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The Stability of Tax Elasticities over the Business Cycle in European Countries*

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Abstract

We estimate short- and long-run tax elasticities that capture the relationship between changes in national income and tax revenue. We show that the short-run tax elasticity changes according to the business cycle. We estimate a two-state Markov-switching regression on a novel data set of tax policy reforms in 15 European countries from 1980 to 2013, showing that the elasticities during booms and recessions are statistically (and often economically) different. The elasticities of personal income taxes, corporate income taxes, indirect taxes and social contributions tend to be larger during recessions. Estimates of long-run elasticities are in line with existing literature.

Policy points

- Estimating the change in tax revenue induced by a change in income – the so-called tax elasticity – is fundamental for government revenue forecasts.

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Keywords: tax elasticity, tax policy discretionary change, business cycle, European economy, Markov-switching regimes.

JEL classification numbers: C24, C29, E32, E62, H20, H30.

- We use a two-state Markov-switching regression model that permits the tax elasticity to vary over the business cycle.
- Our estimates show that there is a clear tendency for short-run elasticities of corporate income taxes, indirect taxes, social contributions and, to a lesser extent, personal income taxes to increase on average during recessions compared with booms.
- The current EU framework requires member countries to estimate a cyclically adjusted budget balance and use constant tax elasticities. However, our results suggest that the elasticities change over the cycle and thus potentially complicate the cyclically adjusted balance estimation.

I. Introduction

Estimating the tax elasticity – i.e. the tax revenue change brought about by a given change in national income – is an essential step in implementing fiscal policy. Governments use the tax elasticity to forecast revenues when preparing their budgets and to estimate the cyclical component of the budget balance as a prerequisite to assessing the fiscal stance. Clearly, large forecasting errors lead to budget surprises and inaccurate assessments of the fiscal stance, possibly leading to undue fiscal policy responses. Such an outcome might be especially undesirable for European Union members: in the current surveillance framework, a significant deviation from the medium-term budgetary objective may trigger a specific correction mechanism.

Tax elasticities are mainly estimated using two distinct approaches. The first relies on micro data and detailed information on the national tax code, while the second is based on econometric techniques. Current practice at international institutions such as the Organisation for Economic Cooperation and Development (OECD) or the European Commission (EC) relies heavily on the first approach.[1] The academic literature, on the other hand, has mainly followed the second approach, using econometric techniques to disentangle the *long-run tax elasticity* – i.e. how tax revenue will tend to grow over time as income grows – capturing the potential growth of tax revenue, from the *short-run tax elasticity* – i.e. the percentage change in tax revenue in response to a 1 per cent change in income – capturing how tax revenue will fluctuate over the business cycle as income fluctuates. Wolswijk (2009) provides an example of this research.

We adopt the second approach, but examine the commonly made assumption that the short-run tax elasticity is constant over the business cycle.

The empirical analysis covers 15 European countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands,

[1]See Girouard and André (2005) for a detailed illustration.

Norway, Portugal, Spain, Sweden and the UK. The data sample is quarterly over the period 1980–2013.

As a first contribution, we propose a regression-based model where short-run tax elasticities are allowed to shift as the economy shifts between booms and recessions, providing an estimate of tax elasticities in each state and showing that their difference across states is statistically significant. In particular, our results show a clear tendency for short-run elasticities of corporate income taxes, indirect taxes, social contributions and, to a lesser extent, personal income taxes to increase during recessions. The tendency for short-run elasticities to increase in recession also holds across countries, though less pronouncedly. This is so for seven of the countries, while elasticities are larger in booms for four countries. In the remaining four countries, no tendency prevails.

There are various theoretical rationales for a time-varying tax elasticity. One motivation concerns composition effects, i.e. the relative change of tax base shares in GDP (consumption, wages, asset prices) over the business cycle.[2] Behavioural aspects of taxation also impinge on the variability of tax elasticities. Tax compliance, in fact, is expected to change over the business cycle, as taxpayers facing economic downturns are prone to perceive a smaller risk of penalties due to tax evasion compared with larger potential gains from avoiding bankruptcy.[3] Moreover, cyclical economic downturns can push economic activity from the formal to the informal sector. This is consistent with evidence that tax collection efficiency appears to be lower over economic contractions.[4] Income inequality matters as well. As the economy slows down, the lower end of the income distribution bears the largest part of layoffs, while most income tax revenues come from the higher end of the distribution, for which earning and spending patterns remain relatively stable over the business cycle.

We take concerns about time-varying tax elasticities seriously and test the stability over the business cycle of the short-run elasticity of selected tax categories (personal income tax, corporate income tax, indirect tax and social contributions) with respect to their bases (*tax-to-base elasticity*) along with the elasticity of the same bases with respect to GDP as a proxy for the overall level of income (*base-to-GDP elasticity*). Following the warnings of Sobel and Holcombe (1996), we also estimate the long-run elasticity and assume that it is immune to regime shifts since it reflects the long-run, potential, relationship between taxes and bases as well as between bases and GDP.

[2]An example is provided by Larch and Turrini (2009). They show that the increase in tax elasticities with respect to GDP at the end of the 1990s and early 2000s was mainly due to the increased share of consumption in total income in Germany and to a combination of high wage share, rising imports and high asset prices in France.

[3]See Brondolo (2009).

[4]See Sancak, Velloso and Xing (2010).

We finally combine, both for the long-run and the short-run estimates, the tax-to-base and base-to-GDP elasticities in an overall estimate of *tax-to-GDP elasticity*.

As a second contribution, this paper proposes a method to deal with the omitted variables bias arising from the effect of discretionary tax policy changes on the relationship between tax revenue and income. Most current studies typically tackle this bias by removing the government *ex ante* estimates of tax policy changes from the tax revenue, thus obtaining a time series that only represents the effect of income changes. We use, instead, a method based on qualitative information, originally proposed by Singer (1968). Specifically, we take into account exogenous tax policy changes by including in our models a series of dummy variables based on analysis of the narrative record of EU member states' and others' tax reforms collected by the European Commission.

The remainder of the paper is organised as follows. In Section II, we illustrate how our econometric methodology allows for an explicit association of estimated regimes to business-cycle phases, thus overcoming most of the methodological drawbacks affecting existing attempts to estimate time-varying tax elasticities, which we discuss in Section II.1. We also discuss our method for dealing with exogenous tax policy changes. Section III presents the data description and sources, including our choice of proxy for each tax category base. We also illustrate the method we use to make the narrative record of tax reforms operational. In Section IV, we discuss our results and how they relate to the existing literature on tax elasticities. Finally, Section V draws policy implications and concludes.

II. Empirical methodology

Current empirical literature on tax elasticities typically follows a two-step procedure. In the first step, a regression model with log-level variables is estimated to obtain the long-run, potential effect of income changes on tax revenues. Given non-stationarity of the relevant time series, however, the ordinary least squares (OLS) estimates would be asymptotically biased with inconsistent standard errors. To avoid this bias, the log-level regression model is usually augmented with leads and lags of the growth rate of the independent variable, thereby obtaining the dynamic ordinary least squares (DOLS) model proposed by Stock and Watson (1993). Given its ability to accommodate higher orders of integration, and to deal with endogeneity among regressors and serial correlation issues,[5] this estimator has proved to be superior to standard OLS estimates or to vector error correction mechanism (VECM) models,[6] especially in small samples. Thus, we opt for a DOLS approach in conjunction with the

[5]Koester and Priesmeier, 2012.
[6]Johansen, 1995.

Newey and West (1987) correction to avoid inconsistency of the standard errors.

Changes in tax policy also complicate econometric estimates of tax elasticities. The main challenge derives from a huge omitted variable bias that arises because tax revenue changes are determined not only automatically by changing economic conditions but also by discretionary tax policy changes – legislated changes in tax rates, tax base definitions and tax administration.

Several studies[7] deal with this bias by collecting detailed information on national tax policy changes and then quantifying and removing from revenues the effect of discretionary measures using the proportional adjustment method proposed by Prest (1962).[8] However, as far as we know, tax reform databases for the countries we analyse are unavailable.[9] If one collected this information from national sources, its reliability would be at least subject to scepticism because of cross-country differences in tax codes and tax reform classification methods.[10] Moreover, as clearly shown by Barrios and Fargnoli (2010), comparability across countries is also limited by differences in accounting rules (accrual versus cash basis of accounting) or in the very definition of discretionary measure (based on a 'no-policy change' versus 'current legislation' assumption). Finally, we should bear in mind that discretionary measures represent *ex ante* government estimates of the revenue effect of tax policy changes rather than *ex post* realisations, heavily relying on the accuracy of financial and macroeconomic baselines and forecasts.[11]

We thus contribute to the literature by suggesting an alternative approach – originally proposed by Singer (1968) but recently set aside by the literature on tax elasticities – to deal with this omitted variables bias. We rely on qualitative

[7]See Wolswijk (2009), Bettendorf and van Limbergen (2013) and Mourre and Princen (2015) among others.

[8]A note on terminology is in order here. Most authors researching tax elasticities call tax revenue changes arising from changing economic conditions *endogenous* as opposed to revenue changes arising from discretionary tax policy changes, which they call *exogenous* (see, for example, Princen et al. (2013, p. 12)). As argued by Romer and Romer (2010), however, tax policy changes can be discretionary while being endogenous at the same time. They can be made, in fact, in response to business-cycle conditions or to finance public expenditures, so that they are systematically correlated with output – and are in this sense *endogenous*. This is why we reckon the term *automatic* as opposed to discretionary tax policy changes to be more appropriate than *endogenous*.

[9]We are indeed aware of one such database at annual frequency developed by the European Commission and based on information on discretionary measures collected through questionnaires sent out to EU member states in the context of the Output Gap Working Group (OGWG) of the Economic Policy Committee, covering a large sample of EU countries (see Barrios and Fargnoli (2010) and Princen et al. (2013) for an analytical description). Mourre and Princen (2015) use it to analyse tax elasticities in the EU. Unfortunately, this database is unavailable to the public.

[10]In fact, we are able to use this approach in a companion paper that focuses on Italy. See Boschi, d'Addona and Marino (2019).

[11]Such estimates depend on a number of crucial assumptions about the fiscal multiplier, the effect of tax reforms on the bases, the informal sector, tax compliance and so forth.

information provided by a narrative record of tax policy changes.[12] For each tax category and each European country, we codify a series of quarterly indicator variables to record when a tax policy change takes effect. This way of considering tax reforms in regression models avoids all problems discussed above since it is unaffected by differences in accounting rules or the definition of reforms, as well as the accuracy of forecasts of reforms' effects. Obviously, though, it cannot account for the different sizes of discretionary changes.

We emphasise that our intent is to estimate an overall tax revenue elasticity with respect to income, as approximated by GDP (tax-to-GDP). Rather than estimating it directly by regressing tax revenues on GDP, we prefer to estimate first the elasticity of tax revenues relative to their bases and then the elasticity of tax bases relative to GDP, thus following Girouard and André (2005) and Perotti (2005) among others.[13] This procedure allows us to understand, and comment on, the separate role of tax bases in determining the asymmetric behaviour of tax elasticities over the business cycle.

Therefore, for each tax category, we first estimate the following long-run DOLS model of revenue:

$$\log T_t = \theta^{TB} + \delta^{TB} \log B_t + \sum_{j=-k}^{k} \varphi_{1j}^{TB} \Delta \log B_{t+j} + \varphi_2^{TB} D_t^T + \gamma_t^{TB}, \tag{1}$$

where T_t and B_t are the tax revenue and base in year t respectively, θ^{TB} is a constant, D_t^T is the tax policy intervention dummy, γ_t^{TB} is an error term and δ^{TB} is the long-run tax-to-base elasticity.

Next, we estimate the same regression model but with variables taken in first log-differences to gauge the short-run tax elasticity – that is, the percentage change in tax revenue associated with a 1 per cent change in base. It is well known that estimates from this specification could be biased if the variables are cointegrated. To overcome this problem, we follow common practice[14] and include lagged residuals of the long-run regression model among the regressors, thereby obtaining an error correction model (ECM).

The main novelty of this paper consists of accounting for business cycles in the short-run regression model to capture the possible non-linear relationship between tax revenues and income. To do so, we model the underlying economy as a Markov process that switches between two states (s), the first characterised

[12]This narrative approach is much in the spirit of Ramey and Shapiro (1998).

[13]Notice that Sobel and Holcombe (1996) only estimate the elasticity of the tax base relative to GDP and take it as an approximation of the revenue-to-GDP elasticity. On the other hand, Bruce, Fox and Tuttle (2006), Wolswijk (2009), Koester and Priesmeier (2012) and Bettendorf and van Limbergen (2013), among others, only estimate the elasticity of tax revenues relative to their bases.

[14]For example, Sobel and Holcombe (1996), Bouthevillain et al. (2001), Wolswijk (2009) and Bettendorf and van Limbergen (2013).

by a high growth rate of output ('boom', b) and the second by a low growth rate of output ('recession', r).

We thus estimate the above short-run tax-to-base elasticity model conditioning on the state of the economy $s_t = b, r$ at time t:

$$(2) \qquad \Delta \log T_t = \alpha^{TB}(s_t) + \beta^{TB}(s_t)\Delta \log B_t + \lambda^{TB}(s_t)\gamma_{t-1}^{TB} + \varphi_3^{TB}(s_t)D_t^T + \varepsilon_t^{TB},$$

where all coefficients, including the tax revenue short-run elasticity, β^{TB}, are conditional on the economy state (s_t), and ε_t^{TB} is an error term.

Two short-run effects are captured in any time period: tax revenues can respond to changes in the tax base as well as to the long-run disequilibrium between revenue and base that exists at the beginning of the period.

Since we are ultimately interested in estimating the tax revenue elasticity with respect to income, we need to take into account the likely fluctuation of the relevant tax base with respect to income. Hence, we proceed in the same way as above for the tax base by first estimating

$$(3) \qquad \log B_t = \theta^{BY} + \delta^{BY} \log Y_t + \sum_{j=-k}^{k} \varphi_{1j}^{BY} \Delta \log Y_{t+j} + \varphi_2^{BY} D_t^T + \gamma_t^{BY},$$

where Y_t is the income, or GDP, level in year t and δ^{BY} is the long-run base-to-GDP elasticity.

Then we feed the lagged error term γ_{t-1}^{BY} into the regression model with log-differenced variables to obtain

$$(4) \qquad \Delta \log B_t = \alpha^{BY}(s_t) + \beta^{BY}(s_t)\Delta \log Y_t + \lambda^{BY}(s_t)\gamma_{t-1}^{BY} + \varphi_3^{BY}(s_t)D_t^T + \varepsilon_t^{BY},$$

where all coefficients are conditional on the state of the economy, and β^{BY} is the short-run base-to-GDP elasticity.

The overall tax revenue elasticity relative to income – the tax-to-GDP elasticity – is given by[15]

$$(5) \qquad \delta^{TY} = \delta^{TB} \times \delta^{BY}$$

for the long run and

$$(6) \qquad \beta^{TY}(s_t) = \beta^{TB}(s_t) \times \beta^{BY}(s_t)$$

for the short run.

We therefore obtain, for each tax category, one long-run tax-to-GDP elasticity along with two short-run tax-to-GDP elasticities, one for each state of the economy ('boom' or 'recession').

[15] See Girouard and André (2005) and Perotti (2005) for a formal derivation.

As a point of comparison, we also estimate short-run *linear* elasticities for tax-to-base and base-to-GDP, and then combine them in a tax-to-GDP estimate.

1. Regime estimation

Only a few studies, using a variety of econometric methods, devote the deserved attention to time-varying tax elasticities. Bruce, Fox and Tuttle (2006) use an error correction model, augmented with a dummy variable to allow for asymmetric adjustment to the long-run equilibrium, to estimate long-run and short-run elasticities of personal income and sales taxes in the US. They find asymmetric behaviour in most of the 50 states. The same methodology is applied by Wolswijk (2009), who focuses on the Netherlands because of the availability of data on discretionary tax measures. He estimates a regression model of tax revenues on their bases allowing for asymmetric deviations from the long-run equilibrium. Estimates for five tax categories confirm significant differences between short-run and long-run tax-to-base elasticities, especially over economic downturns, with evidence of asymmetric behaviour. Similarly, Bettendorf and van Limbergen (2013) distinguish between good and bad times by using either the long-run equilibrium or the output gap as an indicator and find evidence of time-varying elasticities for different tax categories in the Netherlands. Poghosyan (2011) estimates rolling regressions to quantify short-run tax elasticities of five tax categories relative to their bases and to find evidence of asymmetric behaviour over the business cycle. He then uses a panel model to compare short- and long-run elasticities in Lithuania with those in 10 new EU member states. His contribution confirms the importance of allowing for cyclical differences in tax elasticities. Similar evidence is found for South Africa by Jooste and Naraidoo (2011) using a smooth transition regression model. Sancak, Velloso and Xing (2010) instead use a panel model to estimate the efficiency and elasticity of VAT, personal income tax and social contributions for a variety of advanced and developing countries. By interacting a dummy variable for good and bad times with the output gap, they find that the effect of the size of the output gap, though significant, is not different between good and bad times. Average efficiency, however, appears to be lower in bad times, which means that tax collection is lower in recessions. Belinga et al. (2014) concentrate on tax buoyancy in good and bad times, which differs from tax elasticity because it does not separate out the effect of discretionary tax measures. Using a dummy variable approach akin to Sancak et al. (2010)'s method, by which they interact the short-run tax buoyancy with a dummy variable taking the value 1 for years of positive growth, they find that short-term buoyancy increases over recessions with respect to booms for total tax revenue and, specifically, for social contributions and property taxes. Similarly to Sancak et al. (2010), Mourre and Princen (2015) interact the output gap as well as other business-cycle indicators with the tax elasticities and find evidence of asymmetric behaviour for European countries. Dudine and Jalles (2017) instead use a discrete choice model, exploiting a logistic specification of the business-cycle signal, to allow for asymmetric behaviour. Focusing on tax buoyancy rather than elasticity, they find for advanced countries – the relevant comparison group for our study – that only corporate income tax has greater buoyancy over contractions than over expansions.

To estimate time-varying tax elasticities, we use the methodology proposed by d'Addona and Musumeci (2013)[16] and model an economy where output switches between two (unobservable) states: a high mean state ('boom') and a low mean state ('recession'). Since agents (for example, taxpayers) cannot observe the state of the economy, they infer the probability of being in a particular state by looking at realisations of the output growth rate, which therefore acts as a state signal. We indicate the latent state of the economy by s_t and assume that it follows a hidden Markov chain with transition probabilities matrix P.[17]

Specifically, we model the output growth rate as having a regime-dependent process in its mean with i.i.d.[18] normal innovations:

$$(7) \qquad \Delta \log Y_t = \mu(s_t) + \varepsilon_t,$$

where μ is the mean of the process conditional on the unobservable state of the economy s_t and ε_t is a random Gaussian shock with standard deviation σ. Through the observation of realisations of $\Delta \log Y_t$, agents infer the underlying state of the economy by formulating the posterior probability of being in each state based on information available up to time t and on knowledge of the population parameters. Hence, the filtered posterior probability is

$$(8) \qquad \widehat{\xi}_{t|t} = \Pr\{s_t = s|\Omega_t\},$$

where s identifies the state of the economy (b for boom and r for recession) and Ω_t denotes the information set including all data and parameters up to time t. Agents update their beliefs according to

$$(9) \qquad \widehat{\xi}_{t|t} = \frac{\widehat{\xi}_{t|t-1} \otimes \zeta_t}{1'(\widehat{\xi}_{t|t-1} \otimes \zeta_t)},$$

where $\otimes$ indicates the element-by-element product, 1 denotes a vector of ones whose dimension corresponds to the number of states and ζ_t is a vector

[16]See Boschi, d'Addona and Goenka (2012) for an extension to a multivariate model.
[17]See Hamilton (1989).
[18]i.i.d. stands for independent and identically distributed.

of Gaussian density functions of output growth rates conditional on the state s_t:

$$(10) \qquad \zeta_t = \begin{bmatrix} f(\Delta \log Y_t | s_t = b, \Omega_{t-1}) \\ f(\Delta \log Y_t | s_t = r, \Omega_{t-1}) \end{bmatrix}$$

with the density of $\Delta \log Y_t$ conditional on the state s_t defined as

$$(11) \qquad f\,(\Delta \log Y_t \,| s_t = s, \Omega_{t-1}\,) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left\{ \frac{-(\Delta \log Y_t - \mu(s_t))^2}{2\sigma^2} \right\}.$$

For each country, we first obtain the posterior probability, $\widehat{\xi}_{t|t}$, of the economy being in each state at time t by estimating the regime-switching model using a Markov chain Monte Carlo (MCMC) procedure that closely follows the algorithm described in section 9.1 of Kim and Nelson (1999). We then estimate the long-run regression model for each tax category. Finally, we estimate the short-run regression model by maximum likelihood using the MCMC probabilities as weights for the regression in each state of the economy. Specifically, we maximise log L with

$$(12) \qquad L = \prod_{t}^{T} \widehat{\xi}^{s}_{t|t} \left\{ \frac{1}{\sqrt{\pi\sigma_s^2}} \exp\left[\left(Z_t - \hat{C}^s X_t \right) \left(Z_t - \hat{C}^s X_t \right)' / 2\sigma_s^2 \right] \right\},$$

where Z_t indicates the short-run model dependent variable (tax revenue or base), $\hat{C}^s$ indicates the vector of coefficients to be estimated and X_t is the vector of regressors (base or GDP with leads and lags).

In our view, using a Markov-switching model to detect the underlying state of the economy represents a significant improvement with respect to the existing literature on asymmetric elasticities. Papers that rely on dummy variables or business-cycle indicators to distinguish between business-cycle phases[19] may suffer from drawbacks. First, they rely on the selection of an exogenous indicator to label business cycles. Thus the identification of different economic periods relies on subjective judgement. In Markov-switching models, regime identification is endogenous instead. Second, dummy-variable- and indicator-based models are unable to detect the intensity of the business cycle, providing only a binary signal of being in a specific phase of the economy. The Markov-switching model, on the other hand, provides the *probability* of being in a certain economic phase, which can be easily interpreted as its intensity. Third, those models are not able to provide any

[19]Bruce, Fox and Tuttle, 2006; Wolswijk, 2009; Sancak, Velloso and Xing, 2010; Belinga et al., 2014; Mourre and Princen, 2015; Dudine and Jalles, 2017.

information on the dynamics of economic regimes, thus limiting the sample size of recessions to those periods when the dummy variable or the indicator turns on. Our approach, by contrast, rests on a much larger sample size by estimating the probability of being in a boom or recession in each and every time period, so that it can employ all available observations. This method also allows us to formally test the significance of the difference between elasticities across business-cycle phases.

It is also worth noting that in the literature reviewed above, asymmetric behaviour is conceived with respect to a reference term, such as the long-run equilibrium, and therefore does not necessarily associate the tax elasticity with business-cycle phases. But even when one looks at asymmetric deviations with respect to the output gap as an indicator of the business cycle, such association is deterministic rather than stochastic. We emphasise that our methodology instead results in a close association of the two short-run elasticities with the business-cycle phases and, most importantly, such association is stochastic in nature since it is obtained from the posterior probability of the economy being in a boom or in a recession. This represents another significant methodological improvement with respect to the existing literature.

Finally, compared with studies that use rolling windows to deterministically compute elasticities at each and every sample year to examine behaviour over the business cycle,[20] our method is operationally more useful since it might be easily incorporated in surveillance and forecasting frameworks. In fact, we provide one short-run elasticity for boom periods and one for recession periods, while those papers offer a different elasticity for each and every sample year. Princen et al. (2013) themselves acknowledge that their elasticities are difficult to interpret and highly erratic.

III. Data

Data are quarterly over the period 1980Q1–2013Q1, though the sample range changes across countries and tax categories depending on the minimum available length of time series for each country (see Table 1).

We use two sources: the Organisation for Economic Cooperation and Development (OECD) quarterly sector accounts Data Warehouse and the European Central Bank (ECB) Data Warehouse. Except where indicated, data from the OECD and the ECB come originally at current prices, in millions of national currency. Where necessary, data are seasonally adjusted using the TRAMO/SEATS programs.[21] Data are also deflated using the indicated, appropriate, deflator to render them in real terms.

[20]For example, Poghosyan (2011), Bettendorf and van Limbergen (2013) and Princen et al. (2013).
[21]See Gómez and Maravall (1996).

TABLE 1

Data sample coverage for regression models

	PIT	*CIT*	*IND*	*SC*
Austria	99Q1–13Q1 (57)	99Q1–13Q1 (57)	91Q1–13Q1 (89)	99Q1–13Q1 (57)
Belgium	-	-	95Q2–13Q1 (72)	99Q1–13Q1 (57)
Denmark	99Q1–13Q1 (57)	99Q1–13Q1 (57)	91Q2–13Q1 (88)	99Q1–13Q1 (57)
Finland	99Q1–13Q1 (57)	99Q1–13Q1 (57)	91Q1–13Q1 (89)	99Q1–13Q1 (57)
France	80Q1–13Q1 (133)	80Q1–13Q1 (133)	91Q1–12Q4 (88)	99Q1–13Q1 (57)
Germany	99Q1–12Q4 (56)	99Q1–12Q4 (56)	91Q2–12Q4 (87)	99Q1–13Q1 (57)
Greece	00Q1–13Q1 (53)	00Q1–13Q1 (53)	00Q1–13Q1 (53)	00Q1–11Q1 (45)
Ireland	02Q1–13Q1 (45)	02Q1–13Q1 (45)	00Q2–13Q1 (52)	00Q2–13Q1 (52)
Italy	99Q1–13Q1 (57)	99Q1–13Q1 (57)	91Q1–13Q1 (89)	99Q1–12Q4 (56)
Netherlands	05Q1–13Q1 (33)	05Q1–13Q1 (33)	91Q1–13Q1 (89)	99Q1–13Q1 (57)
Norway	02Q1–13Q1 (45)	-	80Q1–13Q1 (133)	-
Portugal	99Q1–13Q1 (57)	99Q1–13Q1 (57)	96Q1–13Q1 (69)	99Q1–13Q1 (57)
Spain	01Q2–13Q1 (48)	01Q2–12Q4 (47)	01Q2–13Q1 (48)	01Q2–11Q2 (41)
Sweden	99Q1–13Q1 (57)	99Q1–13Q1 (57)	93Q2–13Q1 (80)	-
UK	99Q1–13Q1 (57)	99Q1–13Q1 (57)	90Q1–13Q1 (93)	99Q1–13Q1 (57)

Note: This table reports the maximum data sample range for each country and each tax category. The number of observations is in parentheses.

We use the OECD database for the following data:

- The personal income tax (PIT) revenue data consist of general government receipts from current taxes on income, wealth, etc. levied on the households and non-profit institutions serving households sector. We express PIT revenues in real terms using the GDP deflator. PIT revenue data for Belgium are unavailable, while those for Greece are used in nominal terms due to unavailability of the national deflator. The PIT base is obtained as the sum of gross operating surplus and mixed income, compensation of employees, property income and gross entrepreneurial income of the households and non-profit institutions serving households sector. We use the GDP deflator to obtain deflated PIT base data. Similarly to revenues, the PIT base data for Belgium are unavailable, while those for Greece are in nominal terms.
- The corporate income tax (CIT) revenue data consist of general government receipts from current taxes on income, wealth, etc. levied on corporations (both non-financial and financial). The CIT revenue data for Austria, Belgium and Norway are unavailable. The CIT base is given by the sum of gross operating surplus and mixed income, property income and gross entrepreneurial income. The CIT base data for Belgium, Denmark, the Netherlands and Norway are unavailable. The CIT revenue and base

data are deflated using the GDP deflator, except for Greece, whose data are in nominal terms.

- The indirect tax (IND) base is given by private final consumption expenditure. Data consist of chained volume estimates of private final consumption expenditure, in millions of national currency, national reference year, seasonally adjusted. Chained volume data for Belgium and Greece are unavailable and we must resort to data in current prices. Moreover, data for Greece are not seasonally adjusted at source, so we use TRAMO/SEATS to adjust them.
- The social contributions (SC) base is given by gross wages and salaries. Data are seasonally adjusted and adjusted for working days, at current prices in millions of national currency. Data are expressed in real terms using the GDP deflator, except for Greece due to unavailability of the national deflator. Norway's and Sweden's data on gross wages and salaries are unavailable.
- The GDP deflator is in the national base/reference year and seasonally adjusted.
- The private final consumption expenditure deflator is in the national base/reference year and seasonally adjusted.
- The GDP level is given by the chained volume estimate of gross domestic product. Data are in millions of national currency, national reference year, seasonally adjusted at source. The exception is data for Greece, which are not seasonally adjusted at source.
- The real GDP growth rate is computed with respect to the previous quarter, seasonally adjusted. For Greece, we compute the GDP growth rate from the chained volume estimate of the level seasonally adjusted using TRAMO/SEATS.

We use the ECB database for the following data:

- The indirect tax (IND) revenue data consist of general government indirect tax receipts. Seasonal adjustment is obtained using TRAMO/SEATS. We obtain deflated revenue data using the private final consumption expenditure deflator. Indirect taxes for Belgium and Greece are in nominal terms due to unavailability of the national deflator. Norway's data on indirect tax revenues are unavailable.
- Social contributions (SC) refer to general government social contributions. Seasonal adjustment is achieved using TRAMO/SEATS. The series are expressed in real terms using the GDP deflator. Social contributions for Greece are in nominal terms due to unavailability of the national deflator. Norway's data on social contributions are unavailable.

1. Tax policy change dummies

To consider discretionary tax policy changes in the regression models, we proceed as follows. For each country and each tax category, we codify a quarterly dummy variable that takes the value 1 in quarters when a tax policy change took effect and 0 otherwise. To overcome concerns about the comparability of tax reform classification methods, we rely on information collected and processed by the European Commission in the annual survey of taxation trends in the European Union.[22] Being the survey conducted by the EU country policy analysts, we can be sufficiently confident that uniform criteria and methodology for classifying and dating reforms are followed. One further advantage of this source is that we avoid getting bogged down in minor changing details of national tax systems because the European Commission only reports major reforms. As for time alignment, we enter the value 1 only in quarters for which the European Commission's report clearly indicates the month when the reform was implemented and took effect. When the reform was adopted within annual budget law, the dummy takes the value 1 in the first quarter of the year following budget approval. If only the year is reported, we enter a value of 1 for each and every quarter of that year.[23]

IV. Results

A preliminary analysis of all the time series involved indicates that all variables can be reasonably considered to be driven by I(1) or I(2) stochastic trends, which justifies the use of DOLS and ECM approaches.[24] For each country and each tax category, we estimate the long-run DOLS regression as well as the short-run Markov-switching regimes ECM regression, for both the tax-to-base and the base-to-GDP model.[25] We then combine the estimated values to obtain a single tax-to-GDP elasticity for each country and each tax category. The number of leads and lags in the DOLS model is chosen according to the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC).

As detailed in the previous section, the tax reform dummy variables are coded so that they take the value 1 when reforms come into force. However, because reforms start to be discussed before they are legislated and usually take time to be implemented, people can develop expectations about them

[22]All reports are available at https://ec.europa.eu/taxation_customs/business/economic-analysis-taxation/taxation-trends-eu-union_en.

[23]We postpone to future research an investigation of the quantitative effect of discretionary tax changes on elasticity estimates. For our purposes in this paper, we consider it methodologically appropriate to include them.

[24]Unit root test results are available upon request.

[25]Long-run estimations were also performed using generalised least squares (GLS) regressions, by which similar results were obtained.

and modify their behaviour much before reforms become law. We take these expectations into account by estimating two versions of each model – one includes the dummy variable with no leads and the other version, under the hypothesis of reforms foresight, includes the dummy variable with a lead. The AIC and SIC are used to choose between the two model specifications. When the criteria results for the tax-to-base elasticity differ from those for the base-to-GDP elasticity model, we choose the model that gives the largest criterion improvement.[26]

One result holds across all countries and tax categories – non-linearity is always statistically significant, as shown by the likelihood ratio test statistics and small *p*-values,[27] though the difference between boom and recession short-run elasticities is not always economically relevant.[28]

Before discussing details, we summarise across tax categories and across countries the results on short-run tax elasticity non-linearity – our main focus in this paper.

Across tax categories, we notice a clear tendency for short-run elasticities to increase in recessions with respect to booms. This happens for all tax categories, as shown by the median tax-to-GDP elasticities reported in Tables 5, 8, 11 and 14, but the largest increase is obtained for corporate income taxes, for which the mean tax-to-GDP short-run elasticity increases from 1.05 in booms to 5.88 in recessions, while it increases by 0.31 for indirect taxes, 0.18 for social contributions and 0.06 for personal income taxes.

Across countries, results are less clear-cut but still show a tendency for larger elasticities in recessions to prevail. As shown in Table 2, this is so for 7 out of 15 countries (Austria, Finland, France, Greece, the Netherlands, Sweden and the UK), while short-run elasticities tend to be larger in booms for 4 countries (Germany, Ireland, Norway and Portugal). In the remaining 4 countries (Belgium, Denmark, Italy and Spain), the number of elasticities that are larger in booms equals the number of elasticities that are larger in recessions. However, we need to bear in mind that, for some countries, estimates could not be obtained for all tax categories (Austria, Belgium, Denmark, the Netherlands, Norway and Sweden).

Non-linearity results are also visually summarised in Figures 1–4, each of which reports on a web graph the short-run elasticities in booms (squares) and recessions (rhombuses) for each country.

Below we illustrate in more detail the results for each tax category.

[26]These AIC and SIC results are available upon request.

[27]We test for regime invariance through a likelihood ratio test with statistic $\lambda_{LR} = 2[\log L(\tilde{\delta}) - \log L(\tilde{\delta}_r)]$, where $\tilde{\delta}$ is the unconstrained maximum likelihood estimator and $\tilde{\delta}_r$ is the constrained estimator obtained by maximising the likelihood function under the null hypothesis H_0 of tax elasticity regime invariance. Under H_0, λ_{LR} has an asymptotic χ^2 distribution with degrees of freedom equal to the number of restrictions.

[28]Notice that the two-step estimation procedure reduces the power of the test for non-linearity, whose results tend thus to be conservative.

TABLE 2

Summary of short-run Markov-switching results

	Larger in booms				Larger in recessions			
	PIT	*CIT*	*IND*	*SC*	*PIT*	*CIT*	*IND*	*SC*
Austria		-	√		√	-		√
Belgium	-	-		√	-	-	√	
Denmark		-	=	√	√	-	=	
Finland					√	√	√	√
France					√	√	√	√
Germany	√		√	√		√		
Greece		=	√		√	=		√
Ireland	√	√		√			√	
Italy	√	√					√	√
Netherlands		-			√	-	√	√
Norway	√	-	-	-		-	-	-
Portugal	√	√		√			√	
Spain	√	√					√	√
Sweden				-	√	√	√	-
UK	√					√	√	√

Note: This table reports a summary of short-run tax-to-GDP results. For each country and each tax category, the symbol '√' indicates whether short-run tax elasticity is larger in boom or recession; the symbol '=' indicates that elasticity does not change across business-cycle phases; and the symbol '-' indicates that overall tax-to-GDP estimates could not be obtained.

1. Personal income tax

The tax-to-base elasticities for PIT are reported in Table 3. The long-run elasticity ranges from 0.1 in Portugal to almost 3 in Germany. The short-run, linear, elasticity is much lower than the long-run one, except for Austria, Denmark, Italy, Portugal and Spain, and more imprecisely estimated, as shown by the large standard errors. Non-linearity is statistically significant for all countries. The difference between elasticity in booms and recessions ranges from more than 3.30 in Austria to 0.13 in Germany. On average, and in absolute value, it increases from 0.43 in booms to 0.74 in recessions. The short-run linear elasticity always lies within the boom and recession elasticities, except for Germany and Spain. The short-run elasticity is larger in recessions in 8 countries but is smaller in the remaining 6. The median absolute value increases slightly from 0.40 to 0.44. The Markov-switching models, however, fit the data at varying degrees depending on the country – R^2 ranges from 0.04 for France to 0.61 for Austria. Koester and Priesmeier (2012) report a long-run tax-to-base elasticity for the German PIT much smaller than our estimate (1.75 versus 2.99), while the opposite is true for the short-run linear elasticity (1.41 versus 0.93). Regarding the Netherlands, Wolswijk (2009) estimates a long-run PIT tax-to-base elasticity similar to ours (1.57 versus 1.32); his short-run estimate

TABLE 3

Elasticity of PIT revenue with respect to its base

	LR elasticity δ^{TB} *(s.e.)*	*SR linear elasticity* β^{TB} *(s.e.)*	*SR MS elasticity* β^{TB} *(s.e.)* Boom	Recession	*MS model* R^2	*Likelihood ratio test statistic [p-value]*
Austria	$0.39_{\bullet\bullet}$	0.46	$-0.03_{\bullet\bullet\bullet}$	3.31^{*}	0.61	166
	(0.23)	(0.41)	(0.28)	(1.68)		[0.00]
Belgium	-	-	-	-	-	-
Denmark	$0.30^{***}_{\bullet\bullet\bullet}$	$0.67^{***}_{\bullet\bullet}$	$0.53^{***}_{\bullet\bullet\bullet}$	0.80^{***}	0.47	200
	(0.10)	(0.15)	(0.17)	(0.23)		[0.00]
Finland	1.39^{***}	$0.48^{**}_{\bullet\bullet}$	$0.40^{*}_{\bullet\bullet}$	0.92	0.47	174
	(0.28)	(0.24)	(0.22)	(0.68)		[0.00]
France	$2.03^{***}_{\bullet\bullet}$	0.46	0.23	1.12	0.04	430
	(0.52)	(0.56)	(0.47)	(0.88)		[0.00]
Germany	$2.99^{***}_{\bullet\bullet\bullet}$	0.93^{***}	0.93^{***}	0.80^{*}	0.41	223
	(0.37)	(0.22)	(0.21)	(0.47)		[0.00]
Greece	$0.54^{***}_{\bullet\bullet}$	$0.13_{\bullet\bullet\bullet}$	$-0.01_{\bullet\bullet\bullet}$	0.40	0.21	128
	(0.18)	(0.20)	(0.10)	(0.59)		[0.00]
Ireland	$0.68^{***}_{\bullet\bullet}$	0.30	0.53	$0.24_{\bullet}$	0.29	111
	(0.13)	(0.43)	(0.87)	(0.44)		[0.00]
Italy	$0.31_{\bullet\bullet}$	0.40	0.45	0.27	0.19	176
	(0.29)	(0.42)	(0.49)	(0.57)		[0.00]
Netherlands	1.32^{**}	1.06	0.40	1.29	0.17	72
	(0.50)	(1.06)	(0.67)	(1.94)		[0.00]
Norway	1.19^{***}	$0.19^{***}_{\bullet\bullet\bullet}$	$0.09_{\bullet\bullet\bullet}$	$0.25^{***}_{\bullet\bullet\bullet}$	0.37	151
	(0.32)	(0.06)	(0.07)	(0.08)		[0.00]
Portugal	$0.10_{\bullet\bullet\bullet}$	0.50	1.02	0.27	0.39	160
	(0.28)	(0.42)	(0.66)	(0.47)		[0.00]
Spain	0.76^{***}	0.80	0.29	0.01	0.26	139
	(0.21)	(0.58)	(0.59)	(0.89)		[0.00]
Sweden	1.39^{***}	$0.30_{\bullet\bullet}$	$0.28_{\bullet\bullet}$	0.48	0.08	193
	(0.29)	(0.35)	(0.29)	(1.13)		[0.00]
UK	1.05^{***}	$0.53^{***}_{\bullet\bullet\bullet}$	0.77^{***}	$0.18_{\bullet\bullet}$	0.36	211
	(0.08)	(0.17)	(0.19)	(0.31)		[0.00]
Mean	1.03	0.52	0.43	0.74		
Median	0.91	0.47	0.40	0.44		
Std dev.	0.78	0.27	0.31	0.83		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the PIT revenue with respect to its base, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test *p*-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

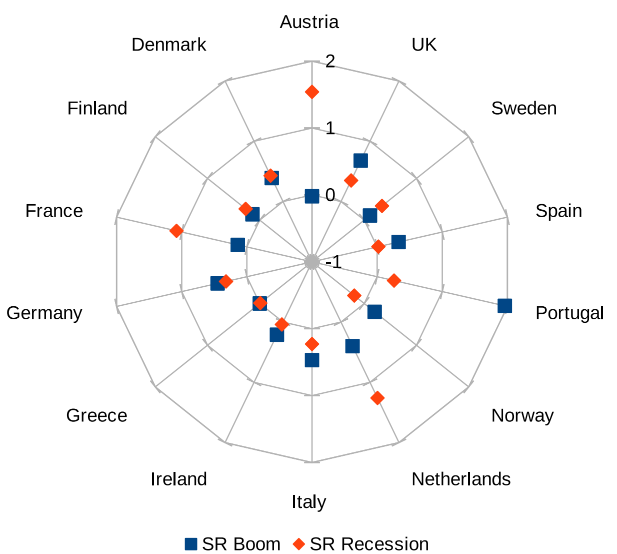
amounts to 1.89, while ours is 1.06. He does not find any evidence of asymmetry around the trend value, while in our model the non-linear short-run elasticity shifts from 0.40 in booms to 1.29 in recessions. Our short-run results for the Netherlands are more in line with those of Bettendorf and van Limbergen (2013), who obtain a value of 1.07, while their long-run PIT elasticity is 0.89.

As for the base-to-GDP elasticities reported in Table 4, the average long-run elasticity is larger than the short-run one, although the only large differences are recorded for Greece, Ireland and Norway. The variability of the long-run elasticity is smaller than that of the tax-to-base elasticity. The standard deviation across countries amounts to 0.40 (compared with 0.78 for the tax-to-base elasticity). Non-linearity is statistically significant for all countries. The difference between boom and recession elasticities varies between 0.02 for the Netherlands and more than 1 for the UK, excluding Norway for which the difference is implausibly large. The short-run linear elasticity lies within the non-linear ones for all countries. For 10 countries out of 14, the PIT base-to-GDP short-run elasticity is larger in booms than in recessions. On average, it goes from 0.84 in booms to 0.75 in recessions.

Combining the tax-to-base and base-to-GDP elasticities as discussed in Section II, we obtain the PIT tax-to-GDP elasticity measure shown in Table 5 and Figure 1. The short-run elasticity is larger in booms for 7 out of 14

FIGURE 1

Short-run tax-to-GDP elasticity of PIT in boom and recession



Note: This figure shows the PIT short-run tax-to-GDP elasticity in boom (square) and recession (rhombus) for each country.

TABLE 4

Elasticity of PIT base with respect to GDP

	LR elasticity δ^{BY} *(s.e.)*	*SR linear elasticity* β^{BY} *(s.e.)*	*SR MS elasticity* β^{BY} *(s.e.)*		*MS model* R^2	*Likelihood ratio test statistic [p-value]*
			Boom	Recession		
Austria	1.37$^{***}_{\bullet\bullet\bullet}$	0.55$^{**}_{\bullet\bullet}$	0.58$^{***}_{\bullet\bullet}$	0.46$_{\bullet}$	0.24	235
	(0.12)	(0.20)	(0.19)	(0.30)		[0.00]
Belgium	-	-	-	-	-	-
Denmark	0.86$^{***}_{\bullet}$	0.56$^{***}_{\bullet\bullet}$	0.73***	0.54$^{**}_{\bullet}$	0.53	220
	(0.08)	(0.17)	(0.22)	(0.24)		[0.00]
Finland	0.61$^{***}_{\bullet\bullet\bullet}$	0.32$^{**}_{\bullet\bullet\bullet}$	0.35$^{**}_{\bullet\bullet\bullet}$	0.30$^{**}_{\bullet\bullet\bullet}$	0.48	211
	(0.06)	(0.12)	(0.15)	(0.13)		[0.00]
France	0.94***	0.71$^{***}_{\bullet\bullet\bullet}$	0.59$^{***}_{\bullet\bullet\bullet}$	0.96***	0.44	696
	(0.06)	(0.08)	(0.06)	(0.22)		[0.00]
Germany	1.02***	0.46$^{***}_{\bullet\bullet\bullet}$	0.49$^{***}_{\bullet\bullet\bullet}$	0.40$^{***}_{\bullet\bullet\bullet}$	0.32	234
	(0.23)	(0.11)	(0.13)	(0.12)		[0.00]
Greece	1.11***	0.07$_{\bullet\bullet\bullet}$	0.12$_{\bullet\bullet\bullet}$	−0.03$_{\bullet\bullet\bullet}$	0.50	140
	(0.10)	(0.08)	(0.10)	(0.08)		[0.00]
Ireland	1.51$^{***}_{\bullet\bullet\bullet}$	0.33$^{*}_{\bullet\bullet\bullet}$	0.39$^{**}_{\bullet\bullet\bullet}$	0.18$_{\bullet\bullet\bullet}$	0.34	156
	(0.06)	(0.18)	(0.17)	(0.25)		[0.00]
Italy	1.27$^{***}_{\bullet\bullet\bullet}$	0.91***	1.05***	0.84***	0.62	210
	(0.07)	(0.16)	(0.21)	(0.24)		[0.00]
Netherlands	1.56$^{***}_{\bullet\bullet\bullet}$	1.00***	1.00***	0.98***	0.57	110
	(0.14)	(0.22)	(0.28)	(0.26)		[0.00]
Norway	−0.26$_{\bullet\bullet\bullet}$	0.98	2.11***	−0.77	0.32	118
	(0.29)	(0.85)	(0.73)	(1.57)		[0.00]
Portugal	1.78$^{***}_{\bullet\bullet}$	1.18***	1.93***	0.98***	0.48	200
	(0.32)	(0.22)	(0.56)	(0.22)		[0.00]
Spain	1.35$^{***}_{\bullet\bullet\bullet}$	1.49$^{***}_{\bullet\bullet\bullet}$	1.13***	1.49$^{***}_{\bullet\bullet\bullet}$	0.83	231
	(0.05)	(0.12)	(0.11)	(0.15)		[0.00]
Sweden	0.81$^{***}_{\bullet}$	0.54$^{***}_{\bullet\bullet\bullet}$	0.39$^{***}_{\bullet\bullet\bullet}$	0.70$^{***}_{\bullet\bullet}$	0.46	252
	(0.11)	(0.10)	(0.01)	(0.13)		[0.00]
UK	1.14$^{***}_{\bullet\bullet}$	1.32$^{***}_{\bullet}$	0.88***	1.92$^{***}_{\bullet\bullet\bullet}$	0.70	232
	(0.06)	(0.17)	(0.15)	(0.33)		[0.00]
Mean	1.11	0.74	0.84	0.75		
Median	1.13	0.64	0.66	0.74		
Std dev.	0.40	0.41	0.58	0.51		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the PIT base with respect to GDP, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test *p*-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

TABLE 5

Elasticity of PIT revenue with respect to GDP

	LR elasticity $\delta^{TB} \times \delta^{BY}$	*SR linear elasticity* $\beta^{TB} \times \beta^{BY}$	*SR MS elasticity* $\beta^{TB} \times \beta^{BY}$	
			Boom	Recession
Austria	0.54	0.25	–0.02	1.54
Belgium	-	-	-	-
Denmark	0.26	0.38	0.39	0.43
Finland	0.84	0.16	0.14	0.27
France	1.90	0.33	0.14	1.08
Germany	3.06	0.42	0.45	0.32
Greece	0.60	0.01	–0.00	–0.01
Ireland	1.03	0.10	0.21	0.04
Italy	0.40	0.36	0.47	0.23
Netherlands	2.05	1.06	0.40	1.26
Norway	–0.31	0.18	0.20	–0.19
Portugal	0.17	0.59	1.96	0.26
Spain	1.03	1.19	0.33	0.02
Sweden	1.13	0.16	0.11	0.34
UK	1.20	0.70	0.68	0.35
Mean	1.04	0.42	0.39	0.45
Median	0.94	0.35	0.27	0.30
Std dev.	0.82	0.35	0.49	0.48

Note: This table reports the product of the PIT tax-to-base and base-to-GDP elasticities combined in a single tax-to-GDP elasticity for the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) cases. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

countries while it is larger in recessions for the other 7 countries. Changes across regimes are due to revenues for 8 out of 14 countries (Austria, Denmark, Finland, France, Germany, Greece, Ireland and the Netherlands), while they are mostly due to bases in the remaining 6 countries (Italy, Norway, Portugal, Spain, Sweden and the UK). The mean and median PIT short-run tax-to-GDP elasticities are larger in recessions than in booms by 0.06 and 0.03 respectively.

We can compare long-run tax-to-GDP results with the elasticity of revenues relative to the output gap used within the EU framework for fiscal surveillance of member states.[29] We find elasticities that are smaller than the EU ones for 8 out of 12 countries (Norway is not included in the EU study), while ours

[29]See, for example, Mourre et al. (2013, table A.1, p. 30).

are larger in 4 cases. Long-run PIT elasticities for Finland (0.84) and the UK (1.20) are similar to the EU elasticities (0.91 and 1.18).

2. Corporate income tax

Table 6 reports the CIT tax-to-base elasticities. On average, long-run elasticities are slightly larger than 1. For France, Greece, Spain and the UK, the null hypothesis of this coefficient being 1 is strongly rejected. Short-run linear elasticities are generally smaller than the long-run ones (almost half on average) and nearly all have large standard errors. The estimate for France is exceptionally large (and much larger than the long-run one) and very precisely estimated. Most other coefficients, though, are lower than 1. As for the PIT case, non-linearity in short-run elasticities is strongly supported by the likelihood ratio tests, and in most countries – Finland, France, Germany, Italy, Spain, Sweden and the UK – the difference between booms and recessions is economically relevant. Except for Germany, the short-run linear elasticity of all countries lies between the boom and recession ones. For 5 out of 10 countries, the recession elasticity is larger than the boom one, while for 4 countries the opposite is true. Greece reports both elasticities at zero. The estimate for France drives a mean recession value almost three times the boom one. Koester and Priesmeier (2012) estimate a long-run profit tax-to-base elasticity in Germany around half what we find (0.77 versus 1.54), while their short-run elasticity is larger than ours (0.43 versus 0.15), though within our non-linear range. Our short-run model for Germany, however, produces such large standard errors that the elasticity estimate results are unreliable.

The estimates of the CIT base-to-GDP elasticities reported in Table 7 are generally more precise than the tax-to-base ones, as shown by the small standard errors and by the R^2 values of the Markov-switching models. The mean and median absolute values of the long-run elasticities are close to 3, but those of Greece and Spain are not statistically different from 1. On average, the short-run linear elasticities are only slightly smaller than the long-run ones, being larger than 2 for all countries except Greece. Short-run non-linearity is strongly supported by the likelihood ratio test and the difference between the two regimes' elasticities is relevant for all countries except Greece, Ireland and Portugal. Short-run elasticities in recessions are on average larger than those in booms by almost 1. The recession elasticities are larger than the boom ones in 10 out of 11 countries.

Table 8 and Figure 2 report the overall tax-to-GDP elasticities. They show elasticities being larger during recessions than booms in only 5 out of 10 countries. Changes across regimes are mostly due to revenues for 4 out of 10 countries (Finland, France, Ireland and Sweden), while they are mostly due to bases for 5 countries (Germany, Italy, Portugal, Spain and the UK). On

TABLE 6

Elasticity of CIT revenue with respect to its base

	LR elasticity δ^{TB} *(s.e.)*	*SR linear elasticity* β^{TB} *(s.e.)*	*SR MS elasticity* β^{TB} *(s.e.)* Boom	Recession	*MS model* R^2	*Likelihood ratio test statistic [p-value]*
Austria	-	-	-	-	-	-
Belgium	-	-	-	-	-	-
Denmark	-	-	-	-	-	-
Finland	1.18^{***}	0.25	$-0.08_{\bullet\bullet}$	1.05	0.52	82
	(0.25)	(0.45)	(0.49)	(0.85)		[0.00]
France	$0.46^{*}_{\bullet\bullet}$	$3.73^{***}_{\bullet\bullet\bullet}$	0.60	$9.99^{***}_{\bullet\bullet\bullet}$	0.67	208
	(0.27)	(0.60)	(0.47)	(1.68)		[0.00]
Germany	1.54^{***}	0.15	0.39	0.78	0.20	100
	(0.42)	(0.73)	(0.82)	(1.04)		[0.00]
Greece	$0.13^{*}_{\bullet\bullet\bullet}$	$-0.00_{\bullet\bullet\bullet}$	$0.00_{\bullet\bullet\bullet}$	$0.00_{\bullet\bullet\bullet}$	0.10	170
	(0.07)	(0.10)	(0.10)	(0.20)		[0.00]
Ireland	0.86^{***}	$0.01_{\bullet\bullet\bullet}$	$0.16_{\bullet\bullet}$	$-0.13_{\bullet\bullet\bullet}$	0.17	88
	(0.21)	(0.33)	(0.34)	(0.39)		[0.00]
Italy	$1.26^{***}_{\bullet}$	$-0.21_{\bullet\bullet}$	$-0.67_{\bullet\bullet}$	$0.12_{\bullet}$	0.34	114
	(0.14)	(0.51)	(0.70)	(0.50)		[0.00]
Netherlands	-	-	-	-	-	-
Norway	-	-	-	-	-	-
Portugal	1.16^{***}	$0.21_{\bullet\bullet\bullet}$	0.29	$0.19_{\bullet\bullet\bullet}$	0.23	134
	(0.10)	(0.16)	(0.51)	(0.16)		[0.00]
Spain	$3.21^{***}_{\bullet\bullet\bullet}$	1.21	2.21	–0.06	0.35	28
	(0.61)	(2.25)	(2.87)	(2.98)		[0.01]
Sweden	1.11^{***}	$-0.11_{\bullet\bullet\bullet}$	$0.08_{\bullet\bullet\bullet}$	$-1.50^{**}_{\bullet\bullet\bullet}$	0.50	117
	(0.25)	(0.19)	(0.17)	(0.58)		[0.00]
UK	$0.63^{***}_{\bullet\bullet\bullet}$	$0.43_{\bullet}$	$0.19_{\bullet}$	0.61^{**}	0.39	128
	(0.09)	(0.30)	(0.43)	(0.27)		[0.00]
Mean	1.15	0.63	0.47	1.44		
Median	1.14	0.21	0.24	0.40		
Std dev.	0.84	1.14	0.65	3.04		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the CIT revenue with respect to its base, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test *p*-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

TABLE 7

Elasticity of CIT base with respect to GDP

	LR elasticity δ^{BY} *(s.e.)*	*SR linear elasticity* β^{BY} *(s.e.)*	*SR MS elasticity* β^{BY} *(s.e.)* Boom	Recession	*MS model* R^2	*Likelihood ratio test statistic [p-value]*
Austria	$2.29^{***}_{\bullet\bullet\bullet}$	$3.52^{***}_{\bullet\bullet\bullet}$	$3.70^{***}_{\bullet\bullet\bullet}$	$3.44^{***}_{\bullet\bullet\bullet}$	0.59	197
	(0.17)	(0.49)	(0.46)	(0.53)		[0.00]
Belgium	-	-	-	-	-	-
Denmark	-	-	-	-	-	-
Finland	$2.57^{***}_{\bullet\bullet\bullet}$	$3.12^{***}_{\bullet\bullet\bullet}$	$3.00^{***}_{\bullet\bullet\bullet}$	$3.34^{***}_{\bullet\bullet\bullet}$	0.56	163
	(0.23)	(0.46)	(0.52)	(0.60)		[0.00]
France	$3.00^{***}_{\bullet\bullet\bullet}$	$2.55^{***}_{\bullet\bullet\bullet}$	$2.07^{***}_{\bullet\bullet\bullet}$	$4.30^{***}_{\bullet\bullet\bullet}$	0.46	510
	(0.32)	(0.32)	(0.22)	(1.24)		[0.00]
Germany	$3.01^{***}_{\bullet\bullet\bullet}$	$2.19^{***}_{\bullet\bullet\bullet}$	$1.88^{***}_{\bullet\bullet}$	$2.38^{***}_{\bullet\bullet\bullet}$	0.54	202
	(0.71)	(0.33)	(0.37)	(0.34)		[0.00]
Greece	1.12^{***}	$-0.02_{\bullet\bullet\bullet}$	$-0.03_{\bullet\bullet\bullet}$	$-0.08_{\bullet\bullet\bullet}$	0.23	150
	(0.19)	(0.10)	(0.15)	(0.09)		[0.00]
Ireland	$1.89^{***}_{\bullet\bullet\bullet}$	$2.00^{***}_{\bullet\bullet\bullet}$	$1.97^{***}_{\bullet\bullet\bullet}$	$2.08^{***}_{\bullet\bullet}$	0.56	131
	(0.24)	(0.34)	(0.32)	(0.50)		[0.00]
Italy	$3.45^{***}_{\bullet\bullet\bullet}$	$2.90^{***}_{\bullet\bullet\bullet}$	$2.40^{***}_{\bullet\bullet\bullet}$	$3.73^{***}_{\bullet\bullet\bullet}$	0.65	203
	(0.26)	(0.35)	(0.42)	(0.68)		[0.00]
Netherlands	-	-	-	-	-	-
Norway	-	-	-	-	-	-
Portugal	$3.44^{***}_{\bullet\bullet}$	2.28^{**}	2.13	2.33^{**}	0.16	145
	(1.18)	(1.00)	(1.48)	(1.14)		[0.00]
Spain	1.66^{***}	$3.02^{***}_{\bullet\bullet}$	$2.27^{***}_{\bullet}$	$5.32^{***}_{\bullet\bullet\bullet}$	0.34	143
	(0.39)	(0.86)	(0.68)	(1.22)		[0.00]
Sweden	$3.80^{***}_{\bullet\bullet\bullet}$	$3.66^{***}_{\bullet\bullet\bullet}$	$3.37^{***}_{\bullet\bullet\bullet}$	$4.44^{***}_{\bullet\bullet\bullet}$	0.40	148
	(0.49)	(0.95)	(0.78)	(0.95)		[0.00]
UK	$3.99^{***}_{\bullet\bullet\bullet}$	$3.61^{***}_{\bullet\bullet\bullet}$	$2.62^{***}_{\bullet\bullet\bullet}$	$3.73^{***}_{\bullet\bullet\bullet}$	0.68	183
	(0.33)	(0.48)	(0.43)	(0.86)		[0.00]
Mean	2.75	2.62	2.31	3.20		
Median	3.00	2.90	2.27	3.44		
Std dev.	0.93	1.04	0.96	1.42		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the CIT base with respect to GDP, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test *p*-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

TABLE 8

Elasticity of CIT revenue with respect to GDP

	LR elasticity $\delta^{TB} \times \delta^{BY}$	*SR linear elasticity* $\beta^{TB} \times \beta^{BY}$	*SR MS elasticity* $\beta^{TB} \times \beta^{BY}$	
			Boom	Recession
Austria	-	-	-	-
Belgium	-	-	-	-
Denmark	-	-	-	-
Finland	3.03	0.79	–0.23	3.51
France	1.39	9.53	1.24	43.00
Germany	4.63	0.32	0.73	1.85
Greece	0.14	0.00	–0.00	–0.00
Ireland	1.62	0.01	0.32	–0.27
Italy	4.36	–0.60	–1.61	0.43
Netherlands	-	-	-	-
Norway	-	-	-	-
Portugal	3.99	0.47	0.62	0.45
Spain	5.33	3.67	5.00	–0.31
Sweden	4.22	–0.39	0.27	–6.68
UK	2.50	1.56	0.50	2.26
Mean	3.12	1.73	1.05	5.88
Median	3.51	0.54	0.56	1.15
Std dev.	1.67	2.95	1.47	13.21

Note: This table reports the product of the CIT tax-to-base and base-to-GDP elasticities combined in a single tax-to-GDP elasticity for the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) cases. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

average, the CIT tax-to-GDP elasticity is much larger in recessions than in booms (5.88 versus 1.05).

In comparison with the estimates used within the EU fiscal surveillance framework,[30] our long-run tax-to-GDP elasticities are larger in 8 out of 10 countries, while they are smaller in the remaining 2 countries. The difference appears relevant in most cases, except France and Ireland.

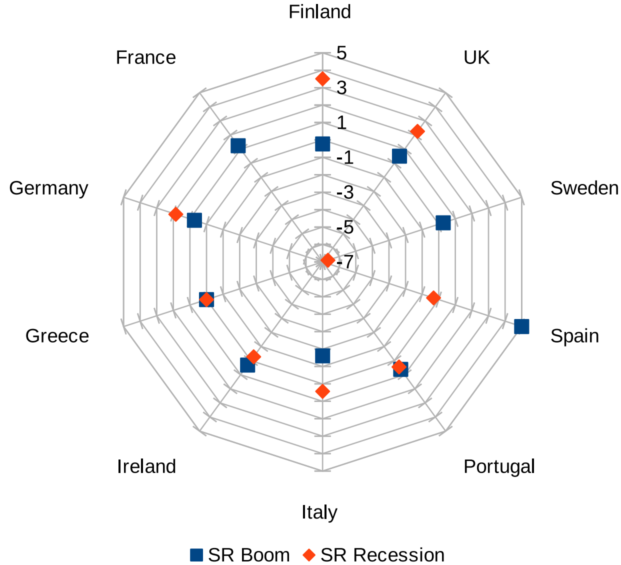
3. Indirect tax

The tax-to-base elasticities for indirect taxes are reported in Table 9. The mean and median absolute values of the long-run elasticities are close to 1.5, but variability across countries is large. The short-run linear elasticity is estimated to be lower than the long-run one for 8 out of 14 countries, with

[30]See Mourre et al. (2013, table A.1, p. 30).

FIGURE 2

Short-run tax-to-GDP elasticity of CIT in boom and recession



Note: This figure shows the CIT short-run tax-to-GDP elasticity in boom (square) and recession (rhombus) for each country. The recession elasticity for France is not reported since its large value (43) would render the figure unreadable.

larger standard errors. Non-linearity is statistically significant for all countries, with large likelihood ratio statistics and *p*-values close to zero. The linear short-run elasticity always lies between the boom and recession ones, except for Greece, whose large standard errors, however, render such comparison not meaningful. On average, short-run elasticities are larger in recessions than in booms by 0.45. The largest increase from booms to recessions is recorded for the UK. The R^2 of the Markov-switching models ranges from less than 0.10 for Italy and Sweden to more than 0.40 for Portugal and the Netherlands. Koester and Priesmeier (2012) estimate a long-run elasticity for German VAT with respect to its base of 0.79, while our estimate is close to zero. By contrast, their short-run elasticity estimate of 0.90 is almost identical to our result (0.88).

For the Netherlands, Wolswijk (2009) estimates a VAT long-run elasticity of 0.90 along with two short-run values – 0.64 below the long-term level and 1.10 above the long-term level. Similarly, Bettendorf and van Limbergen (2013) estimate for the same country a long-run elasticity slightly less than 1 with respect to the consumption base, while the short-run value is larger but still close to 1. Their VAT short-run elasticities range between 1.186 in good times and 0.709 in bad. Our results, instead, suggest a 1.38 long-run elasticity, while

TABLE 9

Elasticity of IND revenue with respect to its base

	LR elasticity δ^{TB} *(s.e.)*	*SR linear elasticity* β^{TB} *(s.e.)*	*SR MS elasticity* β^{TB} *(s.e.)*		*MS model* R^2	*Likelihood ratio test statistic [p-value]*
			Boom	Recession		
Austria	0.96^{**}	1.47	1.56^{**}	0.00	0.33	319
	(0.42)	(1.49)	(0.62)	(1.86)		[0.00]
Belgium	$-0.13_{\bullet\bullet\bullet}$	0.96^{**}	0.85^{***}	1.37^{*}	0.29	258
	(0.29)	(0.43)	(0.26)	(0.76)		[0.00]
Denmark	$1.75^{***}_{\bullet\bullet\bullet}$	0.78^{***}	0.72^{***}	0.80^{***}	0.25	332
	(0.25)	(0.16)	(0.26)	(0.19)		[0.00]
Finland	$1.34^{***}_{\bullet}$	0.81^{***}	$0.59^{***}_{\bullet}$	1.60^{**}	0.29	311
	(0.19)	(0.24)	(0.22)	(0.62)		[0.00]
France	$0.31_{\bullet\bullet}$	$0.40^{*}_{\bullet\bullet\bullet}$	$0.31^{*}_{\bullet\bullet\bullet}$	0.82	0.15	372
	(0.28)	(0.22)	(0.18)	(0.82)		[0.00]
Germany	$-0.50_{\bullet\bullet\bullet}$	0.88^{*}	0.89^{**}	0.57	0.18	281
	(0.44)	(0.45)	(0.42)	(1.97)		[0.00]
Greece	0.97^{***}	$0.09_{\bullet\bullet\bullet}$	$0.04_{\bullet\bullet\bullet}$	$0.05_{\bullet\bullet\bullet}$	0.16	157
	(0.08)	(0.10)	(0.07)	(0.19)		[0.00]
Ireland	$1.84^{***}_{\bullet\bullet\bullet}$	1.07^{***}	0.70^{**}	1.10^{***}	0.38	183
	(0.10)	(0.23)	(0.34)	(0.24)		[0.00]
Italy	$2.75^{***}_{\bullet\bullet\bullet}$	0.55	0.39	1.69	0.08	299
	(0.33)	(0.47)	(0.44)	(1.77)		[0.00]
Netherlands	$1.38^{***}_{\bullet\bullet\bullet}$	0.06	$-0.10_{\bullet}$	0.17	0.48	248
	(0.13)	(0.72)	(0.64)	(2.15)		[0.00]
Norway	-	-	-	-	-	-
Portugal	$1.43^{***}_{\bullet\bullet}$	1.90^{***}	1.63^{**}	2.38^{***}	0.41	189
	(0.21)	(0.62)	(0.63)	(0.85)		[0.00]
Spain	1.30^{***}	2.18^{***}	1.98^{***}	3.29^{**}	0.33	127
	(0.26)	(0.78)	(0.60)	(1.55)		[0.00]
Sweden	$6.36^{***}_{\bullet\bullet\bullet}$	0.55	0.46	1.27	0.06	184
	(1.70)	(1.34)	(1.07)	(3.32)		[0.00]
UK	$0.82^{***}_{\bullet\bullet\bullet}$	0.70^{*}	$0.20_{\bullet\bullet\bullet}$	1.58	0.33	306
	(0.07)	(0.38)	(0.27)	(1.21)		[0.00]
Mean	1.56	0.89	0.74	1.19		
Median	1.32	0.80	0.65	1.19		
Std dev.	1.54	0.61	0.60	0.91		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the indirect tax revenue with respect to its base, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test *p*-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

TABLE 10

Elasticity of IND base with respect to GDP

	LR elasticity δ^{BY} *(s.e.)*	*SR linear elasticity* β^{BY} *(s.e.)*	*SR MS elasticity* β^{BY} *(s.e.)*		*MS model* R^2	*Likelihood ratio test statistic [p-value]*
			Boom	Recession		
Austria	$0.31^{***}_{\bullet\bullet\bullet}$	$0.08^{***}_{\bullet\bullet\bullet}$	$0.11^{***}_{\bullet\bullet\bullet}$	$0.06_{\bullet\bullet\bullet}$	0.24	508
	(0.04)	(0.02)	(0.02)	(0.04)		[0.00]
Belgium	$0.37^{***}_{\bullet\bullet\bullet}$	$0.59^{***}_{\bullet\bullet\bullet}$	$0.47^{***}_{\bullet\bullet\bullet}$	$0.69^{***}_{\bullet\bullet}$	0.52	359
	(0.10)	(0.08)	(0.05)	(0.13)		[0.00]
Denmark	$0.32^{*}_{\bullet\bullet\bullet}$	$0.47^{***}_{\bullet\bullet\bullet}$	$0.58^{***}_{\bullet\bullet\bullet}$	$0.52^{***}_{\bullet\bullet\bullet}$	0.27	336
	(0.16)	(0.11)	(0.12)	(0.16)		[0.00]
Finland	$0.50^{***}_{\bullet\bullet\bullet}$	$0.44^{***}_{\bullet\bullet\bullet}$	$0.46^{***}_{\bullet\bullet\bullet}$	$0.34^{***}_{\bullet\bullet\bullet}$	0.39	397
	(0.07)	(0.08)	(0.08)	(0.12)		[0.00]
France	$0.69^{***}_{\bullet\bullet\bullet}$	$0.58^{***}_{\bullet\bullet\bullet}$	$0.70^{***}_{\bullet\bullet\bullet}$	$0.36^{**}_{\bullet\bullet\bullet}$	0.39	447
	(0.08)	(0.10)	(0.08)	(0.18)		[0.00]
Germany	$0.50^{**}_{\bullet\bullet}$	$0.29^{***}_{\bullet\bullet\bullet}$	$0.44^{***}_{\bullet\bullet\bullet}$	$0.02_{\bullet\bullet\bullet}$	0.28	401
	(0.21)	(0.10)	(0.10)	(0.15)		[0.00]
Greece	$0.83^{***}_{\bullet\bullet\bullet}$	$-0.11_{\bullet\bullet\bullet}$	$-0.22_{\bullet\bullet\bullet}$	$-0.06_{\bullet\bullet\bullet}$	0.32	148
	(0.05)	(0.10)	(0.14)	(0.13)		[0.00]
Ireland	0.99^{***}	$0.31^{***}_{\bullet\bullet\bullet}$	$0.22^{*}_{\bullet\bullet\bullet}$	$0.34^{**}_{\bullet\bullet\bullet}$	0.24	189
	(0.07)	(0.11)	(0.13)	(0.14)		[0.00]
Italy	$0.79^{***}_{\bullet\bullet\bullet}$	$0.50^{***}_{\bullet\bullet\bullet}$	$0.62^{***}_{\bullet\bullet\bullet}$	$0.31^{**}_{\bullet\bullet\bullet}$	0.35	433
	(0.08)	(0.09)	(0.10)	(0.13)		[0.00]
Netherlands	$1.41^{***}_{\bullet\bullet\bullet}$	$0.52^{***}_{\bullet\bullet\bullet}$	$0.43^{***}_{\bullet\bullet\bullet}$	$0.58^{***}_{\bullet\bullet\bullet}$	0.25	416
	(0.08)	(0.11)	(0.10)	(0.15)		[0.00]
Norway	$-0.04_{\bullet\bullet\bullet}$	$0.26^{***}_{\bullet\bullet\bullet}$	$0.20^{*}_{\bullet\bullet\bullet}$	$0.28^{**}_{\bullet\bullet\bullet}$	0.08	563
	(0.15)	(0.09)	(0.11)	(0.13)		[0.00]
Portugal	1.05^{***}	0.85^{***}	$0.64^{***}_{\bullet\bullet\bullet}$	0.94^{***}	0.61	319
	(0.08)	(0.09)	(0.09)	(0.14)		[0.00]
Spain	$1.15^{***}_{\bullet\bullet\bullet}$	1.04^{***}	1.02^{***}	0.86^{***}	0.70	181
	(0.02)	(0.14)	(0.14)	(0.21)		[0.00]
Sweden	$0.56^{***}_{\bullet\bullet\bullet}$	$0.39^{***}_{\bullet\bullet\bullet}$	$0.41^{***}_{\bullet\bullet\bullet}$	$0.38^{***}_{\bullet\bullet\bullet}$	0.32	380
	(0.05)	(0.08)	(0.07)	(0.13)		[0.00]
UK	$1.19^{***}_{\bullet\bullet\bullet}$	$0.72^{***}_{\bullet\bullet\bullet}$	$0.56^{***}_{\bullet\bullet\bullet}$	$0.74^{***}_{\bullet}$	0.47	443
	(0.05)	(0.09)	(0.08)	(0.14)		[0.00]
Mean	0.71	0.48	0.47	0.43		
Median	0.69	0.47	0.46	0.36		
Std dev.	0.39	0.26	0.23	0.29		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the indirect tax base with respect to GDP, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test *p*-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

TABLE 11

Elasticity of IND revenue with respect to GDP

	LR elasticity $\delta^{TB} \times \delta^{BY}$	*SR linear elasticity* $\beta^{TB} \times \beta^{BY}$	*SR MS elasticity* $\beta^{TB} \times \beta^{BY}$	
			Boom	Recession
Austria	0.30	0.12	0.16	0.00
Belgium	–0.05	0.56	0.40	0.94
Denmark	0.56	0.37	0.42	0.42
Finland	0.67	0.35	0.27	0.55
France	0.21	0.23	0.22	0.29
Germany	–0.25	0.25	0.39	0.01
Greece	0.80	–0.01	–0.01	–0.00
Ireland	1.83	0.33	0.16	0.38
Italy	2.17	0.27	0.24	0.52
Netherlands	1.94	0.03	–0.04	0.10
Norway	-	-	-	-
Portugal	1.51	1.61	1.04	2.23
Spain	1.50	2.28	2.01	2.84
Sweden	3.54	0.21	0.19	0.48
UK	0.98	0.50	0.11	1.18
Mean	1.17	0.51	0.40	0.71
Median	0.89	0.30	0.23	0.45
Std dev.	0.98	0.64	0.53	0.85

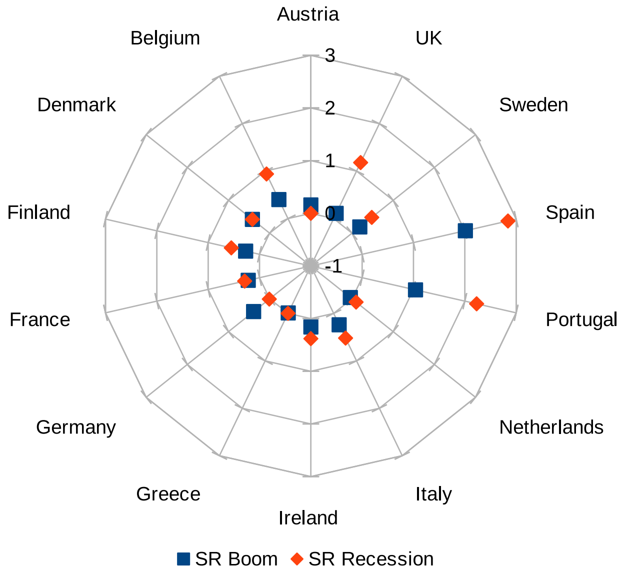
Note: This table reports the product of the indirect tax tax-to-base and base-to-GDP elasticities combined in a single tax-to-GDP elasticity for the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) cases. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

the short-run elasticities are unreliably estimated. Non-linearity is nevertheless strongly supported by the likelihood ratio test.

The variability of IND base-to-GDP elasticities is much lower than the tax-to-base ones (see Table 10). The base-to-GDP estimations are generally more precise than the tax-to-base ones, as shown by the lower standard errors. Short-run elasticities are generally non-linear, as suggested by the large likelihood ratio statistics, although the difference between booms and recessions appears lower than in the tax-to-base case. The largest difference is around 0.42 for Germany. On average, the boom elasticities are slightly larger than the recession ones. Notice, finally, that most base-to-GDP elasticities in the long run, and especially so in the short run, are smaller than 1, showing evidence in favour of consumption smoothing. The 9 countries in which recession elasticities are smaller than boom ones show evidence of lower consumption smoothing in bad times, potentially due to consumers' desire to stay afloat at a preferred consumption level.

FIGURE 3

Short-run tax-to-GDP elasticity of IND in boom and recession



Note: This figure shows the IND short-run tax-to-GDP elasticity in boom (square) and recession (rhombus) for each country.

Tax-to-GDP elasticities are larger in recessions than in booms for 10 out of 14 countries, as shown in Table 11 and Figure 3, with the largest differences obtained for Portugal, Spain and the UK. The mean and median estimates, however, are larger in recessions than in booms. Changes across regimes are mostly due to revenues for all available countries' estimates with the exception of Germany.

Our long-run tax-to-GDP elasticities are lower than 1 – the value assumed within the EU budgetary surveillance framework[31] – in 8 out of 14 countries, and higher than 1 in the remaining 6 countries.

4. Social contributions[32]

Table 12 reports the elasticities of social contributions revenues with respect to their base. Long-run SC tax-to-base elasticities range from 0.43 (Belgium and the Netherlands) to 1.53 (Portugal and the UK). The mean and median estimates are close to 0.80. The mean and median short-run linear elasticities

[31] Mourre et al., 2013, table A.1, p. 30.

[32] Notice that in the models for Greece, Italy and Spain, discretionary tax reform dummies were not included because of multicollinearity due to the value 1 occurring only once.

TABLE 12

Elasticity of SC revenue with respect to its base

	LR elasticity δ^{TB} *(s.e.)*	*SR linear elasticity* β^{TB} *(s.e.)*	*SR MS elasticity* β^{TB} *(s.e.)* Boom	Recession	*MS model* R^2	*Likelihood ratio test statistic [p-value]*
Austria	0.81^{***}	0.59^{*}	$0.51^{**}_{\bullet\bullet}$	0.91^{*}	0.37	226
	(0.17)	(0.32)	(0.22)	(0.52)		[0.00]
Belgium	$0.43^{**}_{\bullet\bullet\bullet}$	0.72^{***}	0.83^{***}	$0.24_{\bullet}$	0.27	242
	(0.20)	(0.25)	(0.20)	(0.44)		[0.00]
Denmark	$-0.81^{***}_{\bullet\bullet\bullet}$	1.45^{***}	$2.81^{***}_{\bullet}$	1.15^{***}	0.38	165
	(0.21)	(0.47)	(0.95)	(0.49)		[0.00]
Finland	0.80^{***}	0.81^{***}	$0.64^{***}_{\bullet\bullet\bullet}$	1.10^{***}	0.63	253
	(0.22)	(0.12)	(0.09)	(0.18)		[0.00]
France	0.95^{***}	$0.41_{\bullet\bullet}$	$0.11_{\bullet\bullet\bullet}$	0.83^{**}	0.35	224
	(0.10)	(0.27)	(0.20)	(0.39)		[0.00]
Germany	$0.47^{***}_{\bullet\bullet\bullet}$	$0.36^{**}_{\bullet\bullet\bullet}$	$0.41^{**}_{\bullet\bullet\bullet}$	$0.13_{\bullet\bullet\bullet}$	0.17	245
	(0.13)	(0.16)	(0.16)	(0.30)		[0.00]
Greece	0.82^{***}	1.08^{**}	1.28^{***}	0.81^{**}	0.49	121
	(0.20)	(0.39)	(0.39)	(0.39)		[0.00]
Ireland	1.22^{***}	0.91^{***}	0.93^{*}	0.88^{***}	0.39	149
	(0.15)	(0.31)	(0.50)	(0.32)		[0.00]
Italy	0.88^{***}	$0.34_{\bullet\bullet\bullet}$	$0.24_{\bullet\bullet\bullet}$	1.14^{*}	0.30	195
	(0.19)	(0.21)	(0.20)	(0.67)		[0.00]
Netherlands	0.43	$-1.88_{\bullet\bullet}$	–0.67	$-7.66^{**}_{\bullet\bullet}$	0.40	143
	(0.70)	(1.24)	(1.10)	(3.22)		[0.00]
Norway	-	-	-	-	-	-
Portugal	$1.53^{***}_{\bullet\bullet\bullet}$	$0.65^{***}_{\bullet\bullet}$	0.63^{**}	$0.65^{***}_{\bullet\bullet}$	0.44	213
	(0.16)	(0.14)	(0.30)	(0.15)		[0.00]
Spain	0.82^{***}	0.81^{***}	$0.63^{***}_{\bullet\bullet\bullet}$	0.95^{***}	0.57	169
	(0.11)	(0.16)	(0.13)	(0.34)		[0.00]
Sweden	-	-	-	-	-	-
UK	$1.53^{***}_{\bullet\bullet\bullet}$	0.74^{**}	0.66^{**}	0.87^{**}	0.25	202
	(0.16)	(0.27)	(0.28)	(0.33)		[0.00]
Mean	0.88	0.83	0.80	1.33		
Median	0.82	0.74	0.64	0.88		
Std dev.	0.36	0.44	0.67	1.93		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the social contributions revenue with respect to its base, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test p-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

TABLE 13

Elasticity of SC base with respect to GDP

	LR elasticity δ^{BY} *(s.e.)*	*SR linear elasticity* β^{BY} *(s.e.)*	*SR MS elasticity* β^{BY} *(s.e.)*		*MS model* R^2	*Likelihood ratio test statistic [p-value]*
			Boom	Recession		
Austria	$0.30^{***}_{\bullet\bullet\bullet}$	$0.27^{***}_{\bullet\bullet\bullet}$	$0.29^{***}_{\bullet\bullet\bullet}$	$0.20_{\bullet\bullet\bullet}$	0.30	304
	(0.09)	(0.06)	(0.06)	(0.12)		[0.00]
Belgium	$0.30^{***}_{\bullet\bullet\bullet}$	$0.02_{\bullet\bullet\bullet}$	$-0.16^{**}_{\bullet\bullet\bullet}$	$0.20_{\bullet\bullet\bullet}$	0.26	269
	(0.09)	(0.10)	(0.06)	(0.29)		[0.00]
Denmark	$0.70^{***}_{\bullet\bullet}$	$0.13_{\bullet\bullet\bullet}$	$0.18_{\bullet\bullet\bullet}$	$0.00_{\bullet\bullet\bullet}$	0.31	235
	(0.13)	(0.13)	(0.14)	(0.18)		[0.00]
Finland	$0.56^{***}_{\bullet\bullet\bullet}$	$0.49^{***}_{\bullet\bullet\bullet}$	$0.48^{***}_{\bullet\bullet\bullet}$	$0.41^{***}_{\bullet\bullet\bullet}$	0.62	267
	(0.07)	(0.07)	(0.07)	(0.10)		[0.00]
France	$0.72^{***}_{\bullet\bullet\bullet}$	$0.53^{***}_{\bullet\bullet\bullet}$	$0.48^{***}_{\bullet\bullet\bullet}$	$0.58^{***}_{\bullet\bullet\bullet}$	0.64	312
	(0.09)	(0.06)	(0.06)	(0.07)		[0.00]
Germany	0.42	$0.40^{***}_{\bullet\bullet\bullet}$	$0.44^{***}_{\bullet\bullet\bullet}$	$0.35^{***}_{\bullet\bullet\bullet}$	0.38	270
	(0.40)	(0.08)	(0.08)	(0.07)		[0.00]
Greece	0.88^{***}	$0.03_{\bullet\bullet\bullet}$	$-0.02_{\bullet\bullet\bullet}$	$0.06_{\bullet\bullet\bullet}$	0.28	144
	(0.14)	(0.05)	(0.04)	(0.11)		[0.00]
Ireland	$1.14^{***}_{\bullet}$	$0.07_{\bullet\bullet\bullet}$	$0.09_{\bullet\bullet\bullet}$	$-0.03_{\bullet\bullet\bullet}$	0.24	188
	(0.08)	(0.16)	(0.15)	(0.21)		[0.00]
Italy	0.88^{***}	$0.40^{**}_{\bullet\bullet\bullet}$	$0.36_{\bullet\bullet\bullet}$	$0.42^{***}_{\bullet\bullet\bullet}$	0.29	210
	(0.09)	(0.15)	(0.22)	(0.14)		[0.00]
Netherlands	$0.47^{***}_{\bullet\bullet\bullet}$	$0.47^{***}_{\bullet\bullet\bullet}$	$0.72^{***}_{\bullet\bullet}$	$0.28^{*}_{\bullet\bullet\bullet}$	0.41	262
	(0.09)	(0.12)	(0.13)	(0.15)		[0.00]
Norway	-	-	-	-	-	-
Portugal	1.22^{***}	$0.57^{***}_{\bullet\bullet}$	0.80^{**}	$0.48^{**}_{\bullet\bullet}$	0.34	228
	(0.18)	(0.20)	(0.32)	(0.22)		[0.00]
Spain	$0.65^{***}_{\bullet\bullet\bullet}$	0.81^{***}	0.79^{***}	0.70^{***}	0.55	189
	(0.06)	(0.13)	(0.13)	(0.18)		[0.00]
Sweden	-	-	-	-	-	-
UK	$0.82^{***}_{\bullet\bullet\bullet}$	$0.60^{***}_{\bullet\bullet}$	$0.42^{***}_{\bullet\bullet\bullet}$	0.82^{***}	0.48	248
	(0.06)	(0.15)	(0.15)	(0.22)		[0.00]
Mean	0.70	0.37	0.40	0.35		
Median	0.70	0.40	0.42	0.35		
Std dev.	0.29	0.25	0.26	0.26		

Note: This table reports, for each country in the first column, the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS) elasticity of the social contributions base with respect to GDP, along with the Markov-switching model R^2 and the likelihood ratio test statistic described in footnote 27. The standard errors (s.e.s) of coefficients and the likelihood ratio test *p*-value are also reported. The symbols *, ** and *** indicate rejection of the null hypothesis that the elasticity is 0 at the 90 per cent, 95 per cent and 99 per cent confidence levels, while the symbols $_{\bullet}$, $_{\bullet\bullet}$ and $_{\bullet\bullet\bullet}$ indicate rejection of the null hypothesis that the elasticity is 1 at the 90 per cent, 95 per cent and 99 per cent confidence levels. The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

TABLE 14

Elasticity of SC revenue with respect to GDP

	LR elasticity $\delta^{TB} \times \delta^{BY}$	*SR linear elasticity* $\beta^{TB} \times \beta^{BY}$	*SR MS elasticity* $\beta^{TB} \times \beta^{BY}$	
			Boom	Recession
Austria	0.24	0.16	0.15	0.18
Belgium	0.13	0.01	–0.13	0.05
Denmark	–0.57	0.18	0.50	0.00
Finland	0.45	0.40	0.31	0.45
France	0.68	0.22	0.05	0.48
Germany	0.20	0.14	0.18	0.05
Greece	0.73	0.03	–0.02	0.05
Ireland	1.39	0.06	0.09	–0.03
Italy	0.77	0.14	0.09	0.48
Netherlands	0.20	–0.89	–0.48	–2.18
Norway	-	-	-	-
Portugal	1.86	0.37	0.50	0.31
Spain	0.53	0.66	0.50	0.67
Sweden	-	-	-	-
UK	1.26	0.44	0.28	0.71
Mean	0.69	0.28	0.25	0.43
Median	0.57	0.18	0.18	0.31
Std dev.	0.52	0.26	0.19	0.58

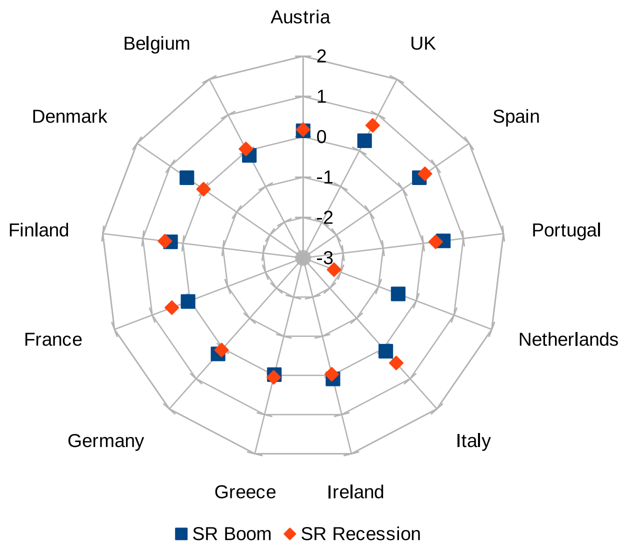
Note: This table reports the product of the social contributions tax-to-base and base-to-GDP elasticities combined in a single tax-to-GDP elasticity for the long-run (LR), short-run linear (SR linear) and short-run Markov-switching (SR MS). The bottom panel of the table reports the mean, median and standard deviation (std dev.) of the absolute values of each type of elasticity across countries.

are lower than the long-run ones. Non-linearity is statistically significant for all countries. The linear elasticity always lies between the boom and recession ones. The difference between the boom and recession short-run elasticities is almost always economically relevant, going from a minimum of 0.02 in Portugal to almost 7 in the Netherlands. The short-run elasticity is larger in recessions than in booms for 8 out of 13 countries. The R^2 of the Markov-switching models ranges from 0.17 for Germany to 0.63 for Finland.

With regards to the SC base-to-GDP elasticities (see Table 13), the mean and median long-run coefficients amount to 0.70. The short-run linear elasticity is lower than the long-run one on average, and lies between the short-run Markov-switching elasticities for all countries except Finland and Spain. Short-run elasticities are generally non-linear. The difference between booms and recessions appears to be generally smaller than in the tax-to-base case. The

FIGURE 4

Short-run tax-to-GDP elasticity of SC in boom and recession



Note: This figure shows the SC short-run tax-to-GDP elasticity in boom (square) and recession (rhombus) for each country.

largest difference is around 0.44 for the Netherlands. The boom elasticities are larger than the recession ones in 8 out of 13 countries.

Tax-to-GDP elasticities are larger in booms than in recessions for 5 out of 13 countries, as shown in Table 14 and Figure 4, with the largest differences obtained for Denmark, France, the Netherlands and the UK. Changes across regimes are mostly due to revenues for all countries except Ireland, Portugal and the UK.

Our estimates of long-run tax-to-GDP elasticities are generally lower than those used by the EU Commission,[33] the only exceptions being those for Ireland, Portugal and the UK.

V. Policy implications and conclusion

In this paper, we present estimates of long-run and short-run elasticities of tax revenues with respect to their bases and of bases with respect to GDP for the main tax categories – personal income taxes, corporate income taxes, indirect taxes and social contributions – for a large selection of EU countries. We propose a method to estimate short-run elasticities that vary with countries'

[33] Mourre et al., 2013, table A.1, p. 30.

business cycles. This method consists of a Markov-switching model by which an economy's output switches between two states: a high mean state ('boom') and a low mean state ('recession').

As a second contribution, we use a simple method to take account of discretionary tax measures when estimating tax elasticities. We construct a database of dummy variables that take the value 1 when a tax reform is implemented and 0 otherwise, based on information collected and processed by the European Commission in the annual survey of taxation trends in the EU.

Our results across tax categories indicate a clear tendency for short-run elasticities to increase in recessions with respect to booms. This holds for corporate income taxes, indirect taxes, social contributions and, to a lesser extent, personal income taxes. Results are confirmed across countries, with a tendency for larger elasticities in recessions to prevail. Short-run elasticity heterogeneity across countries and tax categories remains to be explained by future research.

Our results have potentially important policy implications for fiscal surveillance in the EU. The current EU framework requires the estimation of a cyclically adjusted budget balance, i.e. a budget balance based on discretionary fiscal policy measures, net of the influence of the business cycle on revenues and expenditure. Computing the cyclically adjusted budget balance relies on tax revenue elasticities with respect to the output gap, and the current procedure uses long-run elasticity estimates. Our results show that tax elasticities themselves change over the business cycle, with a clear tendency to increase in recessions relative to booms. In the same direction point results by Princen et al. (2013), whose estimation method, however, gives highly erratic elasticities. Our method, by contrast, results in only two short-run elasticities, one for boom periods and another for recession periods, which might therefore be easily incorporated in the cyclically adjusted budget balance computation procedure.

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