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Dynamic tax revenue buoyancy estimates for a panel of OECD countries

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Abstract: In this paper we provide short- and long-run tax buoyancy estimates for a panel of OECD countries. Our results indicate that total tax revenue estimates are not different from unity, corporate income tax buoyancies exceed unity both in the long- and the short-run, while personal income tax buoyancies are smaller than unity; these results are robust to controlling for changes in the respective tax rates. Moreover, after taking into account the fluctuations of the business cycle, we observe that CIT estimates are larger during periods of contraction rather than periods of economic expansion; these results hold both for the whole panel and the Irish economy. Moreover, we examine the effects of using GNP instead of GDP as a base of economic activity for the Irish economy. Although the results are qualitatively the same, the differences need to be taken into account, especially form an economic policy point of view.

Key Words: Tax revenue buoyancy, Dynamic panels, Error correction models

JEL Classification: H24, H25, H27, H30

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I. INTRODUCTION

Tax revenue buoyancy estimates are extensively used in the context of fiscal policy monitoring and implementation and, in particular, in the analysis, forecasting and surveillance of the revenue side of the budget. In forecasting terms, tax buoyancy estimates are used in order to calculate the expected stream of revenues on a "no policy change" basis, based on forecasts for the evolution of the main macroeconomic variables. Accurate estimates of buoyancies are necessary in order to avoid budget surprises (e.g. shortfall in revenues) that may lead to mistaken assessments of the fiscal stance. This aspect is closely related to the issue of fiscal surveillance, especially within the Euro area, as revenue buoyancy estimates are used in the calculation of cyclically adjusted and structural budget balances, core indicators within the Stability and Growth Pact framework. As noted in Koester and Preismeier (2017), given that the business cycle has a major impact on revenues, accurate elasticity estimates are crucial in order to ensure that the forecasts of cyclical and structural balances are not distorted.

Accurate elasticity estimates are central to the appropriate definition of tax revenue buoyancies. In particular, in the relevant (policy related as well as academic) literature, the terms tax revenue elasticity and tax revenue buoyancy both appear and, in some cases, are used interchangeably (e.g. see Koester and Preismeier (2017)). Nonetheless, it should be noted that the terms have a different meaning, which must be taken into account. Tax elasticities measure the response of tax revenues to changes in the relevant tax bases, taking into account the discretionary measures (related to changes in the tax system and administration, such as changes in statutory tax rates, tax credits etc.) taken by the government. On the other hand, tax buoyancies measure the overall change of tax revenues that results from a one percentage change in the levels of GDP.

The role of tax revenue buoyancy estimates has become even more important in the aftermath of the global financial crisis, as a large number of countries had to face fiscal challenges (increases in the size of deficit and public debt) with some countries forced into the implementation of consolidation programs. In particular, within the euro area, for the countries that received financial assistance in the aftermath of the financial crisis (namely, Greece, Ireland and Portugal) the consolidation programs relied to a large extent on revenue increases (e.g. the Irish program envisaged revenue increases of up to €5 billion, mainly from increases in PIT revenues, while for Greece revenue increases were forecast to increase by almost 4% of GDP over the course of the three-year program).

As most of these programs forecasted positive GDP growth rates in the short-run, it is important to examine whether these increases in GDP will lead to higher or lower respective increases in tax revenues, that is, to examine whether tax revenue buoyancies are greater than unity. Buoyancy estimates larger than one imply that tax revenues will increase by more than GDP, thus leading to a higher tax-to-GDP ratio which could potentially lead to a lower deficit thus ensuring that public finances are on a sustainable path. On the other hand, if GDP growth is negative, then a buoyancy estimate that is larger than one will imply a significant deterioration of the tax-to-GDP ratio. Based on these considerations, this strand of the literature (see Mourre and Princen (2015) and Koester and Preismeier (2017)) classifies a tax as being regressive or progressive based on the value of the buoyancy estimate; in particular, a tax is characterised as being regressive (progressive) if the (long-run) buoyancy estimate is below (above) unity (given that an estimate equal to one is consistent with a constant revenue-to-GDP ratio).

The aim of this paper is to calculate both short- and long-run buoyancy estimates (for Total tax, CIT and

PIT revenues)[1] for a panel of OECD countries, controlling for (discretionary) changes in fiscal policy. Moreover, our aim is to identify the relevant position of Ireland within the panel and examine which of the tax revenue categories is more effective as an automatic stabilizer in the short-run and in ensuring fiscal sustainability in the long-run.

Our results indicate that the long- and short-run buoyancy estimates of total tax revenues are equal to one, making tax revenues a neutral policy stabilizer, while the PIT buoyancy estimates point to a regressive system for the whole panel (as the estimates are below unity). CIT buoyancy estimates are the only ones that are greater than one, indicating that CIT is the most effective tax policy tool overall. Regarding Ireland, the tax system seems to be proportional as the long-run Total Tax revenue buoyancy is almost equal to unity, while the CIT is again shown to be the most effective automatic stabilizer (given that the relevant estimates exceed unity). These results are robust to controlling for the asymmetric effects caused by the fluctuations of the business cycle. Moreover, we conclude that for the Irish economy, it is important from a policy perspective to examine estimates of Irish tax revenue buoyancy, based on GDP and GNP, respectively, as there are deviations between the estimates (although the results remain, qualitatively, the same).

The rest of the paper is structured as follows: section II discusses the evolution of some headline tax rate revenues across the OECD. Section III presents some theoretical considerations along with the estimation approach and the data used. Section IV presents the results of the country-specific and the panel estimations, as well as the robustness analysis performed. Finally, section V concludes.

II. TAX REVENUE GROWTH

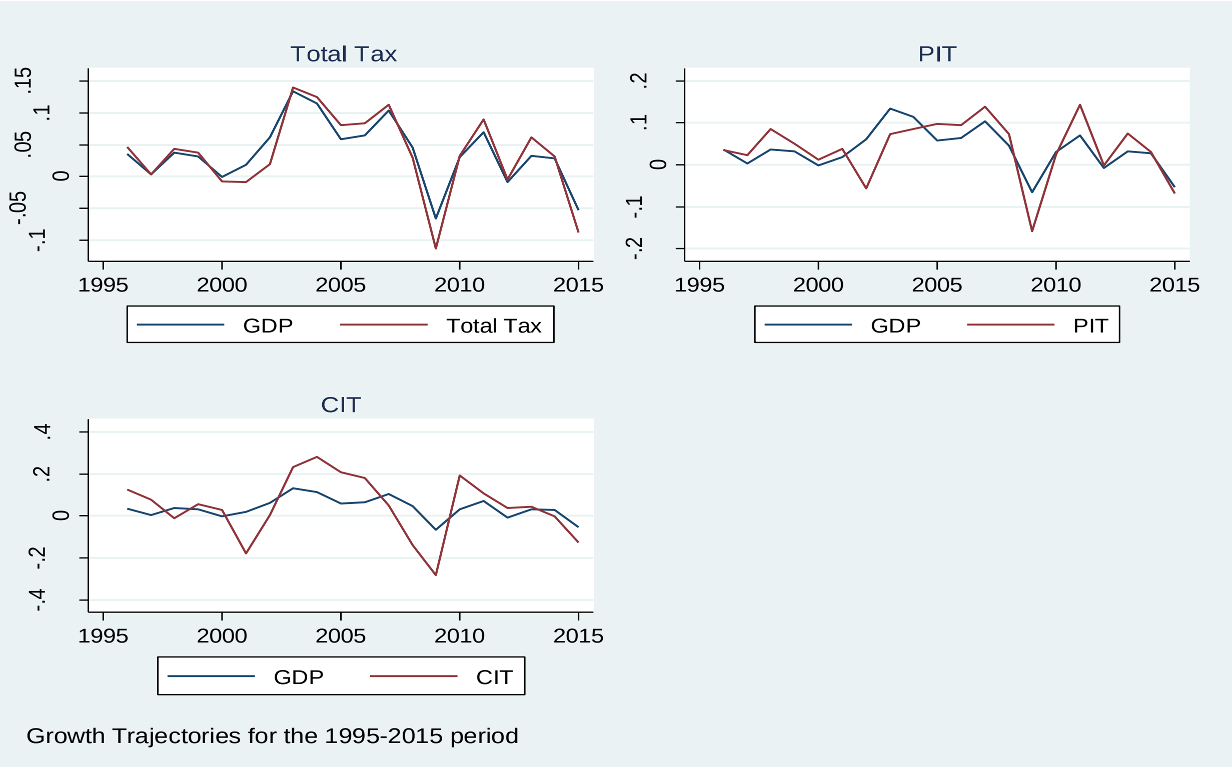
Figure 1 presents the growth trajectory of the tax revenue categories and GDP for a panel of 25 OECD countries for the period 1995-2015. We see that for the period 2000-2004 and after the financial crisis (2007-2010), tax revenue growth was lower than GDP growth, while for the rest of the period, total tax revenue growth was larger than GDP growth. Similar patterns arise for the Personal Income (PIT) and Corporate Income tax (CIT) growth trajectories and, in the CIT case, the deviation between the growth paths is quite large, especially in the early- to mid-2000s period. These observations point to the fact that the respective tax buoyancies have exceeded unity during this period.

In order to be able to compute accurate tax revenue buoyancy estimates, a distinction must be made between short- and long-run estimates. In general, the relevant literature follows the constancy assumption concerning revenue buoyancies; that is, it is assumed that the estimates are identical in the short- and the long-run term. For example, such estimates based on the constancy assumption were used by the OECD in the computation of the Cyclically-Adjusted Balance (see Bouthevillain et.al (2001) and Girouard and Andre (2005)).

However, as mentioned in Koester and Preismeir (2012), Princen et.al (2013) and Mourre and Princen (2015), there are a number of reasons to expect that there will be deviations between short- and long-run estimates. A significant factor contributing to these deviations is the composition effect of growth, i.e. the way in which different components of GDP evolve over time.

[1] VAT revenues, even though in many cases represent a significant amount of total tax revenues, are relatively sparse in the relevant OECD database (as some countries e.g. USA, do not have VAT), leading to a reduction in available observations

Figure 1: Growth trajectories of Total tax, PIT and CIT revenues and GDP



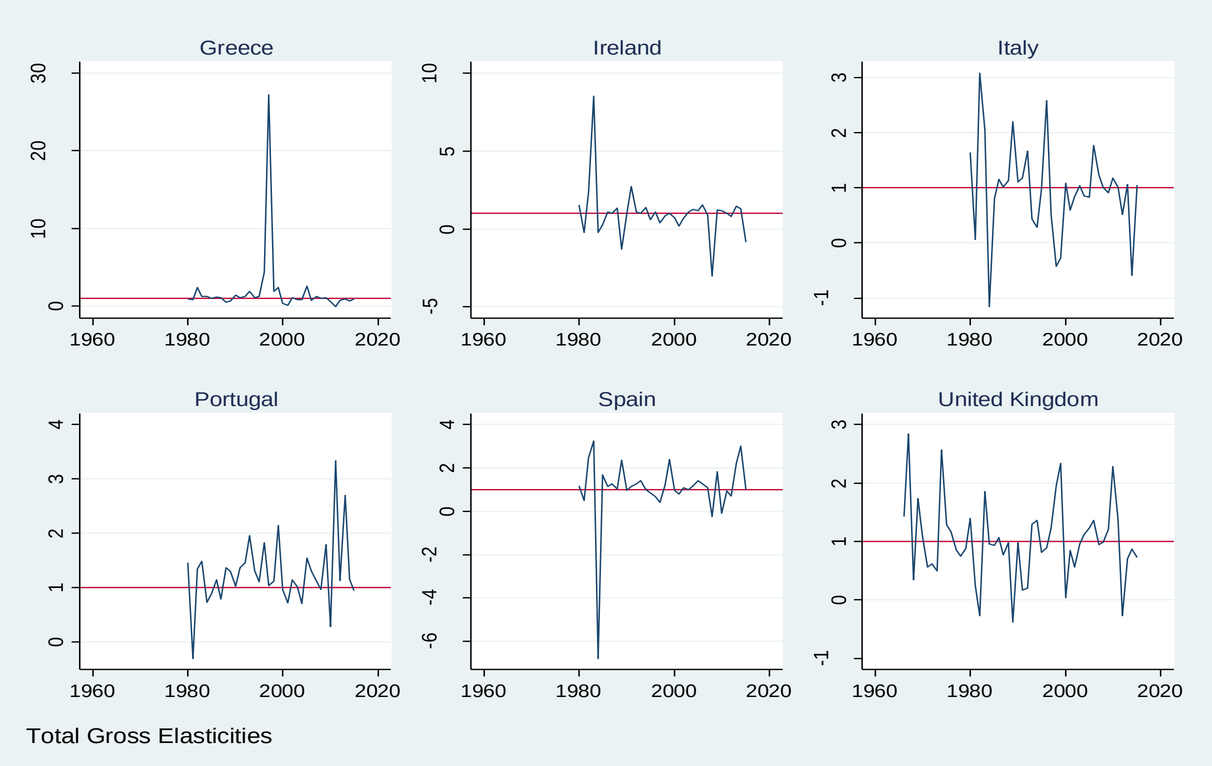
Note: The period 1995-2015 was chosen to ensure that we have a balanced panel. Source: OECD National Accounts and Revenue Statistics

For example, if variations in consumption affect the composition of the relevant expenditures this will lead to fluctuations in tax revenues in a multi-rate VAT system. Another important factor are the so called "dynamic effects", which refer to certain characteristics of the tax system; e.g. PIT revenues may be affected by lags in the collection mechanism, as in some countries income is declared in the following year, or CIT revenues in one period may be affected because of losses carried-forward from a previous period.

A first indication of the deviations between short- and long-run estimates is depicted in Figure 2, which presents the (deterministic) gross total tax revenue buoyancies, that is, the ratio of the growth of total tax revenues to the growth of GDP[2]. It is evident that the short-run gross estimates are quite volatile, with some of them exhibiting changes in sign and others remaining above one (e.g. Portugal) for an extended period of time, indicating that the respective long-run buoyancies exceed unity. Moreover, excluding some year-specific outliers (the values of 27 for Greece, 8 for Ireland and -6 for Spain which are solely due to almost zero GDP growth in those particular years) it seems that the long-run trend of gross estimates is around one. Finally, it is important to note that there appears to be no common pattern in the short-run buoyancies across countries, pointing to an increased degree of heterogeneity in buoyancies amongst countries.

[2] Koester and Preismeier (2017) mention that these gross elasticities represent a good first approximation for the actual elasticity estimates

Figure 2: Gross Total Tax Revenue Buoyancies



Source: OECD National Accounts and Revenue Statistics / Blued Line depicts short-run estimates, while the red line represents a long-run buoyancy equal to one

In general, short-run estimates measure how the short-run fluctuations of the business cycle affect tax revenues, while the long-run estimates measure the reaction of tax revenues to long-run structural changes. From a policy perspective, short-run buoyancies are an important indicator of the tax system's ability to stabilize the economy over the course of the cycle while long-run estimates quantify the impact of growth on long-run fiscal sustainability.

III. TAX REVENUE ELASTICITIES

A. Theoretical Considerations and Literature Review

Tax revenue elasticities quantify the effects of a one percentage change in the base of economic activity (e.g. GDP or an appropriate macroeconomic base) on the corresponding category of tax revenues. They represent the automatic growth potential of the tax system, as they are calculated on a "no policy change" basis.

As noted in Koester and Preismeier (2017), the relevant literature makes a distinction between (net) tax elasticity and tax buoyancy measures. While some authors use both terms interchangeably, in general tax elasticities are calculated using tax revenue series that have been adjusted so as to take into account changes, either legislative or administrative, in the tax policy parameters i.e. tax revenue series that have been corrected for discretionary tax measures (DTMs). This is evident from the definition of tax elasticities given in Creedy and Gemmell (2003):

"Revenue responsiveness is the extent to which tax revenues respond to changes in some tax base, usually income, in the absence of any discretionary action by the fiscal authority, and is typically measured by the *revenue elasticity of tax*".

On the other hand, tax buoyancy measures the overall observed response of a tax revenue category following a one percentage change in the economic base, without taking into account the effects of exogenous policy actions. In general, the identification of discretionary measures is important as it helps in distinguishing between changes in tax revenues that stem from the evolution of the tax base (i.e. *endogenous* changes) and changes that are the result of *exogenous* (direct or indirect) policy induced measures (e.g. changes in the tax rates etc.). Moreover, some authors have indicated that DTMs might play an important role in explaining the variation exhibited by short-run elasticities and their deviation from long-run, equilibrium values.

Barrios and Fargnoli (2010) and Princen et.al (2013) have shown that the size of DTMs is quite small as a percentage of revenues (less than 1.4% in EU countries), although there are some cases (for individual years and countries) where these measures are indeed large. However, they point out that as gross and net elasticities appear to have a high degree of correlation over time, DTMs cannot explain the discrepancy between the elasticity estimates.

Tax buoyancy measures are generally estimated using two approaches: the first one is based on the use of analytical expressions, while the second is based on time-series techniques. The first approach (see Girouard and Andre (2005) for the OECD estimates and Acheson et.al (2017) for the calculation of income tax elasticities for Ireland) is based on the use of detailed micro-data and information regarding the national tax code system (e.g. for the Personal Income Tax elasticity, data on the income distribution and statutory tax rates are used in order to compute the marginal and average tax rates of the representative household). The second approach uses time-series techniques in order to estimate tax elasticities, usually by regressing the logarithm of tax revenues on the log of economic activity, while controlling for other factors that may affect the evolution of tax revenues.

The time-series approach to estimating tax revenue buoyancy uses three different concepts (e.g. see Mourre et.al. (2013) and Koester and Preismeier (2017)):

1. Buoyancies with respect to the output gap, which correspond to the percentage change in the levels of tax revenues induced by an output gap of 1%. These can be decomposed into the following components: elasticity of revenue with respect to its base and the elasticity of revenue base with respect to the output gap. These elasticity estimates have been used both by the European Commission and the OECD within the fiscal surveillance framework.

2. Buoyancies with respect to a macroeconomic base, where an appropriate national accounts category is used as a proxy for the relevant tax base (e.g. the wage bill is usually used as a proxy for the base of the Personal Income Tax and Gross Operating Surplus for CIT).

3. Buoyancies of tax revenues with respect to GDP; this measure has the advantage of allowing for comparisons across different tax categories (given that the tax base is now the same) and across countries. Moreover, when compared to elasticities with respect to the output gap, it has the advantage that it uses an observable base. Finally, as indicated in Princen et.al. (2013), these elasticity estimates are quite close to the ones calculated based on the output gap.

In this paper we follow the third concept and choose GDP as the (common) base of economic activity, as we are interested in cross-country comparisons in order to identify, among others, the relevant position of the Irish economy within the panel of countries. Moreover, we begin with estimating revenue buoyancies as there is no dataset available containing detailed information on tax reforms and other changes to the tax system for the panel of OECD countries[3].

It should be noted that the time-series approach has the advantage of encompassing the overall net effect of existing rules regarding tax credits, exemptions and deductions, thus allowing for international comparisons. On the other hand, it does not take into account information related to statutory rates, income distribution etc. which are an integral part of the analytical approach to elasticity estimations

Although, as already mentioned, we expect that under this approach there won't be large differences between the estimates of tax buoyancy and tax elasticity. In order to control for changes in the tax structure we will include in the econometric specifications time series of tax rates, as changes in these rates over time can be considered as a proxy of discretionary measures (and thus provide us with an indication of the size of tax elasticities).

The literature on dynamic tax elasticity estimates can be broadly distinguished between country-specific estimates and that based on a panel approach. Moreover, within these approaches, another distinction arises in the use of tax revenue series that have been adjusted for discretionary tax policy measures.

The first paper to provide a time-series estimation of short- and long-run tax elasticities is Sobel and Holcombe (1996), who used an Error Correction Model (ECM) to estimate tax base income elasticities for the USA and the adjustment to the long-run equilibrium. Bruce et.al (2006) extend this methodology by incorporating asymmetric responses of short-run estimates, taking into account the relationship between actual and expected tax base growth. They applied their method to the US states in order to obtain tax-to-base elasticities. Poghosyan (2011) assesses the variability of tax elasticities in Lithuania, while Wolswijk (2007, 2009) and Koester and Preismeier (2012) calculate dynamic tax revenue elasticities for Netherlands and Germany, respectively, utilizing databases of neutral tax revenues, that is, tax revenue series that have been adjusted for the effects of discretionary tax measures.

The same approach is used by Havranek et.al (2015) for the Czech Republic, although the authors use quarterly data in their estimations. Deli et.al (2016) estimate income tax revenue elasticities for Ireland, using as a base of economic activity both GDP and GNP, while also controlling for financial sector effects. Finally, Koester and Preismeier (2017) and Boschi and d'Addona (2017) provide country-specific tax-to-GDP elasticity estimates for the EU countries, with the latter introducing a regime-switching approach. As regards panel estimations, Belinga et.al (2014) provide tax-to-GDP elasticity estimates for a panel of OECD countries while Dudine and Jalles (2017) extend this analysis to a larger heterogeneous panel. Finally, Mourre and Princen (2015) provide panel estimations of dynamic tax elasticities for the EU, using a dataset that has been adjusted for DTMs.

[3]There is one dataset that contains information on discretionary tax measures for EU member states, developed by the Output Gap Working Group of the Economic Policy Committee of the European Commission presented in Barrios and Fargnoli (2010) and Princen et.al (2013) that has been recently utilized in Mourre and Princen (2015). However, this dataset has not been made publicly available.

B. Econometric Specification and Estimation Approach

Our econometric specification is based on the following Autoregressive Distributed Lag model -ARDL(p,q):

$$T_{i,t} = \sum_{j=1}^{p} a_{i,j} T_{i,t-j} + \sum_{j=0}^{q} \theta_{i,j} GDP_{i,t-j} + \mu_i + \varepsilon_{i,t} \quad (1)$$

where $T_{i,t}$ denotes the logarithm of the relevant tax category for country i at time t, $GDP_{i,t}$ denotes the logarithm of GDP, μ_i are country-specific fixed effects and $\varepsilon_{i,t}$ is the error-term.

The choice of the appropriate lags for equation (1) is based on the Bayesian Information Criterion (BIC), which indicated that the optimal lag-length is $p = q = 1$. Therefore:

$$T_{i,t} = a_{i,1} T_{i,t-1} + \theta_{i,0} GDP_{i,t} + \theta_{i,1} GDP_{i,t-1} + \mu_i + \varepsilon_{i,t} \quad (2)$$

Now, equation (2) can be transformed into the following Error Correction Model (ECM):

$$\Delta T_{i,t} = \lambda_i \left(T_{i,t-1} - \beta_i GDP_{i,t-1}\right) + \theta_{i,0} \Delta GDP_{i,t} + \mu_i + \varepsilon_{i,t} \quad (3)$$

where $\lambda_i = -\left(1 - a_{i,1}\right)$, $\beta_\iota = \frac{\theta_{i,0} + \theta_{i,1}}{\left(1 - a_{i,1}\right)}$.

In this specification, β_i measures the long-run effects of a change in GDP levels on tax revenues, i.e. it denotes the long-run tax revenue buoyancy. The $\theta_{i,0}$ parameter measures the instantaneous response of tax revenues to changes in GDP (i.e. the short-run buoyancy), while λ_i measures the (country-specific) speed of adjustment between the short- and the long-run; that is, it measures the speed by which the elasticity converges to its equilibrium value.

Equation (3) is estimated for the whole panel using the Mean Group (MG) estimator of Pesaran and Smith (1995) and the Pooled Mean Group (PMG) estimator of Pesaran et.al. (1999), in order to take into account the possible heterogeneity in the panel, both in terms of differences in elasticity estimates across countries and in terms of the dynamic adjustment process towards the long-run equilibrium.

In particular, the standard Fixed Effects approach to panel estimation imposes a large degree of homogeneity, given that it consists of pooling the available data and allowing only for the intercepts (the μ_i parameter in equation (3)) to vary across countries.

On the other hand, the MG estimator allows for a large degree of heterogeneity, as it is assumed that both the intercepts and the slopes (i.e. the buoyancies) are allowed to vary across countries, both in the short- and in the long-run. The buoyancies are estimated following the per-country estimation of equation (3) and then a simple arithmetic average of the country-specific estimates is calculated for the whole panel. The PMG estimator is a combination of pooling and averaging, as it allows for the short-run estimates of the intercepts and the slopes to vary but imposes long-run homogeneity, in the sense that the long-run elasticity estimates are constrained to be equal across countries.

C. Data

Our dataset comprises an unbalanced panel of annual tax revenues covering 25 OECD countries[4] between 1965 and 2015. The availability of data differs among countries and subcategories of tax revenues, being relatively sparse for the period 1965-1995 (as there are, among others, different accession dates to the OECD and different coverage dates by national authorities). The number of years per country varies from 20 years for Slovakia and Slovenia to 50 years for the oldest members.

The tax categories used in this paper, apart from Total Tax revenues, are Personal Income Tax (PIT) and Corporate Income Tax (CIT). Moreover, we include tax rate data and, in particular, following Dudine and Talles (2017) we use the highest marginal PIT for the PIT revenues rate and the base statutory CIT rate for the CIT revenues. The data source is the Revenue Statistics series of the OECD. It should be noted here that the PIT and CIT rates database spans only the period 2000-2015, thereby greatly reducing the time dimension of the sample and the number of observations that will be included in the regression analysis. For the CIT rates series, we were able to extend the time coverage by almost 20 years by including data from Devereux et.al that cover the period 1979-2002, albeit for a smaller number of countries (18 out of the original 25 of our sample). Finally, the dataset includes data on GDP and the rate of inflation, taken from the National Accounts database and the Consumer Indices series of the OECD, respectively.

In Figures 3 and 4 we have plotted the evolution of Total Tax revenues and PIT, CIT revenues, respectively, while Table 1 presents a summary of the basic statistics. It is evident that total tax revenues have remained relatively stable over this period, with a decline occurring in 2007-2009, marking the negative impact of the financial crisis. In the years following the crisis, tax revenues again increased reaching the pre-crisis levels, although 2015 marks another drop, caused by a decline in tax revenue collection.

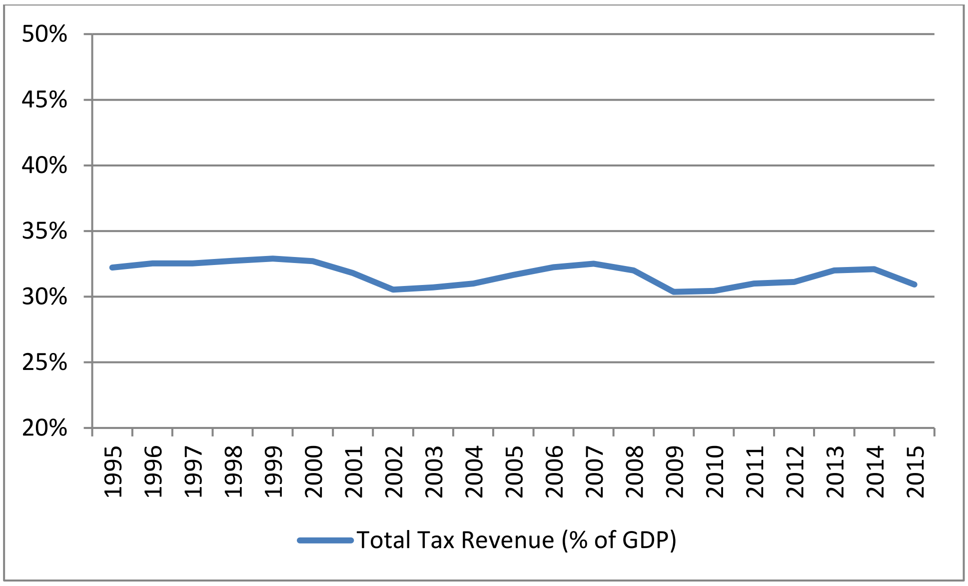
Table 1: Summary Statistics

	Mean	Median	Min	Max
Total	254.8	73.42	1.294	4754.1
PIT	75.73	21.41	0.222	1763.6
CIT	20.28	5.956	0.0612	425.2

The same picture arises in the case of the PIT and CIT revenues. They have remained relatively stable over the period and, although there seemed to be a recovery to the pre-crisis levels especially for PIT revenues, the trajectory was once again reversed in 2014.

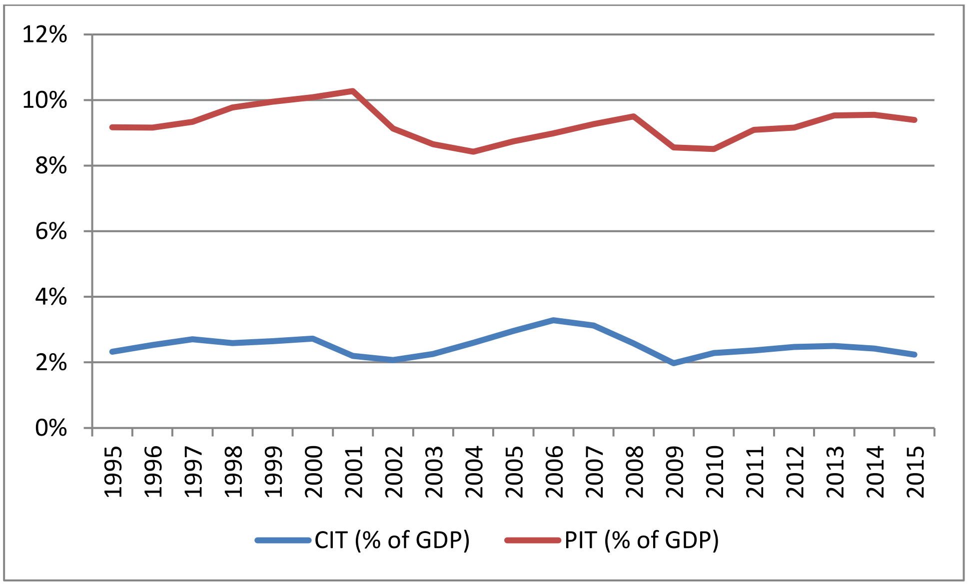
Figure 3: Evolution of Total Tax Revenues.

[4] Namely: Australia, Austria, Belgium, Canada, Czech, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxemburg, Netherlands, New Zealand, Norway, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK, US



Note: The data cover the period 1995-2015 only, to ensure that we have a balanced panel that includes all 25 countries of the sample. Source: OECD Revenue Statistics

Figure 4: Evolution of PIT and CIT.



Note: The data cover the period 1995-2015 only, to ensure that we have a balanced panel that includes all 25 countries of the sample. Source: OECD Revenue Statistics

IV. RESULTS

A. Country-Specific Estimations

We first estimate equation (3) for total tax revenues, as well as the Personal and Corporate Income Tax, using the MG estimator, in order to obtain country-per-country estimates of the short- and long-run buoyancies, as well as estimates for the speed of adjustment.

Table 2 presents a summary of the results while figure 5 presents the kernel densities of the long-run buoyancy estimates. The average of the total tax revenue buoyancy coefficients is slightly above unity (1.029) and most estimates (18 out of 25) are greater than one. However, similar to Dudine and Jalles

(2017), we cannot take this result as an implication that long-run tax buoyancies are significantly different from unity. Rather, the relevant Wald test (last column of table 2) indicates that for the majority of countries long-run elasticity estimates are in fact equal to one. The long-run total tax revenue elasticity for Ireland is 0.894 (see Table 4), lower compared to the median value and statistically different from one.

As regards the long-run PIT buoyancy estimates, on average they are slightly lower than one and the distribution of the estimates is skewed to the right, with only 10 out of the 25 countries of the sample exhibiting estimates that exceed unity. Again, the relevant Wald test indicated that for 16 countries we cannot reject the hypothesis that the long-run PIT buoyancy estimate is equal to one.

For the CIT long-run estimates, we observe that the distribution of estimates is heavily skewed to the left, with 20 out of the 25 countries having a point estimate exceeding unity, however the hypothesis that the long-run value is equal to one cannot be rejected for 18 countries. Ireland exhibits a large CIT elasticity of 1.27, higher compared to the median value, although statistically not different from unity.

In general, cross-country variation is quite low for the Total tax revenue estimates, with a standard deviation of 0.07, while for the CIT elasticity estimates the standard deviation is 0.2. These results, combined with the point estimates, indicate that the long-run total tax buoyancy has been, on average, equal to one while CIT buoyancy has exhibited a much larger degree of variability.

The estimates for the speed of adjustment are negative and statistically significant for all countries, a result consistent with the theoretical expectation of convergence to long-run, equilibrium values.

Table 2: Summary Statistics for Long-run Elasticity Estimates

	Mean	Median	St. Dev.	Min	Max	Elasticity =1
Total	1.029	1.024	0.0777	0.894	1.296	16 countries
PIT	0.983	0.970	0.165	0.695	1.372	16 countries
CIT	1.157	1.129	0.195	0.800	1.562	18 countries

Note: The total number of countries in the sample is 25. The last column presents the results of the Wald test that the elasticity estimate is equal to one.

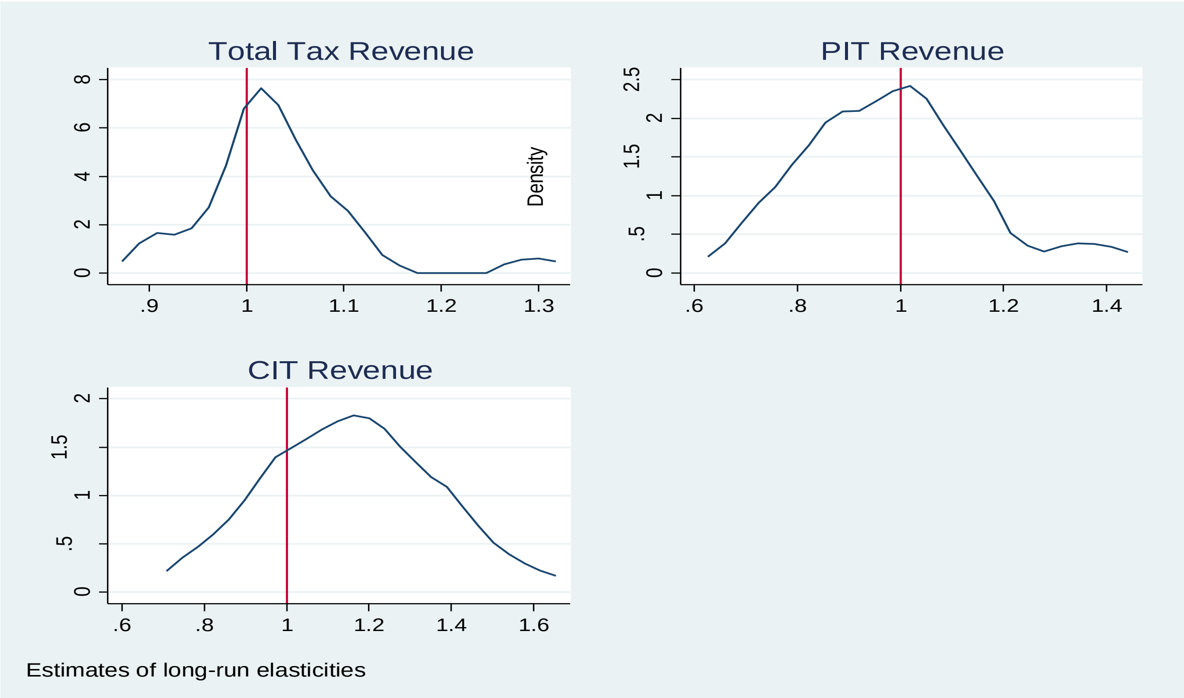
The summary statistics from the estimation of the short-run buoyancies can be found in Table 3 and the respective kernel densities are depicted in Figure 6. The average of the short-run Total Tax revenue buoyancy is slightly above unity, with only 50% of the countries exhibiting point estimates that are greater than one. However, the Wald test indicates that for 22 out of the 25 countries the estimates are not statistically different from one which, when combined with the fact that the variation across countries is relatively low (standard deviation equal to 0.11), indicates that the short-run buoyancy estimates have been on average equal to one over the period. The same holds for the short-run PIT estimates, where the large dispersion (0.17) is explained mainly by the large point estimates for USA (1.77), which is twice the size of the lowest estimate for the sample, recorded for Greece. The distribution of the short-run PIT estimates is skewed to the right with only 8 countries having an elasticity greater than one. In both cases, the estimates for Ireland are slightly lower than the median value (0.991 for the short-run Total Tax revenue elasticity and 0.93 for PIT), although they are not statistically different from one.

Table 3: Summary Statistics for Short-run Elasticity Estimates

	Mean	Median	St. Dev.	Min	Max	Elasticity=1
Total	1.016	0.995	0.110	0.876	1.504	22 countries
PIT	1.011	0.981	0.174	0.845	1.771	25 countries
CIT	1.371	1.221	0. 588	0.685	3.863	23 countries

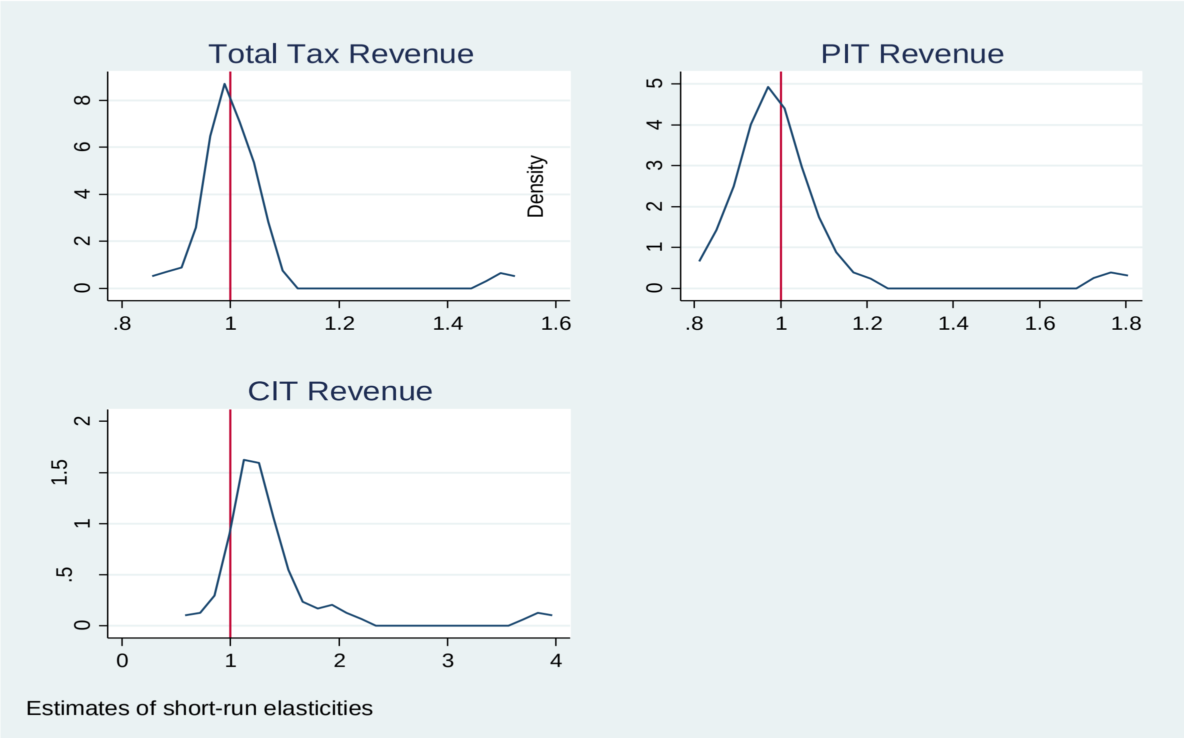
Note: The total number of countries in the sample is 25

Figure 5: Kernel Densities of Long-Run Buoyancies



Finally, the short-run CIT elasticity estimates are on average larger than one, with a mean value of 1.371 and with 23 countries having estimated coefficients greater than one, causing their distribution to be heavily skewed to the left. Moreover, they exhibit a greater degree of variability (standard deviation equal to 0.59) compared to the previous two cases. Only two of the countries have a buoyancy estimate that is lower than one (namely, Luxemburg and Sweden) while the largest estimates are the ones recorded for the US (3.86) and Finland (2.04). Ireland has a CIT buoyancy estimate of 1.26, larger compared to the median valued and almost equal to the respective long-run estimate.

Figure 6: Kernel Densities of Short-Run Buoyancies



Overall, regarding the estimates for the Irish economy (Table 4) we see that they exhibit a very low degree of variability (as indicated by the small differences between the long- and short-run estimates). The differences observed could be the result of discretionary measures undertaken by the government (see section C. II where we use proxies in order to control for these changes) as well as business cycle fluctuations (see section C.III). Moreover, as already stated in the introduction, the differences between short-and long-run estimates may be due to the composition of income growth (e.g. a reduction in the wage-share could lead to decreases in the PIT estimates and increases in CIT estimates).

Table 4: Short- and Long-run Elasticity Estimates for Ireland

	Total	PIT	CIT
Long-run Elasticity	0.894***	0.828***	1.267***
	(0.027)	(0.045)	(0.235)
Short-run Elasticity	**0.991*****	**0.93*****	1.256***
	(0.077)	(0.113)	(0.232)
Speed of Adjustment	-0.359***	-0.278***	-0.099***
	(0.12)	(0.113)	(0.232)

Note: Results from the PG estimation of equation (3). Bold means statistically not different from 1 at the 5% level. ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

B. Dynamic Panel Estimations

Table 5 contains the coefficient estimates for the short- and long-run buoyancies, as well as the speed of adjustment, based on the estimation of equation (3) by the MG and the PMG estimators, using the full panel of countries. Long-run Total Tax revenue point estimates are only slightly larger than unity, and in fact not statistically different from one, both for the MG and the PMG estimates, a result that is in line with the per-country estimations. The same holds for the short-run Total Tax estimates.

Table 5: Panel Elasticity Estimates

Estimator	PMG			MG		
	Total Tax	**PIT**	**CIT**	**Total Tax**	**PIT**	**CIT**
Long-run Elasticity	**1.006***** (0.00514)	0.891*** (0.0114)	1.163*** (0.0267)	**1.030***** (0.0155)	**0.983***** (0.0330)	1.157*** (0.0390)
Short-run Elasticity	**1.005***** (0.0122)	**0.986***** (0.0166)	***1.361****** (0.130)	**1.017***** (0.0221)	**1.012***** (0.0349)	1.372*** (0.118)
Speed of Adjustment	-0.194*** (0.0279)	-0.172*** (0.0253)	-0.261*** (0.0295)	-0.256*** (0.0312)	-0.255*** (0.0278)	-0.320*** (0.0282)
Observations	967	956	956	967	956	956

Note: Estimations from equation (3) using the PMG and MG estimators. Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

As regards the tax subcategories, the PIT estimates are less than unity, with the exception of the MG short-run estimate; however, even this coefficient is not statistically different from one. Finally, in the CIT case, point estimates for the short- and the long-run are greater than one, a result that according to Belinga et.al (2014) can be attributed to the fact that during the period under examination there has been a gradual increase in the share of capital-income ratio (see Stockhammer (2013)).

In all cases, the speed of adjusted coefficients have the expected negative sign and are statistically significant, consistent with the assumption of long-run convergence.

In general, we observe a similar pattern in the results obtained from both estimators. This might indicate that the long-run slope homogeneity assumption imposed by the PMG estimator does not greatly distort the estimated coefficient values. Further evidence that the PMG estimator is preferable in this case can be obtained by performing the Hausman test. The PMG estimator yields efficient and consistent estimates only when the restrictions (slope homogeneity) imposed are valid, whereas the MG estimator is always efficient. The Hausman test is used to examine the differences between the two models and the results indicate that for the Total Tax and CIT cases the PMG estimator is in fact the preferred one.

Before proceeding to the robustness checks in Table 6 we present some regression results for two sub-periods, namely before and after 2000. This split is mainly dictated by the fact that, as already stated, for our main control variables (PIT and CIT rates) observations are available only for the post-2000 period.

On average, long-run Total Tax revenue buoyancy has remained relatively stable and close to unity over the two periods, with the estimate of the pre-2000 period not statistically different from one. The short-run estimates exhibit a very small increase in the post-2000 period; however they are both not statistically different from one.

Table 6: PMG estimations for the two sub-samples

	Total Pre-2000	Total Post-2000	PIT Pre-2000	PIT Post-2000	CIT Pre-2000	CIT Post-2000
Long-run Elasticity	**1.006***** (0.00771)	1.078*** (0.0184)	0.907*** (0.0157)	**0.964***** (0.0184)	1.348*** (0.0476)	**0.992***** (0.0325)
Short-run Elasticity	**0.994***** (0.0237)	**1.067***** (0.0595)	**1.035***** (0.0570)	**0.959***** (0.0646)	**1.130***** (0.0908)	1.725*** (0.296)
Speed of Adjustment	-0.222*** (0.0388)	-0.239*** (0.0394)	-0.278*** (0.0452)	-0.307*** (0.0374)	-0.272*** (0.0412)	-0.473*** (0.0531)
Observations	593	374	583	373	583	373

Note: Estimations from equation (3) using the PMG estimator. Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

The long-run PIT buoyancy estimates increase in the post-2000 period, however they remain lower than unity, while the short-run estimates exhibit the opposite pattern and decrease in the post-2000 period (and they remain statistically not different from one).

Finally, in the CIT estimates we observe the following interesting pattern: long-run elasticities decline substantially over time, while the short-run estimates exhibit a large increase, from 1.23 to 1.724 in the post-2000 period.

The short-run buoyancy estimates from the PMG estimator for Ireland are presented in Table 7. It is evident that the elasticity estimates in the post-2000 period are larger, both when compared to the pre-2000 period as well as when compared with the whole sample estimation, with the exception of the PIT point estimate that exhibits a large decrease. This result may reflect the fact that the Irish wage-share has declined in the second part of the 2000s (following the crisis). This combined with the fact that the Irish PIT system has become more progressive following a number of reforms in the early 2000s, may explain the decrease in the PIT estimate along with the large increase in the CIT estimate.

Table 7: Estimations for Ireland for the two sub-samples

	Total Pre-2000	Total Post-2000	PIT Pre-2000	PIT Post-2000	CIT Pre-2000	CIT Post-2000
Short-run Elasticity	**1.002***** (0.074)	1.129 *** (0.159)	**1.158** *** (0.109)	**0.62** *** (0.154)	**1.091***** (0.332)	1.571*** (0.219)
Speed of Adjustment	-0.392*** (0.121)	-0.4 (0.3)	-0.381*** (0.094)	-0.608*** (0.188)	-0.14 (0.118)	-0.31*** (0.111)

Note: Estimations from equation (3) using the PMG estimator. Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

C. Robustness Checks

I. Controlling for tax rates

As already stated, the difference between tax buoyancy and tax elasticity measures stems from the effects of discretionary tax policy changes; that is, exogenous changes in the tax policy parameters such the tax rates, exemptions, the tax base etc. Such tax reforms were enacted starting in the late 1980s for several countries (see Belinga et.al (2014) and Dudine and Jalles (2017)) and, more recently, since the mid-to-late 2000s as a response to the global financial crisis, especially in European countries that were under pressure to restore the balance of their public finances. If these policy changes are correlated with tax revenues and GDP, then this may lead to deviations between buoyancy and elasticity measures. Given that no comprehensive database containing information on such changes is publicly available, we use tax rates as control variables, as they have been utilized in the literature as proxies for the discretionary changes in tax policy and will provide us with a first approximation to the size of tax elasticities. In particular, we use data on statutory CIT rates and top statutory PIT rates from the OECD Tax Revenue database.

As the coverage of the data obtained from the OECD database is limited, the sample size is greatly reduced. In particular, both PIT and CIT rates are available for the period 2000-2015. The results of the regressions including the controls are presented in table 8.

Table 8: PIT and CIT Elasticities, Controlling for Tax Rates

	PIT	PIT (with control)	CIT	CIT (with control)
Long-run Elasticity	**0.964*****	**0.988*****	**0.992*****	1.186***
	(0.0184)	(0.0158)	(0.0325)	(0.0555)
Short-run Elasticity	**0.959*****	**0.961*****	1.725***	1.793***
	(0.0646)	(0.0780)	(0.296)	(0.307)
Speed of Adjustment	-0.307***	-0.384***	-0.473***	-0.507***
	(0.0374)	(0.0423)	(0.0531)	(0.0630)
Observations	373	373	373	373

Note: Estimations from equation (3) using the PMG estimator. Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Following the inclusion of PIT rates, the PIT long-run elasticity estimate exhibits a slight increase although it still remains below one, while the short-run estimate remains essentially unchanged. All estimates remain statistically equal to unity. The inclusion of CIT rates has led to an increase in the long-run estimate, which is now larger and significantly different than one, while the short-run estimate has a small increase in magnitude.

Table 9: Short-run Elasticity Estimates for Ireland with Controls

	PIT		CIT	
	Without Controls	**With Controls**	**Without Controls**	**With Controls**
Short-run Elasticity	0.62*** (0.154)	0.56*** (0.17)	1.571*** (0.219)	1.584*** (0.242)
Speed of Adjustment	-0.608*** (0.188)	-0.782*** (0.191)	-0.31*** (0.111)	-0.31*** (0.111)

Note: Results from the PMG estimation of equation (3). Bold means statistically not different from 1 at the 5% level. ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

The Irish results indicate that the PIT system is regressive in the post-2000 period, as the elasticity estimate is now 0.56, even lower then when we do not control for tax policy changes. The CIT estimate exhibits a small increase, remaining quite larger than one which implies that the CIT is the most effective automatic stabilizer. This stability can be explained by the fact that during the period under examination (2000-2015) CIT rates have remained stable since 2003.

As an additional robustness check, we use the CIT rates database of Devereux et.al, which allows us to extend the time-span of the sample by almost 21 years; that is, the new sample covers the period 1979-2015. However, the cross-section dimension of the panel is now shorter, given that the new data only cover 18 out of the original 25 countries of the sample.

Table 10: CIT Elasticities, Controlling for Tax Rates in an Extended Sample

	CIT	CIT with control
Long-run Elasticity	1.184***	1.185***
	(0.0285)	(0.0549)
Short-run Elasticity	1.423***	1.524***
	(0.173)	(0.228)
Speed of Adjustment	-0.258***	-0.281***
	(0.0363)	(0.0400)
Observations	734	621

Note: Estimations from equation (3) using the PMG estimator. Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

In this sample, we observe that the inclusion of the CIT rates causes a significant increase in the short-run elasticity estimate, while the long-run value remains essentially unchanged. In the Irish case, the short-run CIT elasticity estimate remains remarkably stable (1.256 after the inclusion of the controls compared to a value of 1.238 without the controls). Again this can be attributed to the fact that, since 1979, CIT rates in Ireland have remained stable for the majority of the time period.

Overall, for the whole panel, in the case of PIT, the inclusion of the tax rate control does not in fact cause significant change in the results (indicating that buoyancy and elasticity measures are the same). However, this does not appear to be the case for the short-run CIT estimates.

II. Controlling for Inflation

The second robustness check that we perform is related to the (possible) effects of inflation. In particular, in our initial estimations we used the nominal series of tax revenues and GDP, which contain both a price and a real component. By running the regressions again using the rate of inflation as an additional control variable we can examine whether price developments do affect the evolution of tax revenues. If the inflation coefficients are statistically insignificant, we may conclude that the same relationships would be obtained had we used real variables.

Table 11 contains the results of the regressions; it may be observed that the inflation coefficients are statistically insignificant both in short- and in the long-run. Moreover, the total tax revenue elasticity estimates do not exhibit significant changes following the inclusion of the control variable (and remain statistically not different from unity). Thus, we can conclude that for this sample of countries, elasticity estimates are neutral to changes in inflation rates.

Table 11: Total Tax Revenue Elasticity with and without Controlling for Inflation

	Not Controlling for Inflation	**Controlling for Inflation**
Long-run Elasticity	**1.006*****	**1.005*****
	(0.00514)	(0.00732)
Short-run Elasticity	**1.005*****	**0.999*****
	(0.0122)	(0.0111)
Long-run price effect		-0.0652
		(0.141)
Short-run price effect		0.0816
		(0.0681)
Speed of Adjustment	-0.194***	-0.192***
	(0.0279)	(0.0284)
Observations	967	965

Note: Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively

III. Asymmetric Effects of the Business Cycle

The observed differences between short- and long-run estimates may be, in part, attributed to cyclical fluctuations which cause discrepancies in the short-term response of tax revenues. That is, there may be asymmetries in the short-run tax buoyancy estimates that cause the variations in the stabilization role of taxation during the different phases of the business cycle.

In order to take into account these possible asymmetries, we include in equation (3) a dummy variable that captures the different phases of the cycle. In particular, the dummy variable takes the value of one in years of positive GDP growth and is interacted with the short-run buoyancy estimate as follows (see also Belinga et.al (2014)):

$$\Delta T_{i,t} = \lambda_i \left(T_{i,t-1} - \beta_i GDP_{i,t-1}\right) + \theta_{i,0} * Dummy * \Delta GDP_{i,t} +$$
$$\theta_{i,0} * (1 - Dummy) * \Delta GDP_{i,t} + \mu_i + \varepsilon_{i,t}$$

so that we obtain two short-run estimates: one for the expansionary and one for the contractionary phase.

Table 12 shows that the tax buoyancy estimates for total tax revenues are large during the contractionary phase of the cycle rather than the expansionary period, indicating that the tax systems in this sample of OECD countries seem to work better as automatic stabilizers in the contractionary phase of the cycle. This result holds in particular for CIT buoyancies for the panel as a whole, as they exhibit the largest value.

In the Irish case (Table 13), the estimates indicate that CIT seems to work better as an automatic stabilizer during contractionary periods, having a larger value than the PIT estimates. The tax system as a whole exhibits short-run buoyancies that are larger during these periods, indicating that it performs better as an automatic stabilizer in bad times rather than good.

Table 12: Asymmetric Short-run Buoyancy Estimates

	Total Tax	PIT	CIT
Short-run Estimate (expansion)	0.996*** (0.0121)	0.988*** (0.0345)	1.269*** (0.129)
Short-run Estimate (contraction)	1.222*** (0.228)	1.391*** (0.503)	1.712*** (0.285)
Speed of Adjustment	-0.193*** (0.0287)	-0.176*** (0.0256)	-0.260*** (0.0310)
Observations	967	956	956

Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively

Table 13: Asymmetric Short-run Buoyancy Estimates for Ireland

	Total Tax	PIT	CIT
Short-run Estimate (expansion)	1.003*** (0.108)	1.024*** (0.138)	1.144*** (0.268)
Short-run Estimate (contraction)	1.15*** (0.325)	0.688* (0.393)	1.612** (0.775)
Speed of Adjustment	-0.066 (0.101)	-0.268*** (0.094)	-0.079 (0.063)
Observations	34	34	34

Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively

IV. Differences between using GDP and GNP

All elasticity estimates presented in this paper have been derived using GDP as a base for economic activity. However, particularly for the case of Ireland, GDP may not be the appropriate indicator for the measurement of domestic activity, due to the impact of large multinational firms on net factor income (e.g. due to the repatriation of profits). As a result, it has been argued that GNP may present a more accurate depiction of the Irish economic activity. This is evident from figure 7 which plots the evolution of GDP and GNP measures. In subplot (a) we observe that GDP is always larger compared to GNP, while in subplots (b) and (c) the magnitude of the difference between the two measures, both in levels and in logs is presented. It is evident that the difference follows an upward trend, indicative of the distortions caused in GDP due to the foreign-owned firms.

This is also the case for other economies in the EU, such as Luxembourg and Netherlands, which exhibit large FDI inflows. For example, in the 2014-2016 period, GNP in Luxembourg was, on average, €18 billion lower compared to GDP, indicating that caution must be taken as to what is the appropriate measure of economic activity.

In order to take into account the possible effects of the differences between GDP and GNP, we use a country-specific Error Correction Model for Ireland in order to estimate short- and long-run elasticity estimates, as well as the adjustment coefficient, following the two-stage approach of Engle and Granger (1987).

In the first stage, the long-run relationship between the respective tax category and GDP is estimated using the Dynamic OLS estimator (see Stock and Watson (1993)), in order to correct for possible coefficient bias and serial correlation:

$$T_t = \alpha_0 + \alpha_1 Y_t + \sum_{i=-j}^{j} \alpha_i \Delta Y_{t+j} + \varepsilon_t \quad (4)$$

where T_t is the log of the respective tax category and Y is the log of the measure of economic activity (either GDP or GNP) in period t. The leads and lags introduced for the log of GDP are the so-called "nuisance" terms that are used in the DOLS estimator to correct for possible endogeneity and autocorrelation issues. The lags of the nuisance terms are chosen based on Bayesian Information Criterion (BIC). In the estimation process, we use the Newey and West (1987) method to calculate standard errors. The α_1 coefficient is the estimate of the long-run elasticity.

In the second step, the following Error-Correction Model is estimated via OLS, using the residuals from the long-run specification:

$$\Delta T_t = \beta_0 + \beta_1 \Delta Y_t + \beta_3 \hat{\varepsilon}_{t-1} + u_t \quad (5)$$

The β_1 coefficient is the short-run elasticity estimate, i.e. it measures the contemporaneous effect of a change in Y, while the β_3 coefficient measures the speed of adjustment toward the long-run, equilibrium value of the elasticity. Some authors (e.g. Koester and Preismeier (2017)) included lags of the dependent variable in specification (5), in order to account for serial correlation; the results from the relevant statistical tests indicate that there are no signs of serial correlation in our case.

The results from the regressions are presented in table 12. It is evident that the use of GNP leads to slightly larger long-run estimates, while the short-run estimates are now substantially lower (although, with the exception of the short-run CIT elasticity, the estimates are not statistically different from one).

Figure 7: Evolution of GDP and GNP

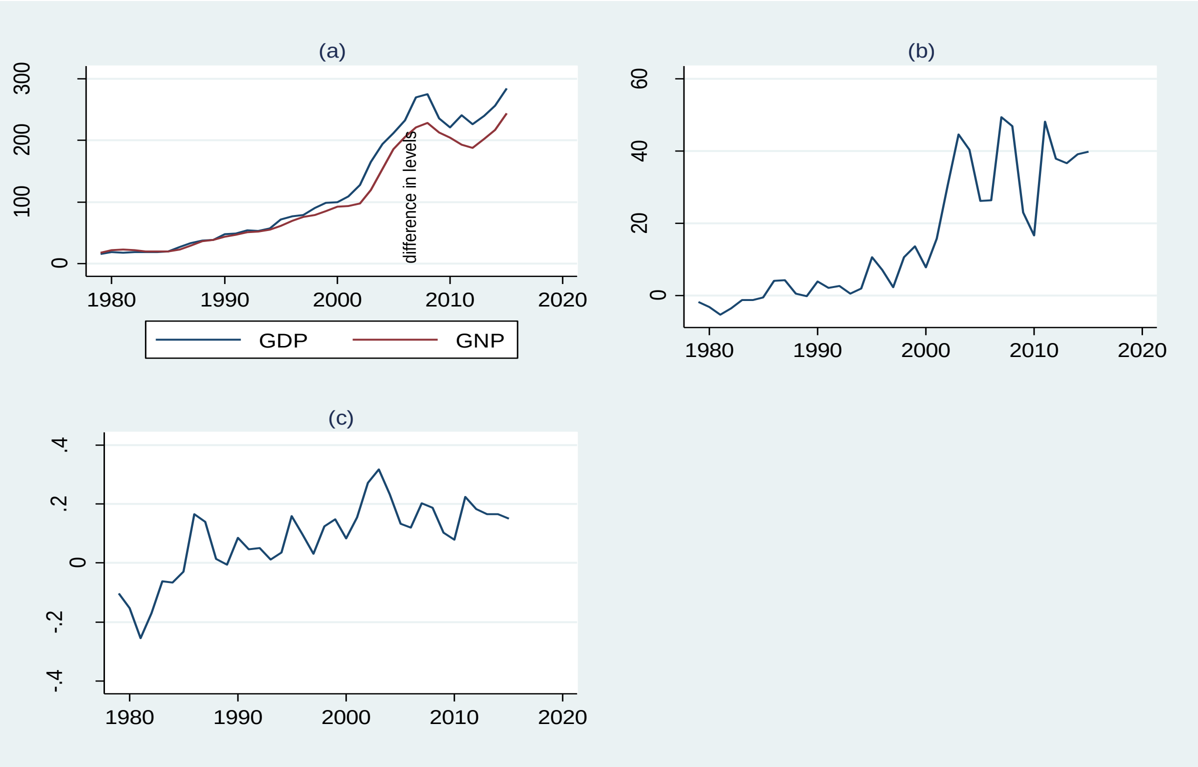


Table 12: Elasticity estimates using GDP and GNP as bases

Base	GDP			GNP		
	Total Tax	PIT	CIT	Total Tax	PIT	CIT
Long-run Elasticity	0.927*** (0.0104)	0.866*** (0.0238)	1.338*** (0.0419)	**1.021***** (0.0165)	0.958*** (0.0248)	1.462*** (0.0514)
Short-run Elasticity	**1.007***** (0.0812)	**0.953***** (0.115)	1.327*** (0.225)	**0.768***** (0.145)	**0.756***** (0.159)	1.182*** (0.290)
Speed of Adjustment	-0.475** (0.177)	-0.241** (0.113)	-0.101 (0.078)	-0.736*** (0.202)	-0.449*** (0.130)	-0.0887 (0.0890)
Observations	34	34	34	34	34	34

Note: Estimations from equation (3). Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

In order to control for the effects of discretionary changes in the conduct of tax policy on the CIT revenue elasticity estimates, we include CIT tax rates in the specification. As we can see in table 13, both in the cases of GDP and GNP we observe that the long-run estimates are slightly decreased, while for the short-run estimates (and especially for the GNP case) the change is negligible.

Finally, when we control for the effects of inflation we observe that the long-run estimates of Total Tax revenues decrease while the short-run ones exhibit a marginal increase (and for the GNP case, both estimates are not statistically different from one). These results, combined with the fact that the inflation estimates are statistically significant, indicate that the elasticity estimates are not neutral with respect to price changes.

Table 13: Controlling for CIT rates

	GDP	GDP (with control)	GNP	GNP (with control)
Long-run Elasticity	1.338***	1.299***	1.462***	1.414***
	(0.0419)	(0.0422)	(0.0514)	(0.0529)
Short-run Elasticity	1.327***	1.347***	1.182***	1.180***
	(0.225)	(0.236)	(0.290)	(0.291)
Speed of Adjustment	-0.101	-0.0937	-0.0887	-0.0893
	(0.078)	(0.0857)	(0.0890)	(0.0967)
Observations	34	34	34	34

Note: Estimations from equation (3). Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Table 14: Controlling Total Tax Revenues for Inflation

	GDP	GDP (with control)	GNP	GNP (with control)
Long-run Elasticity	0.927***	0.907***	**1.021*****	**0.995*****
	(0.0104)	(0.0132)	(0.0165)	(0.0187)
Short-run Elasticity	**1.007*****	**1.020*****	**0.768*****	**0.8*****
	(0.0812)	(0.0847)	(0.145)	(0.153)
Speed of Adjustment	-0.475**	-0.527**	-0.736***	-0.523***
	(0.177)	(0.206)	(0.202)	(0.585)
Observations	34	34	34	34

Note: Estimations from equation (3). Bold means statistically not different from 1 at the 5% level. Standard errors in parentheses; ***, **, * denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Overall, our results indicate that the tax system in Ireland is proportional, as indicated by the long-run Total tax revenue elasticity estimate (in the sense that it implies a constant revenue-to-GDP ratio in the long-run), while PIT is slightly regressive. The CIT appears to be the most effective policy instrument, in the sense that in the short-run it ensures that the respective growth in revenues will exceed that of GDP (since the elasticity estimate is almost 1.2) making it a good automatic stabilizer, while in the long-run it contributes to fiscal sustainability (since the elasticity estimate is 1.4). Finally, the degree of volatility (as measured by the difference of long- and short-run elasticity estimates) is almost the same across tax categories.

V. CONCLUSION

This paper provides estimates of short- and long-run buoyancies for Total Tax revenues, as well as Personal

Income tax and Corporate Income tax revenues, for a panel of 25 OECD countries over the period 1965-2015. The empirical approach was based on the Mean Group and Pooled Mean Group estimators, which allow for a large degree of heterogeneity among the panel.

Our results indicate that long-run Total Tax revenue elasticities are not significantly different from one for the whole panel, a result that also holds for 15 out of 25 countries in the sample. This result is robust to changes in prices and indicates that GDP growth has an overall neutral effect on fiscal performance (as regards the revenue side of the budget). The same holds for the short-run elasticity estimate (also statistically equal to unity) implying that tax revenues are a neutral automatic stabilizer. As regards the main tax categories, long-run PIT elasticity estimates are slightly lower than one for the whole period, as well as in the two sub-samples, pointing to a regressive PIT system for the whole panel. Short-run PIT estimates are also statistically equal to one, although they exhibit a small increase in the post-2000 period. Finally, long-run CIT estimates exceed unity, with the result being robust to the inclusion of both controls. Short-run estimates are the highest among the sample, indicating that CIT is the best automatic stabilizer. The same results hold when we control for the effects of expansionary and contractionary periods, with the whole tax system seeming to work better as an automatic stabilizer during bad times and CIT being the most effective policy tool.

Regarding the Irish economy, the estimates for Total Tax and PIT revenues are lower compared to the median and statistically not different from one (both for the short- and the long-run). However, CIT buoyancy estimates exhibit the largest value, which indicates that CIT is in fact the most effective automatic stabilizer over the period under examination. Moreover, the estimates are robust to the inclusion of policy controls, which serve as proxies to changes in the tax system. In particular, this result that can be attributed to the long-run stability of the tax system, i.e. the fact that the tax policy rates have remained relatively stable in the period under examination. When controlling for the asymmetric effects of the business cycle on short-run buoyancy estimates, we can see that CIT seems to work better as an automatic stabilizer during periods of economic downturn, a result that holds for the tax system as a whole (although the total tax estimate is lower than the CIT estimate). Finally, it appears that the use of GNP as a measure of economic activity in Ireland leads to changes in the estimates for tax revenue buoyancies, which should be taken into account from a policy perspective (although, qualitatively, the results remain unchanged).

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