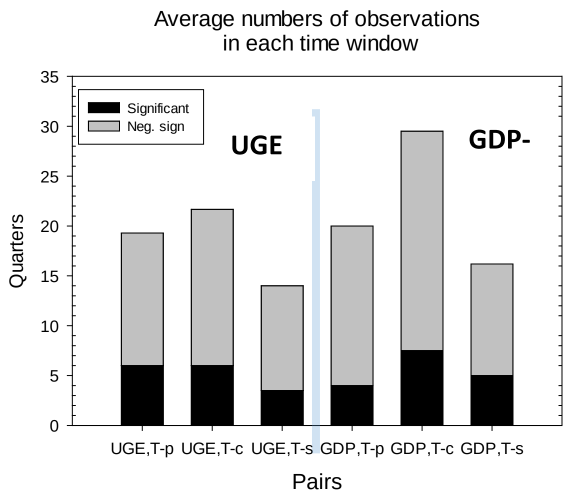
a)



b)



c)



d)

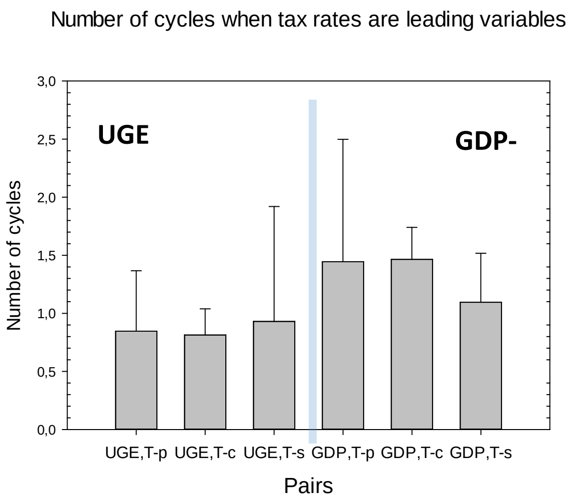


Figure S4 -1 Characteristics of significant time windows. a) Cycle lengths; b) phase shift between tax rates and economy; c) number of observations during significant time windows; d) number of cycles that are completed during consistent LL- relations around a significant time window. UGE = Underground economy, GDP = gross domestic product, T-p = personal tax, T-c = corporate tax, T-s = social security tax.

Common cycle lengths and phase shifts for the whole detrended time series 1982 - 2006 when cycle lengths can be identied, that is when one of the paired series are leading the other, typically 50 % of the time. Data From main text

GDP

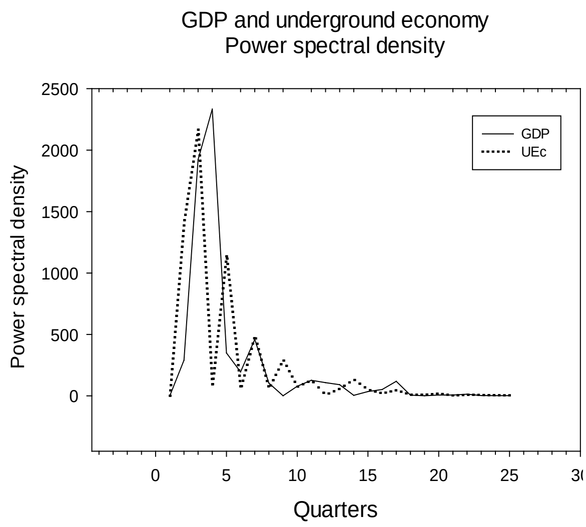
Tax type	Cycle length	PS
Tp	10,91	3,08
Tc	22,31	5,96
Average	**16,61**	**4,52**
	8,06	2,04

UGE

Tax type	Cycle length	PS
Tp	13,62	2,81
Tc	20,48	5,74
Tss	27,5,85	5,85
	17,05	**4,8**
	4,85	1,72

Supplementary material 5: Power spectral density for GDP, UGE, taxes and control probability

a)



b)

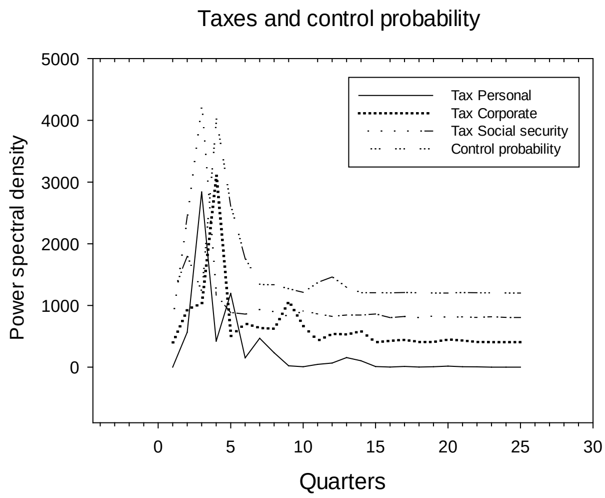


Figure 2 Time series and power spectral density. A) Time series , raw, b) Time series detrended and normalized to unit standard deviation; c) power spectral density for GDP and Underground economy; d) Power spectral density for Taxes and control probability

c)

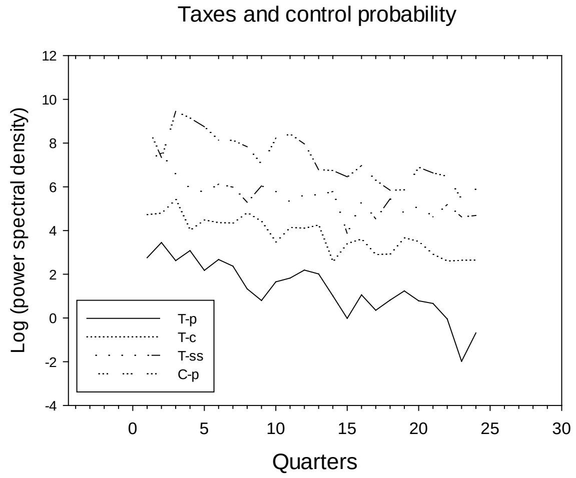


Figure S5-1. Power spectral densities. a) GDP and underground economy, UGE; b) PSD for Taxes and control probability; c) Log Power spectral density for tax variables. The series have common cycles 12 to 14 quarters and at 17 quarters. GDP = gross domestic product, UGE = underground economy, Tax-Pers = Personal taxes, Tax Corp = corporate taxes, Tax ss = social security taxes, Contpr = control probability

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