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Abstract

This paper investigates how tax revenue elasticities develop with respect to their tax base and analyses the specific impact of the business cycle. The main novelty of the paper is to use revenue data net of discretionary tax measures. The latter come from a new database, filled by Member States and managed by the European Commission (DG ECFIN). Based on an EU country panel for the period 2001-13, we estimate short-term and long-term revenue elasticities for consumption taxes, social security contributions, personal income taxes and corporate income taxes, using a wide range of specifications. The estimated revenue-to-base elasticities are broadly in line with the results found in previous research, although the robustness of the estimates varies across tax categories. Then, we add different indicators of the business cycle to test its specific influence on the short-term dynamics of revenue-to-base elasticities. This confirms the existence of a specific impact of the business cycle on short-term revenue elasticities – beyond the direct effect on the tax base – for all revenue categories, except for consumption taxes. Corporate income taxes appear to be the most cyclically-dependent tax category, followed by personal income taxes, for which estimation results turn out particularly robust.

JEL Classification: E32, H2, H3, H6.

Keywords: fiscal policy, government budget, budget balance, revenue elasticity, cyclical adjustment, discretionary tax measures, short-term developments of revenue elasticities: insights from an EU country panel, Mourre, Princen.

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1. INTRODUCTION

The current crisis revealed that revenue was subject to complex dynamic effects, which are not necessarily reflected in short-term revenue elasticities. Revenue elasticity is the standard parameter used to measure the responsiveness of revenue to its base. The economic crisis highlighted that, in practice, short-term elasticities often display large fluctuation from a year to the next and can deviate significantly from the long-term average in a way that is difficult to predict. Several factors were identified to explain those deviations, among which dynamic effects. Revenue may follow the evolution of tax bases with some delay, owing to specific collection mechanisms or statutory lags in declaring the taxable base (e.g. personal income taxed one year after it was earned). Moreover, tax systems are not necessarily indexed to inflation, which may entail a fiscal drag, i.e. generating more revenue in case of strong price increases without any legislative change. Also asset price cycle effects and tax compliance effects may explain further fluctuations in short-term revenue elasticities to their base during downturn and upswings.

This highlights the need for looking into the developments of revenue elasticities over time and also raises the issue of their possible change over the cycle, often neglected in the literature. When computing the elasticity of revenue with respect to the output gap, the literature often assumes that, for several types of revenue, elasticities of revenue to base are identical in the short-term and long-term terms (Bouthevillain *et al.*, 2001, Girouard and André, 2005; Price *et al.*, 2014). This assumption is reasonable when it comes to compute the cyclically-adjusted budget balance (Mourre *et al.*, 2014) and it allows to circumventing the econometric difficulty to estimate the elasticity for each Member State, given the lack of long time series for many countries. However, when considering the actual response of revenue to tax base developments, it becomes necessary to take due account of dynamic effects to better capture the high volatility of revenue in the short-term. This is the first aim of the paper. Moreover, following an error correction mechanism (e.g. Wolswijk, 2009), revenue-to-base elasticities are conventionally assumed independent of the cyclical position of the economy even though they vary over time. The paper also relaxes this assumption to test the specific impact of the business cycle on short-term elasticities.

The two contributions of the paper are to estimate the elasticities of revenue *net of discretionary measures* and to investigate whether elasticities are affected by the business cycle in the short term. The primary novelty of the paper is to correct revenue from new tax measures (also called discretionary tax measures) to remove the impact of tax policy changes from the analysis and focus on the spontaneous reaction of revenue to the change of economic conditions. Data on discretionary tax measures come from a new database filled annually by Member States in the framework of the Output Gap Working Group (OGWG) and managed by the European Commission (DG ECFIN). A second novelty is to measure the impact of the business cycle on short-term elasticities (disaggregated for different revenue categories) using different indicators and specifications.

Using panel data for all EU Member States, this paper estimates long-term and short-term revenue elasticities for four revenue categories. This paper uses pooled-time series for all EU Member States to increase the statistical efficiency of the estimation, whereas recent contributions mainly focussed on a particular country (e.g. the Netherlands (Wolswijk, 2009; Bettendorf and van Limbergen, 2013) and Germany (Koester and Priesmeier, 2012)). It also explicitly estimates long-term and short-term revenue elasticities for four revenue categories over the period 2001-13, while previous literature mostly focussed on short-term elasticities (Price *et al.*, 2014 and Belinga *et al.*, 2014).

The paper is organised as follows. Section 2 presents the methodology and the data used to estimate revenue elasticities. It also sets out the method to adjust revenue from the impact of discretionary measures in order to focus on the endogenous/spontaneous reaction of tax revenue to base developments. In section 3, the elasticity of revenue with respect to its base is estimated for four revenue categories (consumption taxes, social security contributions, personal income taxes and corporate income taxes). In section 4, the estimation of revenue elasticities is re-run to take into account the specific impact of the business cycle. Section 5 concludes. Annex 1 presents the database for discretionary tax measures and describes their size, composition and pattern. Annex 2 presents some additional estimation results, confirming the robustness of the results.

2. METHODOLOGY AND DATA TO ESTIMATE THE ELASTICITY OF REVENUE WITH RESPECT TO ITS TAX BASE

This section explains the methodology and presents the data used to compute the elasticities of each revenue category with respect to its tax base. It first describes how to correct revenue from discretionary measures to eliminate the impact of exogenous variations. Then, it presents the econometric specifications used to estimate long- and short-term revenue elasticities. Finally, it looks into the data based on which the econometric regressions are run and sets out the assumptions underlying the interpretation of the estimation results.

2.1. ADJUSTING REVENUE FOR DISCRETIONARY MEASURES

To only capture the effect of endogenous variation of tax bases on revenue, revenue data need to be netted out of policy-induced tax changes, i.e. discretionary tax measures. Discretionary measures correspond to legislative or administrative changes in policy that have an impact on revenue, whether already finally adopted or only likely to be implemented. To take into account the dynamic effects of tax law changes, which naturally make the assessment of tax revenue for a given year dependent on previous' year tax policy decisions, a 'proportional adjustment method' (Barth and Hemphill, 2000) is used, considering all years where these measures are expected to operate.

The proportional adjustment method consists in adjusting past tax revenue data, so as to show the value that would have prevailed if the current year's tax system had been in place from the first year on. The intuition behind this method is to back-cast the series by 'adding' from the very first year on all the discretionary measures taken at a later stage. This 'addition' is done by imputing the weight of discretionary measures (in total revenue) in a given year to all previous years in cascade. This backward proportional adjustment allows for 'neutralising' the impact of various discretionary measures when considering revenue developments over time. The adjusted series obtained are thus 'cleaned' from discretionary measures effects and only reflect the evolution of non-discretionary revenue. Specifically, if year t is taken as the current year, DM_t are the discretionary measures in year t and R_t is the revenue in year t, the method assumes that discretionary measures in the current year are nil (i.e. $DM_t = 0$) and therefore that the adjusted revenue for year t, AR_t equals the revenue in year t, R_t. The adjusted revenue of year j, AR_j, is then computed as follows.

$$AR_j = R_j * \prod_{k=j+1}^{t} \left(\frac{R_k}{R_k - DM_k} \right) \text{ for all j} < \text{t}$$

The formula makes clear that the variation in adjusted revenue (*net* revenue) between t-1 and t will be larger/smaller than the variation of unadjusted revenue (*gross* revenue) when DM_t is smaller/larger than zero. Filtering the impact of policy-driven measures, the method helps to compare revenue across the years and allows the calculation of revenue elasticities net of the effect of discretionary measures.

2.2. ESTIMATING LONG- AND SHORT-TERM REVENUE ELASTICITIES

An error correction model is used to estimate long- and short-term elasticities in a dynamic setting. Tax revenue is in the short-run continuously subject to endogenous changes in the tax base, moving it away from its long-term trend. Whenever revenue is moved away from its path, however, it tends to be pushed back toward its long-term equilibrium. In order to allow a variable to be dynamic in the short-run, while remaining at equilibrium in the long-run, Engle and Granger (1987) developed error correction models (ECM). Those models remove the error on the residuals when determining the short-term dynamics in line with the long-run equilibrium. The error correction model can be specified as follows:

$$\Delta logAR_{i,c,t} = \beta_0 + \beta_1 \Delta logB_{i,c,t} + \beta_2 ECT_{i,c,t} + \mu_{i,c,t} \quad (1)$$

In equation (1) AR_{ict} is the revenue adjusted for discretionary measures of tax category c of country i in year t, B_{ict} is the tax base of tax category c of country i in year t, ECT is the error correction term of tax category c of country i in year t and $\mu_{i,t}$ is the residual for tax category c of country i in year t. The coefficient of interest β_1 measures how revenue varies following a one percentage change in the tax base. It denotes the short-term revenue elasticity with respect to the tax base. Coefficient β_2 indicates the time needed for revenue to return to its long-run equilibrium after an endogenous change in the tax base ('adjustment speed'). Short-term changes in revenue can therefore be due to two effects: the responsiveness of revenue to tax base changes (β_1) and the time needed for revenue to move toward its long-term value (β_2). The error correction model is specified using both one-stage and two-stage estimation.

In a one-stage approach, both the long-term and the short-term elasticities are estimated simultaneously using an error correction model. To estimate long- and short-term revenue elasticities, the error correction model can be specified as follows:

$$\Delta logAR_{i,c,t} = \beta_0 + \beta_1 \Delta logB_{i,c,t} + \beta_2 (logAR_{i,c,t-1} - \beta_3 logB_{i,c,t-1}) + \mu_{i,c,t} \quad (2)$$

where β_1 denotes the short-term revenue elasticity with respect to the tax base. In this equation, the error correction term is composed of the lagged dependent and main independent variables $(logAR_{i,c,t-1} - \beta_3 logB_{i,c,t-1})$. Coefficient β_3 indicates the long-term effect of a one percentage change of the tax base on the adjusted revenue. The long-term effect is distributed over the following years according to the rate of the error correction term β_2. Additional control variables, as well as a dynamic component, i.e. the one year lag of the first difference of the explanatory variable, can be introduced to polish the model. The model is corrected for autocorrelation of order one and the error structure is constrained to be heteroskedastic.

In a two-stage approach, the long-term elasticity is estimated first, using general least square (GLS), while the short-term elasticity is derived from an error correction model embedding the residual of the first equation. Given the non-stationarity of the revenue data, using linear regression to estimate short-term elasticities could lead to spurious correlation. In order to avoid that an apparent relation between unrelated series is considered significant, Engle and Granger (1987) suggest two-stage estimation. As a first stage, the long-term revenue elasticity is estimated using GLS regression (equation 3). As a second stage, an error correction model is used to determine the short-term dynamics of the tax base on revenue in line with the long-run equilibrium (equation 4).

$$logAR_{i,c,t} = \alpha_0 + \alpha_1 logB_{i,c,t} + \gamma_{i,c,t} \quad (3)$$

$$\Delta logAR_{i,c,t} = \beta_0 + \beta_1 \Delta logB_{i,c,t} - \beta_2 \gamma_{i,c,t-1} + \mu_{i,c,t} \quad (4)$$

In equation (3), γ_{ict} is the error term of tax category c of country i in year t and α_1 denotes the long-term revenue elasticity. It measures how revenue varies following a one percentage change in the tax base To estimate the short-term revenue elasticity, equation (3) is differenced once to get stationary variables and the lagged error correction term of the long-term specification $\gamma_{i,c,t-1}$ is added to correct for the deviation from the long-term relationship. β_1 denotes the short-term revenue elasticity and β_2 the adjustment speed. The model is corrected for autocorrelation of order one and the error structure is constrained to be heteroskedastic.

2.3. DATA

Data are collected for four revenue categories. These are consumption taxes, social security contributions, personal income taxes and corporate income taxes, as used in Bouthevillain *et al.*, 2001 and Girouard and André, 2005). In the European Commission AMECO data, annual revenue data are available for taxes linked to imports and production (consumption taxes), current taxes on income and wealth (direct taxes) and social contributions.

Macroeconomic variables are used as a proxy of the actual tax bases, so as to compute elasticities, reflecting the response of revenue to changes in its base. Early research computing elasticities (Giorno *et al.*, 1995) estimated tax bases according to strong assumptions: for personal income taxes and social security contributions statutory tax rates were applied to the income distribution; for consumption and corporate income taxes revenue elasticities were imposed. In this paper, all bases are approximated using macroeconomic variables. Private consumption is used to approximate the tax base of consumption taxes ('Taxes on production and imports'), total compensation of private sector employees is used for social security contributions ('Social contributions'), gross wage for personal income taxes ('Current taxes on income and wealth - households') and one-year lagged gross operating surplus for corporate income taxes ('Current taxes on income and wealth – corporations'). Given the complexity of the tax codes and their heterogeneity across countries, in particular for corporate income taxes, the selected macroeconomic variables are only rough approximations of the different tax bases. In order to control for specific tax characteristics, explanatory variables are added to the econometric specifications.

Data cover all EU Member States over the time period 2001-13. Data for the four revenue categories, as well as the macroeconomic variables used as proxy for the different tax bases are pooled together in a panel data set, yielding 364 country-year observations. Data are derived from the 2014 spring forecast vintage of the European Commission (completed by data of the 2014 autumn forecast for Croatia over the time span 2001-08) and from Eurostat. All data used are expressed in nominal terms, i.e. reflecting current prices. Statutory tax rates of value added taxes, as well as of personal and corporate income taxation provide from the 2014 Tax Reforms Report (European Commission, 2014). The data on capacity utilisation relate to seasonally-adjusted quarterly information on the manufacturing sector and provide from the Business and Consumer Survey of the European Commission.

Data on discretionary measures are those annually collected by Member States in the context of the OGWG of the Economic Policy Committee of the EU. The database is maintained and managed by the European Commission (DG ECFIN). They are available for all EU Member States but do not cover the full sample period for all countries. The discretionary tax measures database, described in Annex 1, provides detailed data of individual measures exceeding 0.05% of GDP as well as the aggregated value of all measures per year and country (as reported until October 2014). In this paper, detailed information, based on the sum of individual measures, is used to run the main regressions, while aggregated data (reallocated across tax categories based on reasonable assumptions) are used to verify the robustness of the findings. This trade-off needed to be made since individual measures are not exhaustive in terms of coverages (without small measures below a threshold) but are reported with detailed information on their nature, while aggregated figures are all-inclusive, but not broken down into the four categories scrutinised in the paper.

3. ESTIMATION RESULTS OF REVENUE ELASTICITIES

This section provides the estimation results for each of the four revenue categories, following the above-mentioned specifications. First, short-term and long-term revenue elasticities are estimated using a standard simple specification. Then, we make the model more complex: time lags, as well as control variables are added to refine the specification and see if they alter the value of the coefficient of interest. Next, the long-term revenue elasticity is set to unity, to check the plausibility of a unitary assumption. Finally and as a robustness check, the results are compared with those obtained when using an alternative error correction model approach (one-stage or two-stage, depending on the one used in the standard specification) and with the elasticity estimates of previous literature.

3.1. CONSUMPTION TAX ELASTICITIES

Private consumption is considered to approximate the consumption tax base. Given that consumption tax revenue mainly provides from private consumption, the latter is used to approximate the consumption tax base. As a large part of goods and services are subject to a standard VAT rate, the long-term revenue elasticity of consumption taxes is often assumed to be one (Mourre *et al.*, 2014; Price *et al.*, 2014). A unitary elasticity indicates a proportional tax, while an elasticity above unity implies a progressive tax system and below unity a regressive tax system. However, the lower VAT rates applied to basic necessities and the higher VAT rates applied to luxury goods in most countries indicates some progressivity and may explain a certain deviation from the unitary assumption. This slight progressivity of the VAT scale is in practice often counterbalanced by the slow response of excise duties to nominal consumption. Excise duties are a per unit tax, i.e. a specific amount per volume or unit of the item purchased, and thus not automatically indexed with price developments[1]. In order to verify whether the unitary assumption holds, the revenue of consumption taxes is estimated with respect to (nominal) private consumption using a two-stage error correction model.

A two-stage approach seems to indicate a consumption tax elasticity of one or (slightly) above one, both in the short-run and in the long-run. As shown in regressions 1 and 2 of Table 1, the estimated long-term elasticity is slightly above unity, but not necessarily different from one as indicated by the Wald test. As consumption taxes are not only levied on private consumption but also on private residential investment (and, to a lesser extent, government consumption and investment), those items are added as explanatory variables in regressions 3 and 4. The resulting long-term elasticities are below one but the Wald test does not consider them statistically different from one. The corresponding short-term elasticities are above unity and statistically different from one. In regression 5, the long-term elasticity is constraint to unity. According to Table 2, the coefficient of controls and short term elasticities are not much affected by imposing this assumption. This confirms that the long-term elasticity is not very far from unity, underpinning the intuition that consumption tax revenue will not increase/decrease indefinitely with respect to the tax base.

[1] By contrast, a sales tax or VAT is an ad valorem tax and proportional to the price of the good.

Table 1: Revenue to base elasticities – Consumption taxes – Two-stage ECM

	(1) GLS	(2) GLS with lag	(3) GLS with control variable	(4) GLS with lag and control variable	(5) GLS with lag and control variable constrained
Long-term elasticity					
Log(Private consumption)	1.03***	1.08***	0.83***	0.85***	1.00
	(0.03)	(0.04)°	(0.09)°°	(0.12)	(constrained)
Log(Residential investment)	-	-	0.17***	0.16***	0.16***
			(0.02)	(0.03)	(0.03)
Log(Government)	-	-	0.01	0.01	-0.13**
			(0.08)	(0.11)	(0.05)
Observations	364	280	351	270	270
Short-term elasticity					
ΔLog(Private consumption)	1.41***	1.31***	1.09***	1.12***	1.03***
	(0.06)°°°	(0.06)°°°	(0.08)	(0.08)	(0.09)
ΔLog(Residential investment)	-	-	0.11***	0.07***	0.05***
			(0.02)	(0.02)	(0.02)
ΔLog(Government)	-	-	0.04	-0.04	-0.03
			(0.05)	(0.05)	(0.05)
Error-correction term	-0.33***	-0.33***	-0.43***	-0.42***	-0.10***
	(0.04)	(0.04)	(0.05)	(0.05)	(0.02)
Observations	336	280	324	270	270

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test). For the long-term estimates in a two-stage approach à la Engel and Granger, the statistical inference results are only indicative, since based on GLS regressions with fixed-effects and thus potentially affected by the spurious regression effect, given the non-stationary nature of the variables considered in level. The sum of individual discretionary tax data is subtracted from the revenue data, so as to remove the impact of new policy.

The error correction term indicates that when deviating from the long-term value, revenue returns to its long-run equilibrium after approximately three years. The error correction term shows the extent to which the long-run equilibrium drives short-term dynamics. For consumption taxes, about 30 to 40% of the short-term disequilibrium is corrected the following year. When the long-term elasticity is constrained to unity the adjustment speed decreases to approximately 10%. This only reflects the fact that the adjustment becomes less important since the short-term elasticity becomes very close to one and, therefore, already very near its long term (constrained) value.

Robustness tests show that there is some uncertainty about the exact identification between short-term and long-term elasticities. Two types of tests are used to verify the robustness of the findings (Table 2). First, the regressions are rerun based on aggregated data reallocated across tax categories (see Annex 1 for details on the reallocation of aggregated data). The estimations remain very stable to this change of data. Second, one-stage estimation is used, where the long-term elasticity and the short term elasticity are estimated simultaneously, using a GLS regression combining regressors in first difference and in level. The coefficients of those robustness tests (Table 2) are fairly close to those obtained in Table 1, although there seems to be some uncertainty about the exact identification between short-term and long-term elasticities. Short-term elasticities now range from 0.94 to 1.41 and long-term elasticities from 0.77 to 1.15 (see Annex 2 for detailed results). It is therefore analytically appealing to start with the two-stage approach, which allows the sequential identification of long-term and short-term elasticities. Indeed, the long-term elasticity is estimated first using GLS regression, while the short-term elasticity is estimated subsequently using an error correction model incorporating the long-run equilibrium.

Table 2: Revenue to base elasticities - Consumption taxes – Robustness

	Short-term elasticity	Long-term elasticity	Error correction	Nb. of obs.
One-stage model (using the sum of individual discretionary tax data)				
(1) Simple	1.31***/°°°	0.87***/°°°	-0.33***	336
(2) With lag	1.37***/°°°	0.82***/°°°	-0.40***	308
(3) With controls	1.12***	0.91***/°°	-0.33***	324
(4) With lag and controls	1.12***/°	0.87***/°°°	-0.38***	297
(5) With lag and controls but constrained	1.35***	1.00 (constrained)	-0.95***	297
One-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	1.31***/°°°	0.82***/°°°	-0.31***	336
(2) With lag	1.37***/°°°	0.77***/°°°	-0.43***	308
(3) With controls	1.12***	0.87***/°°°	-0.32***	324
(4) With lag and controls	1.12***	0.83***/°°°	-0.41***	297
(5) With lag and controls but constrained	1.41***	1.00 (constrained)	-0.92***	297
Two-stage model (using the sum of individual discretionary tax data)				
(1) Simple	1.41***/°°°	1.03***	-0.33***	336
(2) With lag	1.31***/°°°	1.08***/°	-0.33***	280
(3) With controls	1.09***	0.83***/°°	-0.43***	324
(4) With lag and controls	1.12***	0.85***	-0.42***	270
(5) With lag and controls but constrained	1.03***	1.00 (constrained)	-0.10***	270
Two-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	1.35***/°°°	1.05***/°°	-0.25***	322
(2) With lag	1.26***/°°°	1.15***/°°°	-0.35***	265
(3) With controls	1.07***	0.97***	-0.30***	310
(4) With lag and controls	1.09***	1.08***	-0.42***	255
(5) With lag and controls but constrained	1.02***	1.00 (constrained)	-0.12***	255
Other studies				
OECD (Price *et al.*, 2014)	0.97	-	EU countries	
IMF (Belinga *et al.*, 2014)	1.28***	1.13***	OECD countries	
IMF (Sancak *et al.*, 2010)	-	1.10***	EU countries	
ECB (Bouthevillain *et al.*, 2001)	-	1.00	EU countries	
National studies	1.01(NL)/0.90(DE)	0.90(NL)/0.79(DE)		

Note: See Annex 2 for detailed results. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test). For the long-term estimates in the two-stage approach, the statistical significance displayed is only indicative, since based on GLS regressions with fixed-effects and thus potentially affected by the spurious regression effect, given the non-stationary nature of the variables considered in level. The sum of individual discretionary tax data is subtracted from the revenue data, so as to remove the impact of new policy.

Long-term and short-term consumption tax elasticities – found to be close to one – are in line with the findings of previous literature. The results confirm those found in previous research. The ECB (Bouthevillain *et al.*, 2001) uses a unitary elasticity of consumption tax revenue to private consumption, based on a mix of econometric estimations and assumptions embedded in fiscal laws. Running econometric estimates, the OECD (Price *et al.*, 2014) found that the elasticities of consumption tax revenue to its base averages out to almost one in the EU, although country values could depart from this average. Two IMF studies (Sancak *et al.*, 2010 and Belinga *et al.*, 2014) found a long-term elasticity of approximately 1.10. Country-specific results show a long-term elasticity below but close to one: 0.90 for the Netherlands (Wolswijk, 2009) and 0.79 for Germany (Koester and Priesmeier, 2012).

3.2. SOCIAL SECURITY CONTRIBUTION ELASTICITIES

Total compensation of private sector employees is used as an approximation for the base of social security contributions. Social security contributions are in most EU Member States levied on wage, taking into account cash and non-cash compensation. As suggested in Bouthevillain *et al.* (2001), total compensation of private sector employees is used to approximate the base on which social security contributions are levied[2]. As a single rate applies to this base, social security contributions are assumed to function as a proportional tax, implying a revenue elasticity which is close to unity. However, this proportional tax system only applies to a certain income range, as upper and lower bounds are generally defined. To support low-wage earners in the job market, wage income under a certain threshold is often not subject to social security contributions. Moreover, at the other end of the income distribution, contributions face an upper bound, as they are due up to a maximum amount of earnings. The effective contribution rate is therefore decreasing when income increases beyond the ceiling. Therefore, social security contributions turn out to be slightly progressive in the first two deciles of the wage distribution, flat in the middle and highly regressive in the higher part of the distribution. Given the large share of high earnings in the total wage bill, this latter effect seems to dominate in many countries, so that revenue elasticity below one may be expected, at least in the short term, when the ceiling is not adjusted to inflation.

Table 3: Revenue to base elasticities – Social contributions – One-stage ECM

	(1) GLS	(2) GLS with lag	(3) GLS with lag and constrained
Long-term elasticity			
Log(Compensation)(t-1)	0.96***	0.98***	1.00
	(0.03)°	(0.03)	(constrained)
Error-correction term	-0.27***	-0.21***	-0.98***
	(0.03)	(0.03)	(0.01)
Short-term elasticity			
ΔLog(Compensation)	0.84***	0.82***	0.87***
	(0.03)°°°	(0.03)°°°	(0.03)°°°
ΔLog(Compensation)(t-1)	-	0.06**	-0.06**
		(0.03)	(0.03)
Observations	327	299	299

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test). The sum of individual discretionary tax data is subtracted from the revenue data, so as to remove the impact of new policy.

The social security contribution elasticities consistently stand at around 0.85 in the short term, while the long-term elasticity is very close to one across all specifications. Various regression results confirm the robustness of the findings, which are in line with the findings of previous literature. Table 4 presents the results of various one-stage and two-stage error correction models estimating the social security elasticities. For short-term elasticities, the results are consistent and almost identical across all regression specifications: the coefficient hovers around 0.85 and is – without exception – statistically different from zero and one (at 1% level). Considering dynamics, the cumulated elasticity over the first two years is close to 0.9. For long-term elasticities, estimations close to one are confirmed by all specifications independently of the error correction model used. While one-stage models cannot reject the hypothesis of a unitary long-term elasticity, two-stage models find estimates below and statistically different from one (1% level). These findings are also in line with previous literature. Both Bouthevillain *et al.* (2001), Belinga *et al.* (2014) and Price *et al.* (2014) find elasticities close to one.

[2] This is an approximation of the real base. First, the compensation of employees already includes employees' and employers' social security contributions. Second, it excludes the imputed wages received by the self-employed, which is also part of the legal base of social security contributions. However, these imputed wages cannot be measured directly and it is difficult in practice to break down self-employed earnings between profit and wages.

Table 4: Revenue to base elasticities – Social security contributions – Robustness

	Short-term elasticity	Long-term elasticity	Error correction	Nb. of obs.
One-stage model (using the sum of individual discretionary tax data)				
(1) Simple	0.84***/°°°	0.96***/°	-0.27***	327
(2) With lag	0.82***/°°°	0.98***	-0.21***	299
(3) With lag but constrained	0.87***/°°°	1.00 (constrained)	-0.98***	299
One-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	0.88***/°°°	0.99***	-0.23***	327
(2) With lag	0.86***/°°°	1.02***	-0.20***	299
(3) With lag but constrained	0.91***/°°°	1.00 (constrained)	-0.96***	299
Two-stage model (using the sum of individual discretionary tax data)				
(1) Simple	0.83***/°°°	0.93***/°°°	-0.24***	327
(2) With lag	0.85***/°°°	0.90***/°°°	-0.22***	271
(3) Constrained	0.85***/°°°	1.00 (constrained)	-0.02***	327
Two-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	0.85***/°°°	0.91***/°°°	-0.20***	327
(2) With lag	0.86***/°°°	0.88***/°°°	-0.18***	271
(3) Constrained	0.88***/°°°	1.00 (constrained)	-0.02***	327
Other studies				
OECD (Price *et al.*, 2014)	1.00		EU countries	
IMF (Belinga *et al.*, 2014)	0.58***	0.95***	OECD countries	
ECB (Bouthevillain *et al.*, 2001)	-	1.00	EU countries	

Note: Idem as Table2. See Annex 2 for detailed results

3.3. PERSONAL INCOME TAX ELASTICITIES

Total gross wages are taken as a proxy for the personal income tax base. Labour earnings form the most important component of personal income, larger than capital income, social transfers and self-employed earnings (see Price et al., 2014). Therefore, aggregated gross wages are taken as a proxy for the personal income tax base. Personal income taxation is typically progressive. It is often used by the government for redistributive purposes. The higher the income of an individual, the higher the tax rate his/her income will be subject to. The progressive rate structure and the tax-exempted basic allowance of most personal income tax systems are expected to push the revenue elasticity above unity. A one percentage increase of the tax base will generate an increase in revenue higher than one percent. In other words, the progressivity of personal income taxes results in tax revenue growing more rapidly than the wage bill.

The short-term elasticity is estimated to be significantly above one, in line with the progressivity of the personal income tax, while the long term-elasticity stands slightly over unity. As shown in Table 5, a simple one-stage error correction model generates a short-term elasticity ranging from 1.2 to 1.3 (except for equation 3) and a long-term elasticity of around 1.1. Both elasticities are very significantly different from zero (at 1% level) and the long-term elasticity is also different from one as indicated by the Wald test. The coefficient of the lagged variable is small and not statistically significant. While revenue collected relates in many country countries to the income generated last year, the coefficient of the lagged variable is small and not statistically significant. In regressions 3 and 4 housing investment is added as explanatory variable to reflect the mortgage interest deductibility granted by half of the personal income tax systems in the EU. The results are not robust: while housing investment is very significant in equation 3 (and capturing part of the explanatory power of gross wages), it is no longer significant in equation 4. The substantial adjustment speed (approximately 60%) indicates that personal income tax revenue rapidly adjusts to get back to its long-run equilibrium. When constraining the long-term elasticity to unit (regression 5), the coefficient of the error correction term increases (albeit not dramatically), as well as the short-term elasticity, which further suggests that the "true" long-term elasticity stands (slightly) above unit.

Table 5: Revenue to base elasticities – Personal income taxes – One-stage ECM

	(1) GLS	(2) GLS with lag	(3) GLS with control variable	(4) GLS with lag and control variable	(5) GLS with lag and control variable constrained
Long-term elasticity					
Log(Gross wage)(t-1)	1.11***	1.03***	1.14***	1.05***	1.00
	(0.07)°	(0.08)	(0.07)°°	(0.08)	(constrained)
Error-correction term	-0.58***	-0.61***	-0.58***	-0.60***	-0.80***
	(0.05)	(0.06)	(0.05)	(0.06)	(0.04)
Short-term elasticity					
Δ Log(Gross wage)	1.17***	1.30***	0.93***	1.26***	1.43***
	(0.18)	(0.21)	(0.20)	(0.26)	(0.27)
Δ Log(Gross wage)(t-1)	-	-0.03	-	-0.03	-0.03
		(0.16)		(0.20)	(0.024)
Δ Log(Housing investment)	-	-	0.13***	0.06	0.09
			(0.05)	(0.05)	(0.06)
Δ Log(Housing investment)(t-1)	-	-	-	-0.02	0.03
				(0.05)	(0.06)
Observations	296	271	289	263	263

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test). The sum of individual discretionary tax data is subtracted from the revenue data, so as to remove the impact of new policy.

Robustness tests show that there is some uncertainty about the identification of short-term versus long term elasticities of personal income tax, but overall they seem to indicate elasticities exceeding one. When the one-stage regressions are rerun based on aggregated data reallocated across tax categories (Table 6), elasticities remain in the same range as those obtained when using the sum of individual data (as in Table 5). Short-term elasticities now range from 1.01 to 1.36; long-term elasticities from 1.03 to 1.13 (1% level). When two-stage estimation is used, however, adding the control variable 'housing investment' seems to considerably disrupt the identification of the short-term and long-term elasticities. In regressions 3 and 4 of both two-stage models the short-term and long-term elasticities are considerably below unity. The detailed results in Annex 2 show that this can be explained by the impact of the 'housing investment' coefficient, which is approximately twice as high as in the one-stage models. The control variable thus captures an even bigger effect of the main explanatory variable and drags the elasticities down. Another robustness test is to estimate the revenue elasticities for personal and corporate income taxes together using direct tax revenue. The estimated elasticities are then weighted based on their ten-year (2002-11) average share in total direct tax revenue (EU-28: 70% and 30% for personal and corporate income taxes respectively). It is assumed that every change in personal income tax only affects the part of direct tax revenue allocated to personal income tax and that every change in corporate income tax only affects the part of direct tax revenue allocated to corporate income tax. For personal income taxes, amounting to 70% of total direct taxes, elasticities are multiplied by 1.43. For corporate income taxes, amounting to 30% of total direct taxes, elasticities are multiplied by 3.33.

Table 6: Revenue to base elasticities – Personal income taxes – Robustness

	Short-term elasticity	Long-term elasticity	Error correction	Nb. of obs.
One-stage model (using the sum of individual discretionary tax data per tax category)				
(1) Simple	1.17***	1.11***/°	-0.58***	296
(2) With lag	1.30***	1.03***	-0.61***	271
(3) With controls	0.93***	1.14***/°°	-0.58***	289
(4) With lag and controls	1.26***	1.05***	-0.60***	263
(5) With lag and controls but constrained	1.43***	1.00 (constrained)	-0.80***	263
One-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	1.13***	1.11***	-0.56***	296
(2) With lag	1.36***	1.04***	-0.61***	271
(3) With controls	1.01***	1.13***/°	-0.55***	287
(4) With lag and controls	1.45***	1.03***	-0.60***	263
(5) With lag and controls but constrained	1.54***	1.00 (constrained)	-0.78***	263
Two-stage model (using the sum of individual discretionary tax data)				
(1) Simple	1.16***	1.11***	-0.57***	296
(2) With lag	1.16***	1.12***	-0.61***	246
(3) With controls	0.84***	0.84***	-0.61***	287
(4) With lag and controls	0.42*	0.54**/°°	-0.62***	239
(5) With lag and controls but constrained	0.55*	1.00 (constrained)	-0.48***	240
Two-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	1.10***	1.10***	-0.54***	293
(2) With lag	1.03***	1.08***	-0.54***	241
(3) With controls	0.81***	0.84***	-0.58***	284
(4) With lag and controls	0.56***	0.57**/°	-0.53***	234
(5) With lag and controls but constrained	0.67**	1.00 (constrained)	-0.39***	235
One-stage model with direct taxes as dependent variable and manual recalibration of coefficients				
(1) Simple	1.83***/°°	1.07***/°°	-0.49***	318
(2) With lag	1.82***/°°	0.94***/°°°	-0.43***	291
(3) With controls	1.77***/°	1.17***/°	-0.48***	308
(4) With lag and controls	1.71***	1.12***	-0.42***	282
(5) With lag and controls but constrained	1.48***	1.00 (constrained)	-0.06***	282
Two-stage model with direct taxes as dependent variable and manual recalibration of coefficients				
(1) Simple	1.73***/°°	1.07***/°°°	-0.46***	318
(2) With lag	1.75***/°°	1.42***	-0.50***	264
(3) With controls	1.47***	0.81***/°°°	-0.49***	308
(4) With lag and controls	1.43***	1.08***/°	-0.50***	256
(5) With lag and controls but constrained	1.18***	1.00 (constrained)	-0.07***	308
Other studies				
OECD (Price *et al.*, 2014)	1.84		EU countries	
IMF (Belinga *et al.*, 2014)	0.94***	0.82***	OECD countries	
ECB (Bouthevillain *et al.*, 2001)	-	1.50	EU countries	
National studies	2.01(NL)/1.41(DE)	1.57(NL)/1.75(DE)		

Note: Idem as Table2. See Annex 2 for detailed results

However, the estimated elasticities - based here on macroeconomic estimates - are lower than the results found in previous research. In EU-wide research, Price *et al.* (2014) found an average short-term elasticity of 1.84, which overall is higher than the elasticities estimated above. This difference may be explained by the fact that in the latter personal income tax elasticities are computed along an income distribution calibrated in terms of ratios of average earnings, while in this paper the tax base is approximated using a macroeconomic variable. In country-specific research (Wolswijk, 2009; Koester and Priesmeier, 2012) the short-term elasticity ranges from 1.41 to 2.01 and the long-term elasticity from 1.57 to 1.75. However, using an OECD country panel, Belinga *et al.* (2014) found elasticities below one, reflecting a regressive personal income tax system rather than a progressive one. These differing results show the impact of country specifics and reflect the diversity among national income tax systems, which are difficult to capture in an EU-wide study.

3.4. CORPORATE INCOME TAX ELASTICITIES

Gross operating surplus is taken as a proxy for the corporate income tax base. Corporate income tax is levied on the profits generated by companies. However, tax profits can substantially deviate from accounting profits due to special regimes and tax expenditures, such as interest deductibility and specific tax credits/deductions for SME, but also the possibility for corporations to carry losses forward with an imputation to profits in subsequent years. Given the complexity of the corporate tax system, it is particularly difficult to select an appropriate macroeconomic variable to approximate the tax base. As in previous literature, gross operating surplus of the whole economy is used to approximate the corporate tax base and the change in corporate income tax rate is used as control variable. The elasticity of corporate taxes is expected to be particularly volatile and exceeding one.

Table 7: Revenue to base elasticities – Corporate income taxes – One-stage ECM

	(1) GLS	(2) GLS with lag	(3) GLS with control variable	(4) GLS with lag and control variable	(5) GLS with lag and control variable constrained
Long-term elasticity					
Log(Corporate profits) (t-1)	1.37***	1.43***	1.29***	1.21***	1.00
	(0.14)°°°	(0.17)°°	(0.14)°°	(0.17)	(constrained)
Error-correction term	-0.66***	-0.63***	-0.68***	-0.70***	-0.77***
	(0.09)	(0.11)	(0.10)	(0.11)	(0.08)
Short-term elasticity					
Δ Log(Corporate profits)	1.16***	1.10***	1.08***	0.99***	1.06***
	(0.21)	(0.23)	(0.22)	(0.23)	(0.19)°°°
Δ Log(Corporate profits) (t-1)	-	-0.04	-	-0.08	-0.12
		(0.19)		(0.19)	(0.17)
Δ Log(Corporate tax rate)	-	-	0.38	0.47*	0.44*
			(0.25)	(0.27)	(0.26)
Δ Log(Corporate tax rate) (t-1)	-	-	-	0.42	0.39
				(0.27)	(0.27)
Observations	296	271	296	271	271

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test). The sum of individual discretionary tax data is subtracted from the revenue data, so as to remove the impact of new policy.

As expected, both the short-term and the long-term elasticity for corporate income taxes are estimated above unity. As shown in regressions 1 and 2 of Table 7, a simple one-stage error correction model generates short-term elasticities slightly above one and long-term elasticities considerably above one (with a coefficient significantly different from unity). The short-term dynamic is rapidly converging to the long-run equilibrium, as indicated by the adjustment speed of approximately 60%. The change in corporate tax rate, used as control variable, does turn out to be not statistically significant, which suggests that the discretionary tax measures, employed to 'clean' the revenue series, capture well changes in corporate tax rates.

Table 8: Revenue to base elasticities – Corporate income taxes – Robustness

	Short-term elasticity	Long-term elasticity	Error correction	Nb. of obs.
One-stage model (using the sum of individual discretionary tax data)				
(1) Simple	1.16***	1.37***/°°°	-0.66***	296
(2) With lag	1.10***	1.43***/°°	-0.63***	271
(3) With controls	1.08***	1.29***/°°	-0.68***	296
(4) With lag and controls	0.99***	1.21***	-0.70***	271
(5) With lag and controls but constrained	1.06***/°°°	1.00 (constrained)	-0.77***	271
One-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	1.18***	1.44***/°°°	-0.68***	296
(2) With lag	1.13***	1.51***/°°°	-0.63***	271
(3) With controls	1.11***	1.37***/°°°	-0.71***	296
(4) With lag and controls	1.01***	1.29***	-0.69***	271
(5) With lag and controls but constrained	1.05*/°°°	1.00 (constrained)	-0.75***	271
Two-stage model (using the sum of individual discretionary tax data)				
(1) Simple	1.03***	1.32***/°°°	-0.65***	296
(2) With lag	0.90***	1.02***	-0.61***	246
(3) With controls	0.95***	1.22***/°	-0.68***	296
(4) With lag and controls	0.88***	0.91***	-0.62***	246
(5) With lag and controls but constrained	0.25***/°°°	1.00 (constrained)	-0.43***	248
Two-stage model using aggregated discretionary tax data reallocated across tax categories				
(1) Simple	1.03***	1.37***/°°°	-0.67***	296
(2) With lag	0.93***	1.09***	-0.62***	246
(3) With controls	0.95***	1.26***/°°	-0.70***	296
(4) With lag and controls	0.91***	0.97***	-0.64***	246
(5) With lag and controls but constrained	0.23***	1.00 (constrained)	-0.46***	248
One-stage model with direct taxes as dependent variable and manual recalibration of coefficients				
(1) Simple	1.01***/°°°	1.39***/°°°	-0.49***	318
(2) With lag	1.09***/°°°	1.68***/°°°	-0.43***	291
(3) With controls	0.92***/°°°	1.20***/°°°	-0.48***	308
(4) With lag and controls	0.96***/°°°	1.37***/°°°	-0.42***	282
(5) With lag and controls but constrained	0.76***/°°°	1.00 (constrained)	-0.06**	282
Two-stage model with direct taxes as dependent variable and manual recalibration of coefficients				
(1) Simple	0.74***/°°°	0.81***/°°°	-0.46***	318
(2) With lag	1.16***/°°°	0.37°°°	-0.50***	264
(3) With controls	0.72***/°°°	0.83***°°°	-0.49***	308
(4) With lag and controls	0.93***/°°°	0.28°°°	-0.50***	256
(5) With lag and controls but constrained	0.86***/°°°	1.00 (constrained)	-0.07***	257
Other studies				
OECD (Price *et al.*, 2014)	1.48	1.24	EU countries	
IMF (Belinga *et al.*, 2014)	3.58***	1.41***	OECD countries	
ECB (Bouthevillain *et al.*, 2001)	-	1.20	EU countries	
National studies	0.90(NL)/0.43(DE)	1.07(NL)/0.77(DE)		

Note: Idem as Table2. See Annex 2 for detailed results

Overall, robustness tests seem to confirm that both short-term and long-term elasticities exceed one. As for personal income taxes, several tests are run in order to ascertain the robustness of the results. When the one-stage regressions are rerun based on aggregated data reallocated across tax categories (Table 8), elasticities remain in the same range as those obtained when using individual data. The same is true when two-stage estimation is used, even if the estimated elasticities are slightly lower than when using one-stage estimation. When estimating the revenue elasticities for personal and corporate income taxes jointly using direct tax revenue as a dependent variable, very similar results are found[3].

[3] In this specification, we consider the coefficients of the proxy tax base of corporate income taxes and, then, recalibrate those by the weight of corporate income tax revenue in total direct tax revenue.

The estimated elasticities for corporate income taxes are broadly in line with those found in previous research. Bouthevillain *et al.* (2001) as well as Price *et al.* (2014) found long-term elasticities of approximately 1.20 in the EU. Those results are overall very close to the long-term elasticities estimated above. Price *et al.* (2014) also estimated a short-term elasticity of 1.48, which however differs from this paper's findings. While our paper finds long-term elasticities for the EU which are higher than the short-term ones, Price *et al.* (2014) found short-term elasticities exceeding the long-run equilibrium, on average across the EU. As compared to country-specific studies, Wolswijk (2009) found very close, although slightly lower, results for the Netherlands (short-term elasticity of 0.90 and long-term elasticity of 1.07). This may also illustrate the likely difference in elasticities across Member States. For instance, results for Germany (Koester and Priesmeier, 2012) are clearly lower than what our EU panel estimates indicate (short-term elasticity of 0.43 and long-term elasticity of 0.77).

3.5. COMPARISON ACROSS TAX CATEGORIES

When comparing elasticities across tax categories, corporate income taxes seem to be considerably more elastic than other tax categories in the long-run. Given that - for some tax categories - control variables (used to avoid missing variable bias) may capture part of the elasticity effect vis-à-vis the proxy of the base retained in this paper, the analysis will focus on the estimation results obtained from a lagged model without controls[4]. The results discussed thereafter still hold broadly when adding controls, especially regarding the relative size of short-term and long-term elasticities. Using the specification with lags allows for a better description of the dynamic adjustment. Comparing long-term elasticities across tax categories shows that corporate income taxes are by far the most elastic tax category (Table 9), in line with Price *et al.* (2014) and as seen across most of the econometric specifications. While the long-term corporate tax elasticity largely exceeds one, it is very close to one for the other tax categories. As regards the short-term elasticities, consumption and personal income taxes were found to be the most elastic. The results for social security contributions are confirmed by all robustness tests. For the other tax categories, however, some uncertainty remains about the exact identification of the short-term and long-term elasticities.

Table 9: Revenue to base elasticities – Summary of regressions without control variables

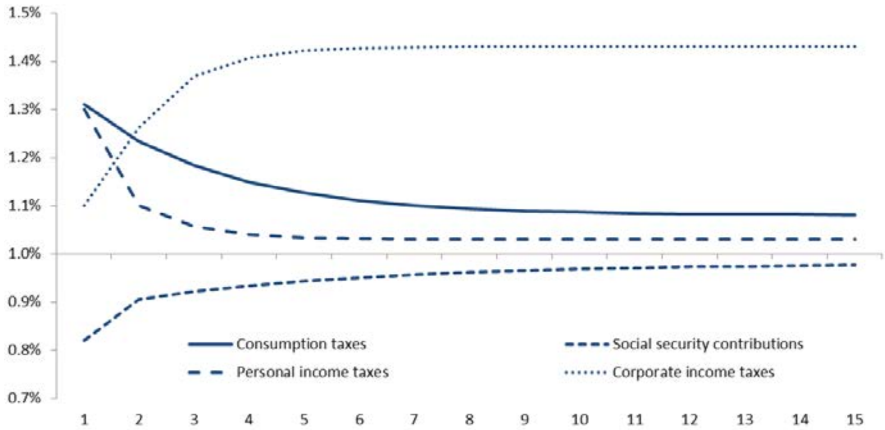
	Consumption taxes	Social security contributions	Personal income taxes	Corporate income taxes
Long-term elasticity	1.08	0.98	1.03	1.43
Short-term elasticity	1.31	0.82	1.30	1.10
Lag	0.00	0.06	-0.03	-0.04
Error correction term	-0.33	-0.21	-0.61	-0.63

As regards the adjustment to equilibrium, both personal and corporate income taxes have the highest adjustment speed. In addition to the size of the elasticity, it is the dynamics of the revenue-base relationship which matters for revenue collection. As done in Koester and Priesmeier (2015), the evolution of revenue elasticities is plotted over time (Figure 1), considering an initial 1% shock in the respective tax base. These impulse response functions show the marked long-term elasticity of corporate income taxes as compared with other tax categories. Only the elasticity of social security contributions does not exceed 1%, both in the short and in the long-run. Figure 1 also shows the differentiated adjustment pattern across tax categories. Whereas both consumption taxes and personal income taxes

[4] Long-term as well as short-term elasticities are significantly reduced using controls, which is seen across all specifications (with lag or without) and across all tax categories.

overshoot and thereafter adjust downwards to their long term value, social security contributions and corporate income taxes undershoot and then adjust upwards to their equilibrium.

Figure 1: Revenue response functions to a unitary base shock for four categories over 15 years



4. TESTING THE SIGNIFICANCE OF A BUSINESS CYCLE INDICATOR IN REVENUE DEVELOPMENTS

While short-term revenue elasticities depart from their long-term value, the specific effect of the business cycle on short-term tax elasticities was very seldom studied. The difference between short term and long term elasticities is shown in the previous sections but also by a wealth of studies (see inter alia Princen *et al.*, 2013). It is further illustrated by the very erratic annual developments of tax revenue observed in many countries. The discrepancy between short-term and long-term tax elasticities may - in part - be the result of cyclical fluctuations, which implies that the short-term response of tax revenue to changes in its base may vary between downturns and upswings. Indeed, while the business cycle has an obvious and well documented impact on tax bases, its specific influence on the relationship between tax revenue and tax base was much less examined. Rare studies (Sancak *et al.*, 2010) investigated this particular aspect on a panel of countries, by adding a 'cyclical effect' in addition to the long-term relationship between revenue and tax base. The authors considered VAT revenue only and used a very simple specification, whereby all the short-term fluctuations around the long-term elasticity was attributed to the business cycle. We first replicate their specification for each of the four main revenue categories and, second, examine the impact of some headline business cycle indicators directly on the short-term elasticities for each of the four main revenue categories.

4.1. ESTIMATING THE IMPACT OF THE BUSINESS CYCLE

First and as done in Sancak *et al.*(2010), the impact of the business cycle is measured by using the output gap as additional variable in the long-term relationship to capture the short-term revenue dynamics. The cyclical term is meant to capture the short-term fluctuation in revenue, that is, the share of annual revenue which is not explained by the (constant) long-term elasticity (multiplied by the log of the corresponding tax base).

$$logAR_{i,c,t} = \alpha_0 + \alpha_1 logB_{i,c,t} + \alpha_2 Y_{GAP} + \gamma_{i,c,t} \qquad (5)$$

In equation (5), γ_{ict} is the error term of tax category c of country i in year t, α_1 denotes the long-term (time-invariant) revenue elasticity and α_2 measures the impact of the output gap, which varies over time. The equation is estimated with GLS using country fixed effects.

As a novelty, the paper estimates how much the short-term revenue elasticity is specifically influenced by the business cycle, allowing the revenue elasticity to differ from activity booms to economic downturns. This is done technically by introducing an interaction term between the tax base and a business cycle indicator. For the estimation of the short-term elasticity, this gives the following specification:

$$\Delta logAR_{i,c,t} = \beta_0 + \beta_1 \Delta logB_{i,c,t} + \beta_2 ECT_{i,c,t} + \beta_3 \Delta logB_{i,c,t} * BCI_{i,t} + \mu_{i,t} \qquad (6)$$

where BCI is a business cycle indicator. Therefore, the short-term elasticity can be written as $\beta_1 + \beta_3 * BCI_{i,t}$, with a constant component and a cyclically-driven component. Equation (6) is estimated using GLS with country fixed effects. For sake of completeness, we also ran the regression (6), where BCI is not interacted with the change in revenue but just introduced as a stand-alone variable. This allows one to check if the specification with interaction (one novelty of the paper) beats a simpler specification with the business cycle indicator added as a simple control variable. This simpler specification, nonetheless, remains more difficult to interpret, since the additional effect is independent from the change in the tax base. It may capture the development in the part of the real tax base that is not covered by the macroeconomic proxy used in the paper.

Various standard indicators of the business cycle are used to ascertain robustness of results. First, we use the *output gap* (Y_{GAP}). It is defined as the difference between potential and actual output and is a back-ward looking estimation of the business cycle. The output gap is measured *ex post* on the most updated series (including forecast used to compute its value for the last known years). It is often revised and could significantly depart from the real time estimate. Moreover, it is an unobserved variable and there are methodological debates on how to compute it best. Therefore, we also use *the sign of the output gap,* which could be defined as a dummy variable, returning one if the output gap is positive and zero otherwise. This measure captures whether or not the economy is running above potential. Its accuracy is less affected by the measurement issues related to the very level of the output gap. Third, we make use of the *capacity utilisation rate,* which is a key indicator of slack in the economy, allowing statisticians and economists to quantify the extent to which the available resources are used. As part of its Business and Consumer Survey (BCS) programme, DG ECFIN of the European Commission has been collecting a time series of capacity utilisation in the manufacturing industry on a quarterly basis, dating back to 1985. It gives a real time estimation of the economic cycle and is not revised after its first release. For sake of comparability with the output gap, the capacity utilisation rate is corrected for its average value. Hence, the *capacity utilisation gap* (CUG) used in the estimation is defined as the difference between the capacity utilisation rate and the average capacity utilisation rate of all observations. It boils down to a real-time output gap for the manufacturing sector based on survey data. As for the output gap, we also use *the sign of the capacity utilisation gap,* as an additional business cycle indicator.

4.2. RESULTS

The business cycle indicator added in the dynamic revenue equation appears significant for all types of revenue but consumption taxes, partly confirming the intuition of Sancak *et al.* about a specific impact of cyclical fluctuations on revenue elasticities. This appears when comparing our specifications (in Table 10) with the simpler specifications à la Sancak *et al.* (in Table 11), in which short-term adjustments are only captured by an indicator of the business cycle. The latter seems to play a role in both specifications in the case of personal income tax and social security contributions. However, consumption tax seems not to be significantly affected by the business cycle anymore, when duly taking into account the short-term dynamic response of revenue to tax base developments, as in equation 6 above (as opposed to equation 5 mirroring Sancak *et al.*'s specification). Conversely, the elasticity of the corporate income tax turns out to be actually affected by the business cycle, when taking proper account of the dynamic adjustment (in our specification, unlike in Sancak *et al.*). Our specification in Table 10 is more complete since it allows for isolating the specific impact of the business cycle on the revenue elasticity *per se* from the dynamic effect of tax base variations (also influenced by the business cycle). In general, while the level of the cyclical variable is significant, its sign, indicating whether the economy runs above or below its potential, is not significant. The remainder of the section covers in turn each specific type of tax, using the more complete specification (equation 6).

Table 10: Business cycle impact and cyclically-adjusted revenue to base elasticities

	Consumption tax	Social security contributions	Personal income tax	Corporate income tax
One-stage error-correction model using several business cycle indicators				
Business cycle impact				
ΔlogTax base*Y_{GAP}	0.01	0.03***	0.19***	0.49*
ΔlogTax base*Positive Y_{GAP}	0.00	0.00**	0.00	0.02
Y_{GAP} (as a stand-alone)	0.03	0.11**	0.73**	-0.20
ΔlogTax base*CUG	-0.01*	0.01**	0.06***	-0.14**
ΔlogTax base*Positive CUG	-0.00	0.00	0.00	-0.03
CUG (as a stand-alone)	-0.04*	-0.01	0.08	0.34***
Short-term elasticity controlling for the business cycle				
ΔlogTax base*Y_{GAP}	1.34***	0.74***	0.83***	0.54**
ΔlogTax base*Positive Y_{GAP}	1.39***	0.80***	1.18***	0.90***
Y_{GAP} (as a stand-alone)	1.36***	0.73***	0.82***	1.19***
ΔlogTax base*CUG	1.40***	0.79***	1.14***	1.22***
ΔlogTax base*Positive CUG	1.38***	0.81***	1.22***	1.25***
CUG (as a stand-alone)	1.38***	0.83***	1.31***	1.06***
Two-stage error-correction model using several business cycle indicators				
Business cycle impact				
ΔlogTax base*Y_{GAP}	0.03*	0.00	0.16***	0.56**
ΔlogTax base *Positive Y_{GAP}	0.00	0.00	0.00	0.02
Y_{GAP} (as a stand-alone)	-0.24***	0.15***	0.62**	-0.23
ΔlogTax base *CUG	-0.01	0.01	0.05***	-0.08*
ΔlogTax base *Positive CUG	0.00	0.00	0.01	-0.01
CUG (as a stand-alone)	-0.03	-0.02	0.06	-0.27***
Short-term elasticity controlling for the business cycle				
ΔlogTax base *Y_{GAP}	1.22***	0.85***	0.87***	0.26
ΔlogTax base *Positive Y_{GAP}	1.33***	0.85***	1.09***	0.65***
Y_{GAP} (as a stand-alone)	1.48***	0.75***	0.79***	0.88***
ΔlogTax base *CUG	1.33***	0.85***	1.08***	0.92***
ΔlogTax base *Positive CUG	1.32***	0.85***	1.09***	0.94***
CUG (as a stand-alone)	1.32***	0.86***	1.20***	0.77***

Note: For each specification of the cyclical effect, the table shows the effect of the business cycle and the value of the short term elasticity.

No clear evidence is found that the business cycle has an impact on the short-term revenue elasticity for consumption taxes. Whatever the business cycle indicator used, the impact of the cycle appears to be non-significant or of small magnitude. When significant, the result generally changes sign with another econometric specification (two-stage versus one-stage) or the use of CUG instead of the output gap.

The short-term revenue elasticity for social security contributions seems to be very slightly impacted by the business cycle. A positive output gap of 3% is estimated to increase the revenue-to-base elasticity up to 0.83, while a negative output gap of 3% is estimated to bring the revenue-to-base elasticity down to 0.65. The cyclical impact is still significant if one considers the CUG instead of the output gap, although of a smaller magnitude. A positive CUG of 3% would increase the revenue-to-base elasticity up to 0.82, while a negative CUG of 3% brings the revenue-to-base elasticity down to 0.76. Turning to robustness, while the cyclical effect (as an interaction term) is not significant anymore using a two-stage approach, the output gap used as a stand-alone is still very significant in this specification. The interpretation of this positive cyclical response could be that the elasticity of social security contributions to the wage bill increases (decreases) in good (bad) times since the share of low and very low wages tends to decline (increase), while they are subject to rebates or exemptions of social security contributions in many Member States in the context of making work pay policy. Moreover, the social security receipts may be reduced in bad times, with the increase of bankruptcies and undeclared work. These effects are however modest according to the econometric results shown in Table 10. A reason is that it could be at least partly offset by the capping in social security contributions, which could moderate the increase in social security contributions in good times.

Table 11: Business cycle impact in the specification à la Sancak *et al.*

	Consumption tax	Social security contributions	Personal income tax	Corporate income tax
Output gap used as control variable				
Long-term elasticity	0.99***	0.99***	1.13***	1.14***
Y_{GAP}	0.52***	-0.17***	0.42**	-0.20

For personal income tax, all the estimates suggest consistently that the short-term revenue-to-base elasticity varies substantially with cyclical conditions. A positive output gap of 3% increases the revenue-to-base elasticity up to 1.4, while a negative output gap of 3% brings the revenue-to-base elasticity down to around 0.6. The cyclical impact is also very significant when CUG is considered instead of the output gap. A positive output gap of 3% would increase the revenue-to-base elasticity up to 1.32, while a negative output gap of 3% reduces the revenue-to-base elasticity to around 0.95. Several factors might compound to explain this effect, for instance, the means-tested nature of some tax exemptions/reductions and the decrease in tax compliance in bad times (possibly due to a rise in liquidity constraints in poor households).

Corporate income tax appears to be the tax category that is most cyclically-dependent. The short-term elasticity of corporate income tax to its base increases by almost 0.5 per unit of output gap. With the output gap standing at -3%, -1%, 1% and 3%, the short-term elasticity is estimated at -0.9, 0.1, 1.0 and 2.0 respectively. The strong reliance of corporate income tax elasticities to the output gap is consistent with the fact that corporate income taxes are highly influenced by the legal possibility for firms to carry their losses forward to subsequent years, possibility more likely to be used in cyclical troughs. This may curtail tax revenue pervasively in bad cyclical conditions, even after a downturn has reached its low point. Another cyclical factor at play, not fully captured by macroeconomic measures of profit used in this paper, is the "zero bound" of corporate income taxes: in period of downturn, the proportion of firms displaying accounting losses (i.e. negative profits) is much higher, while these losses are not taxed.

The results for corporate income tax appear fairly robust. In particular, the sensitivity of elasticities to the output gap is robust to the choice of a one-step or two-step specification. However, it should be noted that the elasticity seems less sensitive to CUG than to the output gap, whereas the sign of the CUG impact is somehow counter-intuitive (negative, in some specifications albeit not all). CUG is less representative as a cyclical indicator, since it only covers the manufacturing sector, while the output gap also captures the cyclical pattern of the services sector which represents almost two thirds of the EU economies. A large proportion of corporate income taxes is indeed collected in the services sector. Moreover, the manufacturing sector generally offers a slightly different cyclical pattern, given its stronger dependence on the world demand compared with services sector, hinging more upon domestic demand.

5. CONCLUSION

This paper estimated the elasticities of revenue to tax base *at constant tax policy*, both in the short and long-term and for four revenue categories. This piece of research has the merit of considering revenue *net of discretionary measures*, so as to capture the endogenous variation of revenue, that is, corrected for the impact of tax policy changes, under the control of the government. As described in Annex 1 in more detail, data on discretionary tax measures come from a new database filled annually by Member States in the framework of the Output Gap Working Group (OGWG) and managed by the European Commission (DG ECFIN). Based on an EU country panel for the period 2001-13 and using different specifications, the paper investigates how revenue elasticities develop with respect to their tax base, for four revenue types, namely, consumption tax, social security contributions, personal income tax and corporate income tax. Both long- and short-term elasticities are estimated using one-stage and two-stage error correction models.

While the estimated values of the revenue-to-base elasticities are broadly in line with those found in previous research, the paper sheds light on the dynamic pattern of elasticities over time. Estimation of long-term elasticities shows that corporate income tax is by far the most elastic tax category, while other tax categories seem to evolve more or less proportionally to their tax base in the long-run. As regards the short-term elasticities, personal income tax was found to be the most elastic. As regards the adjustment to the long-term elasticity in the steady state, both personal and corporate income taxes have the highest adjustment speed. Overall, robustness tests, using different estimation models and specifications, confirm the value found for short-term and long-term elasticities.

A more in depth look at the elasticity of each type of tax points to very different values of elasticities in the short term, alongside differentiated robustness assessment. Consumption tax elasticity is estimated to be one or slightly exceeding one, both in the short-run and in the long-run. The error correction term indicates that when deviating from the long-term value, revenue returns to its long-run equilibrium after approximately three years. Robustness tests show that there is some uncertainty about the exact identification of short-term and long-term elasticities. The long-term social security contribution elasticity is close to one across all specifications, whereas the elasticity hovers around 0.85 in the short term. While the long term-elasticity of personal income tax stands slightly over unity, the short-term elasticity is estimated to be significantly above one, in line with the progressivity of this tax. Robustness tests show that there is some uncertainty about the identification of short-term versus long term elasticity of personal income tax. As expected, both the short-term and the long-term elasticities for corporate income tax are robustly estimated above unity.

As a novelty, the paper estimates how much the short-term revenue elasticity is specifically influenced by the business cycle, allowing the revenue elasticity to differ from activity booms to economic downturns. While short-term revenue elasticities are widely known to depart from their long-term value, the specific effect of the business cycle on short-term tax elasticities per se was very seldom studied. The paper investigates to what extent standard business cycle indicators can explain the volatility of short-term elasticities for each revenue category. Various (standard) indicators of the business cycle are used to ascertain the robustness of results (based on the concept of output gap or capacity utilisation rate).

The empirical results confirm the existence of a specific impact of the business cycle on short-term revenue elasticities – beyond the direct effect on the tax base – for all revenue categories, except for consumption taxes. Corporate income tax appears to be the tax category with the most cyclically-dependent elasticity of revenue. For personal income tax, all the estimates suggest consistently that the short-term revenue-to-base elasticity varies substantially with cyclical conditions. The short-term revenue elasticity for social security contributions seems to be impacted by the business cycle, but only very slightly. By contrast, no clear evidence is found for consumption tax that the business cycle has an impact on its short-term revenue elasticity.

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ANNEX 1 – DISCRETIONARY TAX MEASURES: AN EU-COUNTRY DATABASE

This annex provides further details on the discretionary tax measures database, as well as a broader analysis of the discretionary tax measures data collected for the period 2001-13 ([5]). It updates and extends the explanation and analysis made in Princen *et al.* (2013). The annex is organised as follows: Section 1 describes the database, as well as the data used for the main regressions and for the robustness checks performed in the paper. Section 2 digs into the composition and the pattern of discretionary tax measures.

A1.1. OGWG/ECFIN DATABASE ON DISCRETIONARY TAX MEASURES

The discretionary tax measures database is managed by DG ECFIN and contains data annually reported by Member States in the framework of the Output Gap Working Group (OGWG). The discretionary tax measures database is a web-based tool used in the context of the OGWG of the Economic Policy Committee (EPC) to collect data on individual discretionary tax measures. With this database the European Commission aims to foster a common understanding of discretionary tax measures across Member States. The country delegates of the OGWG are asked to annually report new discretionary tax measures data by updating the discretionary tax measures database. The timing of the annual reporting is broadly aligned with the submission of the Stability or Convergence Programmes (SCP). Up to now, four reporting exercises have been accomplished: 2008, 2011, 2013 and 2014. The next reporting exercise will be launched in April 2015.

According to the definition used by the OGWG, a discretionary tax measure is any legislative or administrative change in policy that has an impact on tax revenues. Strictly speaking, discretionary tax measures are not an ESA 95 ([6]) national account items. As discretionary tax measures result from a policy or an administrative decision, they should be distinguished from: (i) the impact of automatic and semi-automatic indexation or (ii) the revenue increases mandated by law, which occur automatically to offset corresponding increases in specified expenditures, such as an automatic rise in social security contributions in reaction to a surge in social security spending.

Member States are asked to report all individual measures with a budgetary impact accounting for at least 0.05% of GDP in a full year or across years. Individual discretionary tax measures are reported in millions of national currency and on an incremental basis (i.e. as a change with respect to the previous year). Member States are asked to classify the measures according to nine ESA95 categories ([7]) and to provide detailed information on each of them ([8]). As regards the time span, information is provided as from the year 2000 on. Figures related to the year of the reporting exercise and to the following years are assumed to be forecasted data.

As from the 2014 reporting exercise onward, Member States also report the annual aggregate value of all discretionary tax measures regardless of the threshold of 0.05% of GDP. The aggregate values will be referred to as "total reported" discretionary tax measures to distinguish them from the "sum" of individual discretionary tax measures. The main regression results are based on individual discretionary

([5]) This note considers the data reported until mid-October 2015, regardless of the changes that may have occurred after this date.
([6]) European System of National and Regional Accounts.
([7]) D.2r (taxes on production and imports); D.5r (current taxes on income and wealth for households and for corporations); D.61r (social contributions); P.1 (sales); D.39r (other subsidies on production); D.4r (property income); D.7r (other current transfers); D.9r (capital transfers).
([8]) Such as the year of first budgetary impact, the specification about being a one-off measure, the type of one-off measure, the accounting principle, the adoption status and the specification about the effect being policy-induced.

tax measures data, i.e. those exceeding the 0.05% threshold. Additional robustness checks have been performed by simulating a full discretionary tax measure database, i.e. by proportionally reallocating the difference between the total reported and the sum of individual discretionary tax measures to the different ESA95 categories ([9]) (see Table A1). This required, as a preliminary, the time series of the sum and of the total reported to be homogenised in terms of time span. As shown in Table A1, the two series differ for some Member States ([10]). When the "total reported" discretionary tax measures series is shorter than the "sum" discretionary tax measures series, the time series of the total reported was extended using a back-cast procedure based on the rate of change of the sum ([11]).

Table A1. Time series length of "total reported" and "sum" of discretionary tax measures (DTM)

Country	Time series length of the sum of individual DTM	Time series length of the total reported DTM	Back-cast procedure applied	Reallocation of the difference between the sum and the total reported DTM
BE	2000-2013	2000-2013	No	No
BG	2004-2013	2013	Yes	Yes
CZ	2000-2013 (2002)	2000-2013 (2002)	No	Partially
DK	2000-2013	2000-2013	No	Partially
DE	2000-2013	2011-2013	Yes	Yes
EE	2004-2013	2012-2013	Yes	Yes
IE	2000-2013	2011-2013	Yes	Yes
EL	2005-2013	2005-2013	No	No
ES	2000-2013 (2001)	2000-2013	No	Yes
FR	2001-2013	2001-2013	No	No
HR	2012-2013	2004-2013	No	Partially
IT	2001-2013	2001-2013	No	No
CY	2011 - 2013	2011-2013	No	No
LV	2000-2013	2014	Yes	Yes
LT	2001-2013	2001-2013	No	Partially
LU	2012 -2013	2012-2013	No	No
HU	2010 -2013	2010-2013	No	Yes
MT	2000-2013	2000-2013	No	Yes
NL	2001-2013	2001-2013	No	No
AT	2000-2013	2000-2013	No	No
PL	2000-2013	2000-2013	No	Partially
PT	2000-2013	2000-2013	No	No
RO	2010 -2013	2010-2013	No	Yes
SI	2006-2013	2006-2013	No	Partially
SK	2000-2013	2000-2013	No	Partially
FI	2001-2013	2005-2013	Yes	Partially
SE	2000-2013	2000-2013	No	Yes
UK	2001-2013	2001-2013	No	Yes

Note: The time span in the first and in the second column covers only the actual data (up to T-1) and not the forecast data (T, T+1, T+2…T+N). The only exception is made for Latvia (second column) as the data for 2014 is the only available. The years in parenthesis express the case in which there is a gap in the time series. The third column indicates if the back-cast procedure was applied. The fourth column indicates whether there is a difference between the total reported discretionary tax measures and the sum of individual discretionary tax measures that was reallocated to the original series. If the figures in the two series are the same across

([9]) The formula used is, for example in the case of D.r2 "taxes on production and imports", as follow:

$$DTM_{D.2r}^{rescaled} = \sum_{i=1}^{N} DTM_{D.2r\_i} + \left[\left(\frac{\sum_{i=1}^{N} DTM_{D.2r\_i}}{\sum_{i=1}^{N} DTM_{\_i}}\right) * \left(\sum_{i=1}^{N} DTM_{\_i} - Tot\ DTM\right)\right].$$

([10]) Column 1 and 2 of Table A1: this occurs for Bulgaria, Germany, Estonia, Spain, Finland, Croatia, Ireland, Latvia.

([11]) According to the following formula: $\mathrm{Tot}_{t-1} = \mathrm{Tot}_t * \left[\frac{\mathrm{Sum}_{t-1}}{\mathrm{Sum}_t}\right]$ where Tot is the aggregated value of discretionary tax measrues and Sum is the sum of the individual discretionary tax measures. T is the last year for which the variable Total is available. The time span considered for the back-cast exercise is 2001-13. The only exceptions are Latvia and Germany for which the base year is 2014.

the whole time series there is no reallocation (No), if the figures differs across the whole or across a part of the two time series there is a reallocation accordingly (Yes or Partially).

A1.2. DESCRIPTIVE RESULTS

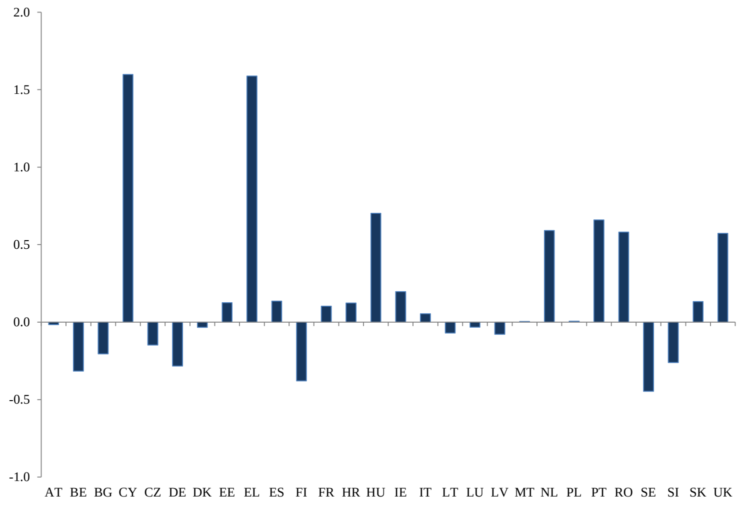
This section shows some descriptive results, providing evidence of the size, the composition and the pattern of discretionary tax measures. A first subsection describes their size and composition both at country level and for the European Union as a whole. A second subsection analyses the factors that impact the size and the structure of discretionary tax measures over time. For analytical purposes, discretionary tax measures data were combined with macroeconomic data from AMECO (Commission 2014 spring forecast) so as to express their budgetary impact as a percentage of GDP.

A1.2.1. SIZE AND COMPOSITION OF DISCRETIONARY TAX MEASURES

The average share of discretionary tax measures in the European Union as a whole over the period 2001-13 is almost nil (less than 0.1% of GDP, and specifically 0.02% for the euro area and 0.09% for the European Union) ([12]). This result can be explained by the fact that positive and negative observations tend to cancel out over the business cycle, as can be seen in Graph A1. Moreover, it has to be taken into account that as country business cycles are not fully synchronised and political cycles differ, discretionary tax hikes in one country tend to be offset by discretionary tax cuts in another country, in any given year.

However, this low average share for the European Union in the medium run conceals a great deal of heterogeneity at a disaggregated level:

Graph A1.1: Total discretionary tax measures (%GDP) in the 2014 reporting exercise by Member State, average 2001 – 13



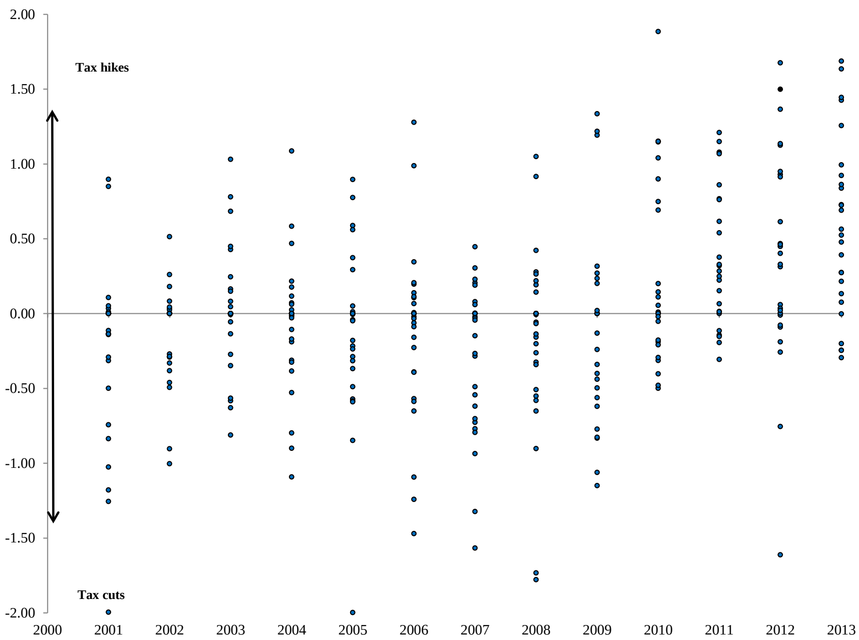
Note: The variable considered is the total reported of discretionary tax measures as calculated with the back-cast procedure described in the previous section. For some Member States, the limited time span allows to calculate the averages over the following time periods: for Cyprus 2011 -2013, for Hungary 2010 – 2013, for Luxembourg 2012 -2013, for Romania 2010 -2013.

([12]) The computation is made on the basis of the total reported of discretionary tax measures. In the calculation of the European Union average the data for Cyprus, Hungary, Luxembourg and Romania are not included because of the limited time span available (less than 5 observations).

- **First, the average size of discretionary measures over the whole period differs considerably among countries**, as they range from -0.45% of GDP (tax cuts) in Sweden to 1.59% of GDP (tax increases) in Greece. Slightly less than one third of the countries display an average share of discretionary tax measures below zero, reflecting tax cuts, whereas the remaining countries display an average share of discretionary tax measures above zero, reflecting tax hikes. A limited number of Member States shows an average close to zero (+/- 0.1 % of GDP).

- **Second, discretionary tax measures can be large for individual years in some countries**, as shown in the numerous outliers in Graph A1.2 ([13]). The absolute value of discretionary tax measures exceeds 1% of GDP in more than 50 occurrences. In the case of the Czech Republic (2009) and Portugal (2002 and 2010) discretionary tax increases were close to 2% of GDP, while discretionary tax cuts were close to 2% of GDP in the case of Ireland (2001) and Portugal (2005). Graph A2 also shows that the entire distribution shifted upward in 2012-13 compared with the previous years: most countries experienced a discretionary tax increase, as part of generalised consolidation strategies.

Graph A1.2: Total discretionary tax measures (% GDP) in the 2014 reporting exercise by Member State for each year, 2001–13



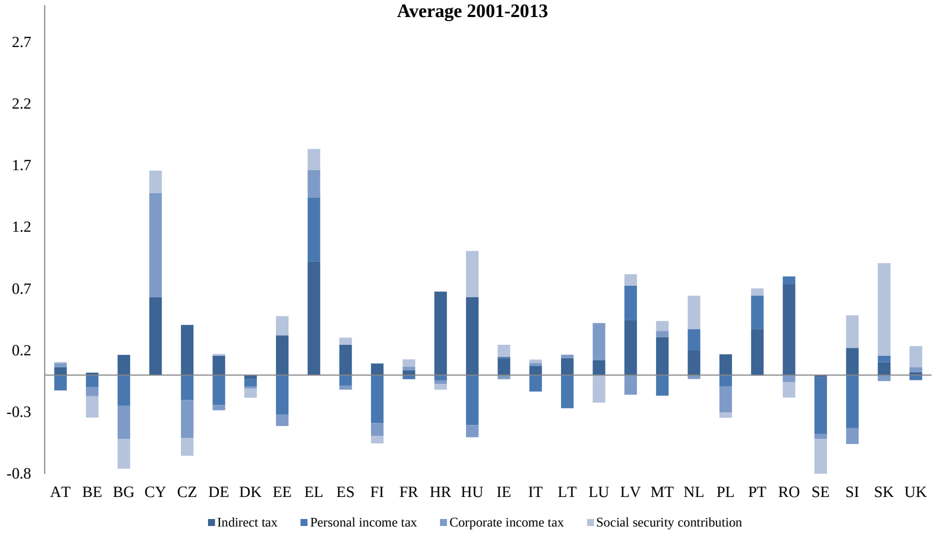
Note: The total discretionary tax measures is subject to the back-cast procedure described in the previous section. For some Member States, the limited time span both of the total discretionary tax measures and the sum does not allow for applying the back-cast procedure. Limited time periods regards: Cyprus (2011 -2013), Hungary (2010 – 2013), Luxembourg (2012 -2013) and Romania (2010 -2013).

- **Third, discretionary tax measures in specific tax categories might not be negligible in size but tend to have offsetting signs**. Within each country, tax shifts among tax categories seem indeed to be a common pattern. As suggested in Graph A1.3, discretionary tax cuts are mainly accounted for by direct taxes (for the average 2001-13): nineteen Member States applied tax cuts in personal

([13]) For the sake of graphical representation some "extreme" outliers are not included in Graph 4. It is the case of Cyprus with 2.2% (2013), Greece with 2.9% (2010), 3.7% (2011), 3.8% (2012), Hungary with 8.25% (2011) and -7.50% (2012), Ireland with 2.46 (2009) and Portugal with 3.9% (2011) and 3.0% (2013).

income taxes and eighteen Member States applied tax cuts in corporate income taxes. In thirteen countries the cuts were related both to personal and corporate income taxes. Considering the average 2011-13, the picture changes decisively suggesting a shift away from direct taxes. Indeed the number of Member States that kept cutting direct taxes decreases to nine for personal income taxes and to ten for corporate income taxes. In a considerable number of countries, the discretionary cuts in direct taxes are (partially) compensated by discretionary increases in indirect taxes, presumably as part of a growth-friendly tax shift.

Graph A1.3: Composition of discretionary tax measures (% GDP) in the 2014 reporting exercise by Member State, average 2001-13



Note: the variables considered are the sum of individual discretionary tax measures by ESA95 code. Indirect tax corresponds to D.2r, personal income tax to D.5r for households, corporate income tax to D.5r for corporations, social security contribution to D.61r. Only Belgium and the Netherlands have a full time series (2001-13) for all the four components shown in the graph. The average for the remaining Member States is computed for the available years.

A1.2.2. PATTERN OF DISCRETIONARY TAX MEASURES OVER TIME AND CHANGES IN THE TAX STRUCTURE

Three distinct policy regimes can be observed in the past decade for the European Union and the euro area (see Graph A1.4). The discretionary tax measures dataset allows for analysing discretionary policy from the revenue side over the period 2001-13 and, hence, covers the start of the financial crisis period 2008-10, as well as the fiscal consolidation period.

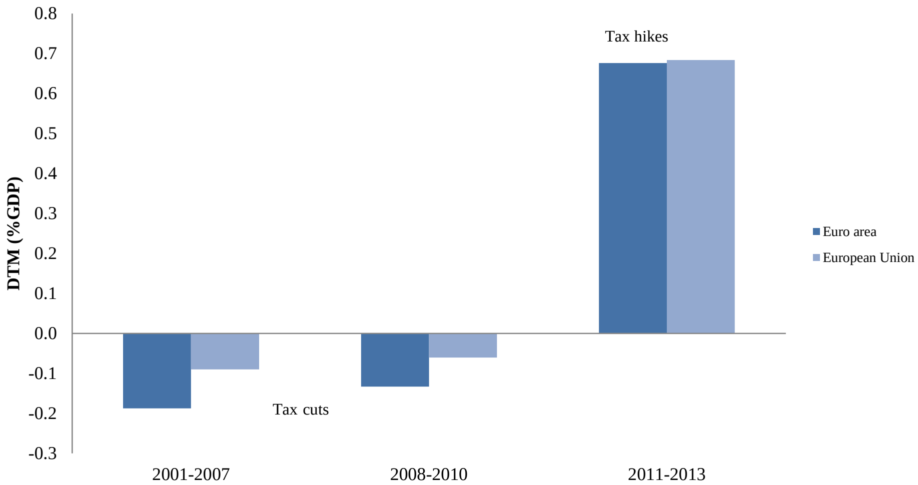
- **Pro-cyclical tax breaks in the pre-crisis boom** (2001-07), characterised by a slightly positive output gap in both the European Union (0.5%) and the euro area (0.7%) on average ([14]). During this period, discretionary tax measures mainly consisted of tax cuts (i.e. entailing lower revenue), providing evidence of mildly pro-cyclical tax policy. This 'benign neglect' was common in good fiscal times, when countries felt they could afford tax cuts, partly because of tax windfalls from booming asset prices.

([14]) The output gaps used here correspond to their ex-post value, as calculated in the Commission 2014 spring forecast, which may differ from real-time output gaps.

- **Counter-cyclical tax breaks in the crisis outbreak** (2008-10), characterised by a negative output gap in both the European Union and the euro area (-2.3%) on average. The crisis regime consisted of large stimulus measures, including tax cuts, which were therefore strongly counter-cyclical.

- **Pro-cyclical tax hikes in the context of fiscal consolidation** (2011-13), in a context of a negative output gap in both the European Union and the euro area (-2.1%) on average. During the consolidation period, characterised by the debt crisis and the lack of fiscal space, Member States have engaged in pro-cyclical tax hikes, as a way to consolidate their public finances, despite poor cyclical conditions. The reporting exercise 2014 indicated an average discretionary tax increase of around 0.7% of GDP both for European Union and euro area.

Graph A1.4: Total DTM over time (total as % GDP), weighted averages for euro area and European Union



Note: The variable considered is the total reported DTM subject to the back-cast procedure described in the previous section. All the 28 Member States are included in the calculation of the weighted average for European Union.

The picture is however different across tax categories:

- **In the pre-crisis period (2001-07), direct taxes were generally decreased**. This was partly financed by a tax shift toward indirect taxation, in particular consumption taxes.

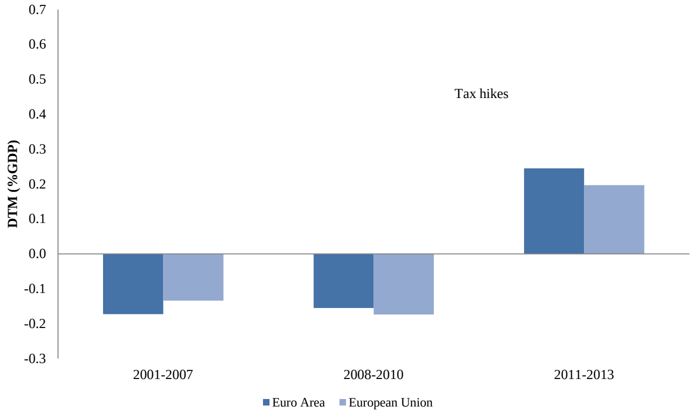
- **In the crisis outbreak period (2008-10), personal and corporate income taxes were further cut, while the trend increase of indirect taxes came to a halt.** The cuts in direct tax, which averaged at around ¼ pp of GDP in both the euro area and the European Union, were implemented in order to support a fast contracting economic activity. The concomitant stabilisation of indirect taxation as a % of GDP was presumably to avoid further depressing consumption in a period of strong contraction of the economic activity.

- **In the subsequent consolidation period (2011-13), discretionary tax hikes can be observed for all types of taxation.** The change in the policy regime, however, is more evident for direct taxes. Discretionary tax measures affecting labour (personal income tax and social security contributions) increases, as shown in Graph A1.5 ([15]). At the level of the European Union as a whole, this increase was lower than that seen in indirect taxes, suggesting that the share of labour taxation declines

([15]) Because of lack of information, it is implicitly assumed that most of personal income taxes relate to labour income. However, part of it corresponds to capital income taxation (taxation on household savings) and to the profits of individual entrepreneurs.

somewhat (although labour taxation increases in absolute terms). For the euro area as a whole, the increase in labour tax and indirect tax was broadly equivalent.

Graph A1.5: Discretionary measures affecting labour taxation over time (personal income taxes, as well as employees' and employers' social security contributions)



Note: Personal income tax corresponds to the sum of individual DTM belonging to the D5.r – Household ESA 95 code, corporate income tax to the D5.r – Corporations ESA 95 code, indirect taxes to the D2.r ESA 95 code, social security contribution to the D61.r ESA 95 code. All the 28 Member States are included in the calculation of the weighted average for EU, but the length of the time series for the ESA95 components of the DTM may vary across Member States.

These changes in the tax structure were different across countries. The size of the changes can be captured by the average absolute change in the tax composition, as shown in Graph A1.6 ([16]). Concerning the policy change between the "crisis regime" (2008-10) and the "consolidation regime" (2011-13), three groups of countries can be identified. The most affected Member States have been Greece, Estonia and Latvia with an average shift lying between 0.5% and 0.6% of GDP. The change in tax structure has also been relatively pronounced in Lithuania and Portugal. Other Member States have experienced more limited changes in their tax composition.

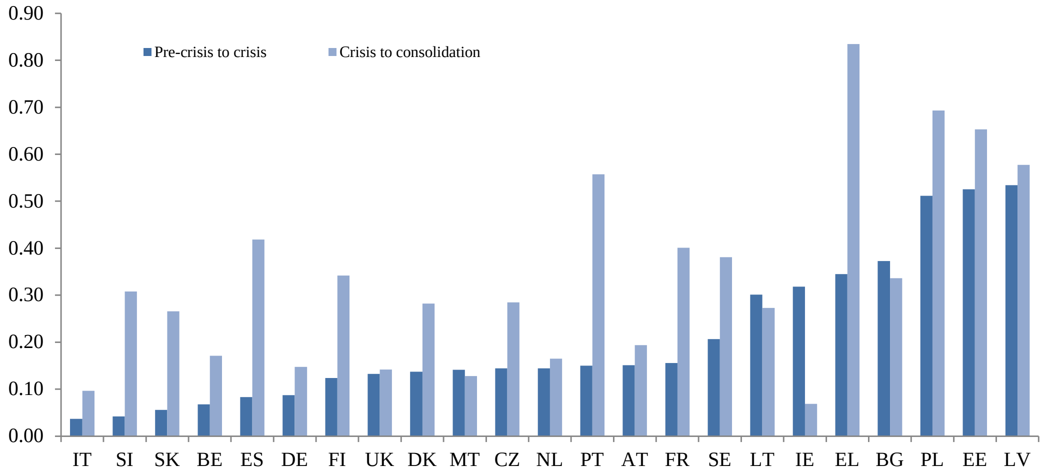
The recent changes in the structure (between the crisis outbreak and the consolidation period) were significantly stronger than the one seen between the pre-crisis period and the crisis outbreak. In a context of fiscal consolidation, Member States have significantly altered the structure of discretionary tax measures and increased taxes across the broad, including those usually considered by economists as distortive (personal income taxation and corporate income taxation). This pattern was seen in most countries, except in the case of Ireland and Lithuania.

Some countries have experienced an absolute tax shift away from labour, others a relative shift (see Graph A1.7). The tax shift is reflected in discretionary cuts in labour taxation, compensated (at least partly) by a rise in indirect taxation. More than one half of the Member States (Austria, Belgium, Bulgaria, Czech Republic, Germany, Estonia, Spain, Croatia, Finland, Hungary, Italy, Lithuania, Luxembourg, Malta, Poland and Slovenia) shifted taxes away from labour (2nd quadrant). Nine Member States increased both indirect taxes and labour taxes, but in different proportion. In Cyprus, Greece and Romania (and to a lesser extent in France, Ireland, Portugal and Latvia) the increase in labour taxes was lower than the increase in indirect taxes. This corresponds to an overall rise in the tax burden, with a relative shift away from labour (since the share of labour taxation in total tax revenue decreased). In contrast, the Netherlands (and to a lesser extent the United Kingdom and Slovakia) has increased the

([16]) The graph illustrates the two components of the average absolute change. The average absolute change in the tax composition takes into consideration the following categories of discretionary tax measures: personal income taxes, corporate income taxes, indirect taxes and social security contribution. In order to compute the average absolute change in tax structure the following formulas are applied: $Average\ Absolute\ Change = \{[(\sum_{i=1}^{4}|\bar{x}_{i_{01\_07}} - \bar{x}_{i_{08\_10}}|)/4] + [(\sum_{i=1}^{4}|\bar{x}_{i_{08\_10}} - \bar{x}_{i_{11\_13}}|)/4]\}/2$

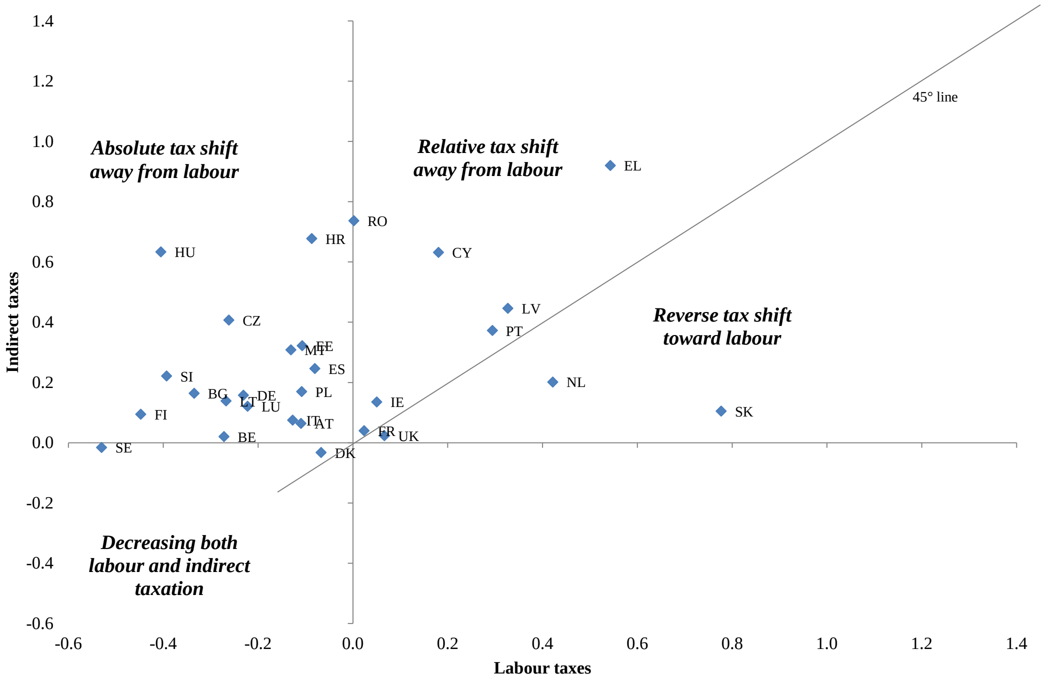
overall tax burden together with the share of labour taxation in total tax revenue (tax shifting to labour). Denmark registered a decrease both in labour and indirect taxation. Given the aforementioned offsetting patterns (across countries, across years and across tax categories), the small share of discretionary tax measures seems less surprising.

Graph A1.6: Average absolute change in tax structure (%GDP)



Note: given the limited length of the time series for indirect taxes, personal income taxes, corporate income taxes and social security contributions, the indicator cannot be computed for the following Member States: Croatia, Cyprus, Hungary, Luxembourg and Romania. Furthermore, the length of the time series for the four abovementioned ESA95 categories of discretionary tax measures may vary across Member States.

Graph A1.7. Indication of tax shifting using discretionary tax measures, average values 2001–13



Note: Labour taxation is defined as the sum of personal income tax and social security contributions. Personal income tax may also include taxation of capital income. This is a caveat of the analysis. In the case of Hungary, since most of the social security contributions are attributable to the private pension's fund that does not influence the amount of tax paid, labour taxes includes only personal income taxes. All 28 Member States are included in the graph, but the length of the time series for the three ESA95 components of the discretionary tax measures used may vary across Member States.

ANNEX 2 – ADDITIONAL REVENUE ELASTICITY ESTIMATIONS

This second annex provides further estimation results broadly confirming the results found previously. The annex is organised as follows: Section 1 provides additional regression results using the original discretionary tax measure database. Section 2 shows the regression results using a full discretionary tax measure database. Section 3 provides the estimations of long and short term elasticities corrected with a business cycle indicator.

A2.1. USING ALTERNATIVE ERROR CORRECTION MODELS TO ESTIMATE ELASTICITIES

Table A2.1.1: Revenue to base elasticities – Consumption taxes – One-stage

	(1) GLS	(2) GLS with lag	(3) GLS controls	(4) GLS with lag controls	(5) GLS with lag constrained
Long-term elasticity					
Log(Private consumption)(t-1)	0.87***	0.82***	0.91***	0.87***	1.00
	(0.04)°°°	(0.04)°°°	(0.04)°°	(0.04)°°°	(constrained)
Error-correction term	-0.33***	-0.40***	-0.33***	-0.38***	-0.95***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)
Short-term elasticity	1.30***	1.37***	1.12***	1.12***	1.35***
ΔLog(Private consumption)	(0.06)°°°	(0.06)°°°	(0.08)	(0.07)°	(0.08)
ΔLog(Private consumption)(t-1)	-	-0.12**	-	-0.34***	-0.08
		(0.06)		(0.08)	(0.09)
ΔLog(Residential investment)	-	-	0.07***	0.07***	0.07***
			(0.02)	(0.02)	(0.02)
ΔLog(Residential investment)(t-1)	-	-	-	0.01	0.03
				(0.02)	(0.02)
ΔLog(Government)	-	-	0.05	0.22***	0.14**
			(0.05)	(0.05)	(0.05)
ΔLog(Government)(t-1)	-	-	-	0.04	0.09*
				(0.05)	(0.05)
Observations	336	308	324	297	297

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.1.2: Revenue to base elasticities – Social security contributions – Two-stage

	(1) GLS	(2) DGLS	(3) (D)GLS constrained
Long-term elasticity			
Log(Compensation)	0.93***	0.90***	1.00
	(0.02)°°°	(0.02)°°°	(constrained)
Observations	355	271	355
Short-term elasticity			
ΔLog(Compensation)	0.83***	0.85***	0.85***
	(0.02)°°°	(0.02)°°°	(0.03)°°°
Error-correction term	-0.24***	-0.22***	-0.02***
	(0.03)	(0.03)	(0.01)
Observations	327	271	327

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.1.3: Revenue to base elasticities – Personal income taxes – Two-stage

	(1) GLS	(2) DGLS	(3) GLS additional controls	(4) DGLS additional controls	(5) DGLS constrained
Long-term elasticity					
Log(Gross wage)	1.11***	1.12***	0.84***	0.54**	1.00
	(0.07)	(0.14)	(0.10)	(0.22)°°	(constrained)
Log(House prices)	-	-	0.23***	0.31***	0.15**
			(0.06)	(0.11)	(0.07)
Observations	324	248	314	240	243
Short-term elasticity					
Δ Log(Gross wage)	1.16***	1.16***	0.84***	0.42*	0.55*
	(0.15)	(0.16)	(0.21)	(0.24)°°	(0.31)
Δ Log(House prices)	-	-	0.20***	0.40***	0.07
			(0.05)	(0.05)	(0.08)
Error-correction term	-0.57***	-0.61***	-0.61***	-0.62***	-0.48***
	(0.05)	(0.06)	(0.05)	(0.06)	(0.06)
Observations	296	246	287	239	240

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.1.4: Revenue to base elasticities – Corporate income taxes – Two-stage

	(1) GLS	(2) DGLS	(3) GLS additional controls	(4) DGLS additional controls	(5) DGLS constrained
Long-term elasticity					
Log(Corporate profits)	1.32***	1.02***	1.22***	0.91***	1.00
	(0.10)°°°	(0.09)	(0.12)°	(0.11)	(constrained)
Log(Corporate tax rate)	-	-	-0.27	-0.14	0.02
			(0.19)	(0.16)	(0.14)
Observations	329	252	329	252	257
Short-term elasticity					
Δ Log(Corporate profits)	1.03***	0.90***	0.95***	0.88***	0.25***
	(0.17)	(0.17)	(0.16)	(0.16)	(0.08)°°°
Δ Log(Corporate tax rate)	-	-	0.23	0.13	0.48
			(0.23)	(0.32)	(0.31)
Error-correction term	-0.65***	-0.61***	-0.68***	-0.62***	-0.43***
	(0.09)	(0.09)	(0.09)	(0.09)	(0.07)
Observations	296	246	296	246	248

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.1.5: Revenue to base elasticities – Personal and corporate income taxes – One-stage

	(1) GLS	(2) GLS with lag	(3) GLS controls	(4) GLS with lag controls	(5) GLS with lag constrained
Long-term elasticity					
Gross wage	0.75***	0.66***	0.82***	0.79***	1.00 (constrained)
Corporate profits	0.42***	0.51***	0.36***	0.41***	1.00 (constrained)
Log(Gross wage)(t-1)	0.36***	0.29***	0.39***	0.33***	-
	(0.06)°°	(0.07)°°°	(0.07)°	(0.07)	
Log(Corporate profits)(t-1)	0.20***	0.22***	0.17***	0.17***	-
	(0.04)°°°	(0.05)°°°	(0.04)°°°	(0.05)°°°	
Error-correction term	-0.49***	-0.43***	-0.48***	-0.42***	-1.43**
	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
Short-term elasticity					
Δ Log(Gross wage)	1.28***	1.28***	1.24***	1.20***	1.51***
	(0.11)°°	(0.11)°°	(0.13)°	(0.14)	(0.19)
Δ Log(Corporate profits)	0.30***	0.33***	0.28***	0.29***	0.47***
	(0.05)°°°	(0.05)°°°	(0.05)°°°	(0.06)°°°	(0.06)°°°
Δ Log(Gross wage)(t-1)	-	0.12	-	0.12	0.75***
		(0.10)		(0.12)	(0.18)
Δ Log(Corporate profits) (t-1)	-	-0.03	-	-0.01	-0.23***
		(0.05)		(0.05)	(0.06)
Δ Log(House prices)	-	-	0.05	0.07**	0.10**
			(0.03)	(0.03)	(0.04)
Δ Log(House prices)(t-1)	-	-	-	-0.01	0.01
				(0.03)	(0.04)
Δ Log(Corporate tax rate)	-	-	0.01	0.02	-0.02
			(0.05)	(0.05)	(0.06)
Δ Log(Corporate tax rate) (t-1)	-	-	-	0.03	0.02
				(0.05)	(0.05)
Observations	318	291	308	282	282

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.1.6: Revenue to base elasticities – Personal and corporate income taxes – Two-stage

	(1) GLS	(2) DGLS	(3) GLS additional controls	(4) DGLS additional controls	(5) DGLS constrained
Long-term elasticity					
Log(Gross wage)	0.75***	0.99***	0.56***	0.76***	1.00
	(0.08)°°°	(0.12)	(0.09)°°°	(0.14)°	(constrained)
Log(Corporate profits)	0.24***	0.11	0.25***	0.08	1.00
	(0.07)°°°	(0.11)°°°	(0.07)°°°	(0.11)°°°	(constrained)
Log(House prices)	-	-	0.11***	0.07*	-0.23***
			(0.02)	(0.04)	(0.04)
Log(Corporate tax rate)	-	-	-0.10*	-0.26***	0.28**
			(0.06)	(0.09)	(0.13)
Observations	345	264	334	256	260
Short-term elasticity					
Δ Log(Gross wage)	1.21***	1.22***	1.03***	1.00***	0.83***
	(0.09)°°	(0.09)°°	(0.11)	(0.11)	(0.12)
Δ Log(Corporate profits)	0.22***	0.35***	0.22***	0.28***	0.26***
	(0.04)°°°	(0.04)°°°	(0.04)°°°	(0.04)°°°	(0.05)°°°
Δ Log(House prices)	-	-	0.06*	0.10***	0.09**
			(0.03)	(0.03)	(0.04)
Δ Log(Corporate tax rate)	-	-	0.03	-0.07	0.00
			(0.05)	(0.05)	(0.05)
Error-correction term	-0.46***	-0.50***	-0.49***	-0.50***	-0.07***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.02)
Observations	318	264	308	256	257

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

A2.2. USING A FULL DISCRETIONARY TAX MEASURE DATABASE TO ESTIMATE REVENUE ELASTICITIES

As explained in Annex 1, additional robustness checks have been performed by simulating a full discretionary tax measure database. By proportionally reallocating the difference between the total reported and the sum of individual discretionary tax measures to the different ESA95 categories (see Table A1), a full discretionary tax measure database has been simulated. This allows testing the robustness of the results found in the main section.

Table A2.2.1: Revenue to base elasticities – Consumption taxes – One-stage

	(1) GLS	(2) GLS with lag	(3) GLS controls	(4) GLS with lag controls	(5) GLS with lag constrained
Long-term elasticity	0.82***	0.77***	0.87***	0.83***	1.00 (constrained)
Log(Private consumption)(t-1)	0.25*** (0.04)°°°	0.33*** (0.04)°°°	0.28*** (0.04)°°°	0.34*** (0.04)°°°	
Error-correction term	-0.31*** (0.04)	-0.43*** (0.04)	-0.32*** (0.04)	-0.41*** (0.04)	-0.92*** (0.02)
Short-term elasticity ΔLog(Private consumption)	1.31*** (0.07)°°°	1.37*** (0.07)°°°	1.12*** (0.10)	1.12*** (0.09)	1.41*** (0.09)
ΔLog(Private consumption)(t-1)	-	-0.08 (0.07)	-	-0.36*** (0.10)	-0.13*** (0.10)
ΔLog(Residential investment)	-	-	0.06*** (0.02)	0.07*** (0.02)	0.07*** (0.02)
ΔLog(Residential investment)(t-1)	-	-	-	0.02 (0.02)	0.04* (0.02)
ΔLog(Government)	-	-	0.11* (0.06)	0.23*** (0.06)	0.20*** (0.07)
ΔLog(Government)	-	-	-	0.07 (0.06)	0.19*** (0.06)
Observations	336	308	324	297	297

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.2: Revenue to base elasticities – Consumption taxes – Two-stage

	(1) GLS	(2) DGLS	(3) GLS additional controls	(4) DGLS additional controls	(5) DGLS constrained
Long-term elasticity					
Log(Private consumption)	1.05***	1.15***	0.97***	1.08***	1.00
	(0.03)°°	(0.05)°°°	(0.09)	(0.12)	(constrained)
Log(Residential investment)	-	-	0.19***	0.20***	0.21***
			(0.02)	(0.02)	(0.02)
Log(Government)	-	-	-0.12	-0.21**	-0.17***
			(0.08)	(0.11)	(0.05)
Observations	352	265	339	255	255
Short-term elasticity					
ΔLog(Private consumption)	1.35***	1.26***	1.07***	1.09***	1.02***
	(0.06)°°°	(0.06)°°°	(0.08)	(0.09)	(0.10)
ΔLog(Residential investment)	-	-	0.10***	0.08***	0.05**
			(0.02)	(0.02)	(0.02)
ΔLog(Government)	-	-	-0.01	-0.07	-0.09
			(0.05)	(0.05)	(0.06)
Error-correction term	-0.25***	-0.35***	-0.30***	-0.42***	-0.12***
	(0.04)	(0.04)	(0.04)	(0.05)	(0.02)
Observations	322	265	310	255	255

Note: Using aggregated data generated some large difference in the adjusted indirect tax revenue for some countries in some years. Hence, the observations for which the adjusted indirect tax revenue was identified as outlier, were dropped from the dataset, i.e. the Czech Republic for the years 2001 and 2003-07, as well as Latvia for the years 2003-08. Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.3: Revenue to base elasticities – Social security contributions – One-stage

	(1) GLS	(2) GLS with lag	(3) GLS with lag constrained
Long-term elasticity	0.99***	1.02***	1.00
			(constrained)
Log(Compensation)(t-1)	0.23***	0.20***	
	(0.04)	(0.04)	
Error-correction term	-0.23***	-0.20***	-0.96***
	(0.03)	(0.03)	(0.01)
Short-term elasticity	0.88***	0.86***	0.91***
ΔLog(Compensation)	(0.03)°°°	(0.04)°°°	(0.04)°°°
ΔLog(Compensation)(t-1)	-	0.07*	-0.03
		(0.04)	(0.04)
Observations	327	299	299

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.4: Revenue to base elasticities – Social security contributions – Two-stage

	(1) GLS	(2) DGLS	(3) (D)GLS constrained
Long-term elasticity			
Log(Compensation)	0.91***	0.88***	1.00
	(0.02)°°°	(0.03)°°°	(constrained)
Observations	355	271	355
Short-term elasticity			
ΔLog(Compensation)	0.85***	0.86***	0.88***
	(0.03)°°°	(0.03)°°°	(0.03)°°°
Error-correction term	-0.20***	-0.18***	-0.02**
	(0.03)	(0.03)	(0.01)
Observations	327	271	327

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.5: Revenue to base elasticities – Personal income taxes – One-stage

	(1) GLS	(2) GLS with lag	(3) GLS controls	(4) GLS with lag controls	(5) GLS with lag constrained
Long-term elasticity	1.11***	1.04***	1.13***	1.03***	1.00
					(constrained)
Log(Gross wage)(t-1)	0.62***	0.64***	0.62***	0.62***	-
	(0.07)	(0.08)	(0.07)°	(0.09)	
Error-correction term	-0.56***	-0.61***	-0.55***	-0.60***	-0.78***
	(0.05)	(0.06)	(0.05)	(0.06)	(0.04)
Short-term elasticity	1.13***	1.36***	1.01***	1.45***	1.54***
Δ Log(Gross wage)	(0.19)	(0.23)	(0.22)	(0.28)	(0.28)
Δ Log(Gross wage)(t-1)	-	0.03	-	0.05	0.12
		(0.18)		(0.24)	(0.25)
Δ Log(House prices)	-	-	0.10*	0.02	0.07
			(0.05)	(0.06)	(0.06)
Δ Log(House prices)(t-1)	-	-	-	-0.05	0.00
				(0.07)	(0.06)
Observations	296	271	287	263	263

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.6: Revenue to base elasticities – Personal income taxes – Two-stage

	(1) GLS	(2) DGLS	(3) GLS additional controls	(4) DGLS additional controls	(5) DGLS (constrained)
Long-term elasticity					
Log(Gross wage)	1.10***	1.08***	0.84***	0.57**	1.00
	(0.08)	(0.15)	(0.11)	(0.23)°	(constrained)
Log(House prices)	-	-	0.22***	0.27**	0.12
			(0.06)	(0.11)	(0.07)
Observations	322	243	312	235	238
Short-term elasticity					
Δ Log(Gross wage)	1.10***	1.03***	0.81***	0.56***	0.67**
	(0.15)	(0.16)	(0.20)	(0.19)°°	(0.31)
Δ Log(House prices)	-	-	0.19***	0.32***	0.04
			(0.05)	(0.04)	(0.09)
Error-correction term	-0.54***	-0.54***	-0.58***	-0.53***	-0.39***
	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)
Observations	293	241	284	234	235

Note: Using aggregated data generated some large difference in the adjusted personal income tax revenue for some countries in some years. Hence, the observations for which the adjusted personal income tax revenue was identified as outlier were dropped from the dataset, i.e. the Czech Republic for the years 2006-07. Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.7: Revenue to base elasticities – Corporate income taxes – One-stage

	(1) GLS	(2) GLS with lag	(3) GLS controls	(4) GLS with lag controls	(5) GLS with lag constrained
Long-term elasticity	1.44***	1.51***	1.37***	1.29***	1.00 (constrained)
Log(Corporate profits)(t-1)	0.99***	0.95***	0.96***	0.89***	-
	(0.15)°°°	(0.17)°°°	(0.15)°°°	(0.17)	
Error-correction term	-0.68***	-0.63***	-0.71***	-0.69***	-0.75***
	(0.10)	(0.10)	(0.10)	(0.11)	(0.08)
Short-term elasticity	1.18***	1.13***	1.11***	1.01***	1.05***
Δ Log(Corporate profits)	(0.22)	(0.23)	(0.23)	(0.24)	(0.19)°°°
Δ Log(Corporate profits) (t-1)	-	-0.08	-	-0.12	-0.16
		(0.19)		(0.19)	(0.17)
Δ Log(Corporate tax rate)	-	-	0.36	0.45*	0.42
			(0.24)	(0.27)	(0.26)
Δ Log(Corporate tax rate) (t-1)	-	-	-	0.41	0.38
				(0.27)	(0.27)
Observations	296	271	296	271	271

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.8: Revenue to base elasticities – Corporate income taxes – Two-stage

	(1) GLS	(2) DGLS	(3) GLS additional controls	(4) DGLS additional controls	(5) DGLS (constrained)
Long-term elasticity					
Log(Corporate profits)	1.37***	1.09***	1.26***	0.97***	1.00
	(0.10)°°°	(0.10)	(0.13)°°	(0.12)	(constrained)
Log(Corporate tax rate)	-	-	-0.27	-0.16	-0.06
			(0.20)	(0.18)	(0.15)
Observations	329	252	329	252	257
Short-term elasticity					
Δ Log(Corporate profits)	1.03***	0.93***	0.95***	0.91***	0.23***
	(0.18)	(0.18)	(0.17)	(0.17)	(0.07)°°°
Δ Log(Corporate tax rate)	-	-	0.21	0.14	0.46
			(0.23)	(0.32)	(0.28)
Error-correction term	-0.67***	-0.62***	-0.70***	-0.64***	-0.46***
	(0.09)	(0.09)	(0.09)	(0.10)	(0.07)
Observations	296	246	296	246	248

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.9: Revenue to base elasticities – Personal and corporate income taxes – One-stage

	(1) GLS	(2) GLS with lag	(3) GLS controls	(4) GLS with lag controls	(5) GLS with lag constrained
Long-term elasticity					
Gross wage	0.78***	0.67***	0.89***	0.82***	1.00 (constrained)
Corporate profits	0.42***	0.51***	0.33***	0.40***	1.00 (constrained)
Log(Gross wage)(t-1)	0.40***	0.29***	0.45***	0.36***	-
	(0.07)°	(0.07)°°	(0.08)	(0.08)	
Log(Corporate profits)(t-1)	0.21***	0.22***	0.17***	0.17***	-
	(0.05)°°°	(0.05)°°°	(0.05)°°°	(0.06)°°°	
Error-correction term	-0.51***	-0.44***	-0.51***	-0.43***	-1.37***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
Short-term elasticity					
Δ Log(Gross wage)	1.35***	1.31***	1.30***	1.22***	1.20***
	(0.13)°°°	(0.14)°°	(0.15)°°	(0.16)	(0.21)
Δ Log(Corporate profits)	0.31***	0.34***	0.28***	0.30***	0.52***
	(0.05)°°°	(0.06)°°°	(0.06)°°°	(0.06)°°°	(0.07)°°°
Δ Log(Gross wage)(t-1)	-	0.18	-	0.18	0.78***
		(0.12)		(0.14)	(0.20)
Δ Log(Corporate profits)(t-1)	-	-0.04	-	-0.02	-0.24***
		(0.05)		(0.05)	(0.06)
Δ Log(House prices)	-	-	0.06	0.09**	0.10**
			(0.04)	(0.04)	(0.05)
Δ Log(House prices)(t-1)	-	-	-	-0.01	0.03
				(0.04)	(0.05)
Δ Log(Corporate tax rate)	-	-	0.01	0.01	-0.05
			(0.05)	(0.06)	(0.06)
Δ Log(Corporate tax rate)(t-1)	-	-	-	0.02	-0.01
				(0.05)	(0.06)
Observations	318	291	308	282	282

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.2.10: Revenue to base elasticities – Personal and corporate income taxes – Two-stage

	(1) GLS	(2) DGLS	(3) GLS additional controls	(4) DGLS additional controls	(5) DGLS (constrained)
Long-term elasticity					
Log(Gross wage)	0.71***	0.95***	0.54***	0.76***	1.00
	(0.08)°°°	(0.13)	(0.09)°°°	(0.15)	(constrained)
Log(Corporate profits)	0.25***	0.13	0.25***	0.10	1.00
	(0.08)°°°	(0.12)°°°	(0.08)°°°	(0.12)°°°	(constrained)
Log(House prices)	-	-	0.10***	0.02	-0.27***
			(0.03)	(0.04)	(0.04)
Log (Corporate tax rate)			-0.13**	-0.38***	0.18
			(0.06)	(0.10)	(0.14)
Observations	342	259	331	251	255
Short-term elasticity					
Δ Log(Gross wage)	1.21***	1.19***	1.01***	1.00***	0.83***
	(0.10)°°	(0.10)°°	(0.13)	(0.12)	(0.13)
Δ Log(Corporate profits)	0.24***	0.35***	0.24***	0.28***	0.26***
	(0.05)°°°	(0.04)°°°	(0.05)°°°	(0.05)°°°	(0.05)°°°
Δ Log(House prices)	-	-	0.05	0.10***	0.08*
			(0.04)	(0.04)	(0.04)
Δ Log(Corporate tax rate)			0.02	-0.08	-0.02
			(0.05)	(0.05)	(0.06)
Error-correction term	-0.38***	-0.45***	-0.40***	-0.45***	-0.07***
	(0.04)	(0.05)	(0.05)	(0.05)	(0.02)
Observations	314	259	304	251	252

Note: Using aggregated data generated some large difference in the adjusted direct tax revenue for some countries in some years. Hence, the observations for which the adjusted direct tax revenue was identified as outlier were dropped from the dataset, i.e. the Czech Republic for the years 2001 and 2004-05. Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

A2.3. REVENVUE ELASTICITIES CORRECTED WITH A BUSINESS CYCLE INDICATOR

Table A2.3.1: Cyclically-adjusted revenue to base elasticities

	(1) Consumption taxes	(2) Social security contributions	(3) Personal income taxes	(4) Corporate income taxes
Long-term elasticity				
Log(Private consumption)	0.99***	-	-	-
	(0.02)°°°			
Log(Compensation)	-	0.99***	-	-
		(0.01)		
Log(Gross wage)	-	-	1.13***	-
			(0.04)	
Log (Corporate profits)	-	-	-	1.14***
				(0.09)
Standard rate				
VAT	0.27	-	-	-
	(0.28)			
PIT	-	-	0.42***	-
			(0.15)	
CIT	-	-	-	-1.96
				(0.71)
Observations	362	353	321	327

Note: Y_{GAP} denotes the output gap. Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.1: Cyclically-adjusted revenue to base elasticities – Consumption taxes – One-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Long-term elasticity	0.82***	0.83***	0.83***	0.83***
Log(Private consumption)(t-1)	0.33***	0.34***	0.33***	0.34***
	(0.04)°°°	(0.04)°°	(0.04)°°	(0.04)°
Error-correction term	-0.40***	-0.41***	-0.40***	-0.40***
	(0.04)	(0.04)	(0.04)	(0.04)
Short-term elasticity	1.34***	1.39***	1.37***	1.36***
Δ Log (Private consumption)	(0.08)	(0.07)	(0.07)	(0.06)
Δ Log (Private consumption)(t-1)	-0.11*	-0.12**	-0.12*	-0.12**
	(0.06)	(0.06)	(0.06)	(0.06)
Δ Log (Private consumption)*Y_{GAP}	0.00	-	-	-
	(0.01)			
Δ Log (Private consumption) * dummy positive Y_{GAP}	-	-0.00	-	-
		(0.00)		
Δ Log (Private consumption)*CUG	-	-	-0.00	-
			(0.01)	
Capacity utilisation gap (CUG)	-	-	-	0.02
				(0.02)
Observations	308	308	308	308

Note: Y_{GAP} denotes the output gap. Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.2: Cyclically-adjusted revenue to base elasticities – Social contributions – One-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Long-term elasticity	0.99***	0.99***	1.00***	1.00***
Log(Compensation)(t-1)	0.22***	0.22***	0.21***	0.19***
	(0.04)	(0.03)°	(0.03)	(0.03)
Error-correction term	-0.22***	-0.22***	-0.21***	-0.19***
	(0.03)	(0.03)	(0.03)	(0.03)
Short-term elasticity	0.74***	0.80***	0.78***	0.79***
Δ Log (Compensation)	(0.05)°°°	(0.03)°°°	(0.03)°°°	(0.03)°°°
Δ Log (Compensation)(t-1)	0.13***	0.08***	0.11***	0.08***
	(0.04)	(0.03)	(0.03)	(0.03)
Δ Log (Compensation)*Y_{GAP}	0.03***	-	-	-
	(0.01)			
Δ Log (Compensation) * dummy positive Y_{GAP}	-	0.00	-	-
		(0.00)		
Δ Log (Compensation)*CUG	-	-	0.02***	-
			(0.00)	
Capacity utilisation gap (CUG)	-	-	-	0.03***
				(0.01)
Observations	299	299	299	299

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.3: Cyclically-adjusted revenue to base elasticities – Personal income taxes – One-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Long-term elasticity	1.01***	1.03***	1.03***	1.02***
Log(Gross wage)(t-1)	0.62***	0.62***	0.65***	0.65***
	(0.07)°°°	(0.08)°°°	(0.08)°°°	(0.08)°°°
Error-correction term	-0.61***	-0.60***	-0.63***	-0.63***
	(0.06)	(0.06)	(0.06)	(0.06)
Short-term elasticity	0.83***	1.18***	1.21***	1.46***
Δ Log (Gross wage)	(0.24)	(0.23)	(0.22)	(0.24)°°°
Δ Log (Gross wage)(t-1)	0.22	0.04	0.08	-0.02
	(0.16)	(0.17)	(0.17)	(0.17)
Δ Log (Gross wage) * Y_{GAP}	0.19***	-	-	-
	(0.04)			
Δ Log (Gross wage) * dummy positive Y_{GAP}	-	0.00	-	-
		(0.00)		
Δ Log (Gross wage) * CUG	-	-	0.06***	-
			(0.02)	
Capacity utilisation gap (CUG)	-	-	-	-0.11
				(0.07)
Observations	271	271	271	271

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.4: Cyclically-adjusted revenue to base elasticities – Corporate income taxes – One-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Long-term elasticity	1.37***	1.42***	1.52***	1.52***
Log(Corporate profits) (t-1)	0.79***	0.86***	0.91***	0.96***
	(0.16)°	(0.16)°°	(0.16)°°	(0.17)°°°
Error-correction term	-0.57***	-0.61***	-0.60***	-0.63***
	(0.11)	(0.11)	(0.11)	(0.11)
Short-term elasticity	0.54**	0.90***	0.88***	1.01***
Δ Log (Corporate profits)	(0.27)	(0.23)	(0.23)	(0.22)
Δ Log (Corporate profits)(t-1)	-0.20	-0.13	-0.05	-0.14
	(0.16)	(0.18)	(0.19)	(0.19)
Δ Log (Corporate profits) * Y_{GAP}	0.49*	-	-	-
	(0.25)			
Δ Log (Corporate profits) * dummy positive Y_{GAP}	-	0.02 (0.01)	-	-
Δ Log (Corporate profits) * CUG	-	-	0.19***	-
			(0.07)	
Capacity utilisation gap (CUG)	-	-	-	0.32***
				(0.11)
Observations	271	271	271	271

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.1: Cyclically-adjusted revenue to base elasticities – Consumption taxes – Two-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Short-term elasticity	1.22***	1.33***	1.31***	1.32***
Δ Log (Private consumption)	(0.07)	(0.06)	(0.06)	(0.06)
Error-correction term (t-1)	-0.32***	-0.34***	-0.33***	-0.33***
	(0.04)	(0.04)	(0.04)	(0.04)
Δ Log (Private consumption)*Y_{GAP}	0.03*	-	-	-
	(0.02)			
Δ Log (Private consumption) * dummy positive Y_{GAP}	-	0.00 (0.00)	-	-
Δ Log (Private consumption)*CUG	-	-	0.00	-
			(0.01)	
Capacity utilisation gap (CUG)	-	-	-	0.00
				(0.03)
Observations	280	280	280	280

Note: Y_{GAP} denotes the output gap. Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.2: Cyclically-adjusted revenue to base elasticities – Social contributions – Two-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Short-term elasticity	0.85***	0.85***	0.85***	0.83***
Δ Log (Compensation)	(0.03)°°°	(0.02)°°°	(0.02)°°°	(0.07)°°°
Error-correction term (t-1)	-0.22***	-0.22***	-0.22***	-0.21***
	(0.03)°°°	(0.03)°°°	(0.03)°°°	(0.03)°°°
Δ Log (Compensation)*Y_{GAP}	0.00	-	-	-
	(0.01)			
Δ Log (Compensation) * dummy positive Y_{GAP}	-	0.00	-	-
		(0.00)		
Δ Log (Compensation)*CUG	-	-	0.01**	-
			(0.00)	
Capacity utilisation gap (CUG)	-	-	-	0.03*
				(0.02)
Observations	271	271	271	271

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.3: Cyclically-adjusted revenue to base elasticities – Personal income taxes – Two-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Short-term elasticity	0.87***	1.09***	1.08***	1.36***
Δ Log (Gross wage)	(0.19)	(0.18)	(0.18)	(0.21)°°°
Error-correction term (t-1)	-0.61***	-0.60***	-0.62***	-0.64***
	(0.06)°°°	(0.06)°°°	(0.06)°°°	(0.06)°°°
Δ Log (Gross wage) * Y_{GAP}	0.16***	-	-	-
	(0.04)			
Δ Log (Gross wage) * dummy positive Y_{GAP}	-	0.00	-	-
		(0.00)		
Δ Log (Gross wage) * CUG	-	-	0.05***	-
			(0.02)	
Capacity utilisation gap (CUG)	-	-	-	-0.10
				(0.07)
Observations	246	246	246	246

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

Table A2.3.4: Cyclically-adjusted revenue to base elasticities – Corporate income taxes – Two-stage

	(1) Y_{GAP} level	(2) Positive Y_{GAP}	(3) CUG level	(4) CUG
Short-term elasticity	0.26	0.65***	0.51***	0.70***
Δ Log (Corporate profits)	(0.27)	(0.20)	(0.18)	(0.19)
Error-correction term (t-1)	-0.54***	-0.58***	-0.57***	-0.58***
	(0.10)°°°	(0.09)°°°	(0.09)°°°	(0.09)°°°
Δ Log (Corporate profits) * Y_{GAP}	0.56**	-	-	-
	(0.24)			
Δ Log (Corporate profits) * dummy positive Y_{GAP}	-	0.02	-	-
		(0.01)		
Δ Log (Corporate profits) * CUG	-	-	0.19***	-
			(0.07)	
Capacity utilisation gap (CUG)	-	-	-	0.22**
				(0.10)
Observations	246	246	246	246

Note: Standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals zero. °, °°, and °°° denote statistical significance at the 10%, 5%, and 1% level, against the hypothesis that the coefficient equals one (Wald test).

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