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Estimating Ireland's Tax Elasticities: a Policy-Adjusted Approach

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Abstract: This paper estimates tax elasticities for Ireland. We compile a new dataset on tax policy changes in Ireland. This allows us to use policy-adjusted revenue when estimating tax elasticities. This gives us a cleaner estimate of the relationship between government revenue and its economic drivers. We find that income tax elasticity estimates are significantly above one when policy-adjusted revenue is used, as opposed to significantly below one when unadjusted revenue is used. This highlights the importance of using policy-adjusted revenue when estimating elasticities. We also estimate elasticities of Pay Related Social Insurance and Value-Added Tax, which have previously received little attention in the Irish literature.

I INTRODUCTION

Tax elasticities are key to understanding and forecasting developments in government revenue. This is important to allow the Government to prudently prepare its expenditure plans. In addition, tax elasticities also reflect how progressive or regressive a tax structure is.

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Ireland's recent economic history has seen large positive and negative fluctuations in government revenue. Much of the variation in government revenue has been due to macroeconomic drivers. For example, greater (taxable) income leads to more income tax being paid. While economic conditions influence the amount of tax being paid, tax policy itself also plays a hugely important role. Tax rates, bands and credits are often adjusted at budget time and can have a significant impact on tax revenue collected.

Up until now, studies which have estimated tax elasticities in Ireland have focused on the role of macroeconomic drivers, without adjusting for the impact of tax policy changes. This paper is the first that comprehensively takes account of tax policy changes when empirically estimating Irish tax elasticities.

We compile a new dataset detailing the impact of policy changes on revenue. These estimates come from budget day documentation. This dataset allows us to adjust revenue for policy changes. The "policy-adjusted revenue" variable is then used when estimating tax elasticities empirically. Stripping out the effect of tax policy changes allows us to more precisely estimate the relationship between tax revenue and economic conditions.

In the Irish case, this adjustment is crucial because income tax has had frequent and often substantial policy changes which impact on receipts. We examine two other revenue sources in this paper: Pay Related Social Insurance (PRSI) and Value-Added Tax (VAT). The adjustment for policy changes, while still important, has less of an impact on these revenue sources because they have had smaller and less frequent policy changes over the time period examined.

We estimate elasticities for these three revenue headings over the years 1987-2017. In line with the international literature, we estimate error-correction-models. These are estimated using both a one-step and two-step approach. We find that our results are not sensitive to which approach is used. Using an error correction model also allows us to estimate long-run and short-run elasticities.

Our estimates suggest a long-run income tax elasticity significantly above one, with a short-run elasticity of a similar magnitude. We find that estimates of the long-run income tax elasticity are significantly below one when unadjusted revenue is used.

The key driver of this result is that income tax policy changes over this period have been procyclical. That is, when income had been growing strongly, tax cuts were introduced. This resulted in income tax growing slower than otherwise would have been the case. Conversely, when downturns have occurred, policy changes to raise revenue were introduced. This meant that revenue did not fall as rapidly as may have been expected. In both cases, policy changes masked the responsiveness of income tax receipts to changes in the economy. Therefore, when estimated without adjusting for policy changes, the income tax elasticity is underestimated.

This has implications both for forecasting and assessing the progressivity of the income tax system. A higher elasticity would imply stronger revenue growth when income is growing, and sharper falls when income is declining. For assessing progressivity, our higher estimates would suggest the income tax system is more progressive than previous estimates would imply.

The results are robust to the specification used or the macroeconomic driver chosen (including relatively new measures of activity such as domestic GVA and modified GNI (GNI*)).

For PRSI, as policy changes are not as frequent or substantial, adjusting revenue for policy changes has less of an impact on estimated elasticities. Long-run elasticities of one are estimated for PRSI, with short-run elasticities of one or less. We find some evidence for the short-run elasticity being significantly lower than the long-run elasticity, implying a subdued initial response from PRSI to a change in income. For VAT, we find that both personal consumption and investment in the building and construction sector play significant roles in both the long- and short-run.

Our findings highlight the importance of adjusting revenue for policy changes, particularly for income tax. This is because income tax policy changes have been correlated with the economic cycle. In addition, these policy changes have been frequent and often significant. This paper also highlights the important distinction that can arise between long-run and short-run elasticities.

II RELEVANT LITERATURE

The literature relevant to this paper is primarily that which estimates tax elasticities either empirically or analytically. Acheson *et al*. (2017) derives elasticities for the Irish income tax system using both analytical and empirical methods. The analytical work is informed by statistical reports from the Revenue Commissioners on the distributions of taxable income. The analytical methods suggest an income tax elasticity of two. When estimated empirically, the elasticity is found to be less than one.

Deli *et al*. (2017) empirically estimate the elasticity of Irish income tax revenue with respect to economic activity (GDP and GNP are used). Using Irish data from 1983-2013, they estimate an elasticity just above one. For the empirical analysis in both of the above papers, they do not adjust revenue for policy changes, so the results are not directly comparable with those in this paper.

Acheson *et al*. (2018) utilise an analytical approach to generate elasticities of Value-Added Tax (VAT) receipts in Ireland. They find elasticities below one when using either household expenditure or household income as the macroeconomic driver.

Köster and Priesmeier (2017) estimate long-run and short-run elasticities for each of 18 Euro Area countries. They also employ an error correction approach, with one-stage and two-stage models estimated. The analysis does not correct for the impact of policy changes on revenue. For Ireland, a long-run elasticity significantly below one is found, using data from 1985-2013. Given that total general government revenue is being used, rather than any specific revenue heading, these results are not directly comparable to those in this paper.[1]

Mourre and Princen (2015) use data on policy changes in the EU to empirically estimate elasticities. The revenue data from 2001-2013 are adjusted for these policy changes. Given the short time period, they use all EU countries and conduct a panel analysis, with individual country elasticities not estimated. Elasticities are calculated for four revenue sources; consumption taxes, social security contributions, income tax and corporation tax. Both short-run and long-run elasticities are calculated using an error correction framework. The approach in our analysis is similar to that in Mourre and Princen (2015), but we focus on one country and use a longer sample of data (1987-2017).

Wolswijk (2007) also estimates long-run and short-run elasticities for several revenue headings in the Netherlands. The revenue figures used are adjusted for the impact of tax policy changes; hence the analysis is similar to that presented in this paper. The results show a long-run income tax elasticity of 1.57, with an even larger short-run elasticity (2.01).

Our paper contributes to the existing literature on Ireland-specific elasticities in three key ways. First, we collect data on the impact of policy changes on revenue collected. This allows us to estimate the relationship between revenue collected and the underlying macroeconomic driver more accurately, after accounting for policy changes. The second contribution this paper makes is to estimate elasticities for PRSI and VAT empirically, which has not been done previously in Ireland. To the author's knowledge, there has been no previous Irish specific empirical work on the elasticities of these two revenue sources. The third contribution we make is estimating both long-run and short-run elasticities in a dynamic setting.

III DATA AND METHODOLOGY

3.1 Data

We assess three headings of government revenue in this paper; income tax, PRSI and VAT. Revenue data are obtained from the Department of Finance Databank. For income tax, the figures used include the Universal Social Charge (from 2011) and the income levy (prior to 2011).[2] While henceforth the phrase "income tax" is used, it is this broader definition that is being referred to. Income

[1] Barrios and Fargnoli (2010) discuss how discretionary tax measures may have altered elasticities in the European Union. As the time series was very short at that stage, elasticities were not estimated in the paper.
[2] The health levy was abolished and merged into the Universal Social Charge in 2011. The health levy had previously not been included in the category "income tax" receipts in previous years. In 2010, the health levy raised €2.018 billion. With this in mind, €2.018 billion is added to the discretionary income tax/USC policy changes listed in the Budget documentation for 2011.

tax, PRSI and VAT combined accounted for two-thirds of central government revenue in 2018.

This paper focuses on estimating revenue elasticities. Revenue elasticities measure the endogenous percentage change in revenue following a one per cent change in the macroeconomic driver of that revenue source. To get a measure of the endogenous revenue response, one needs to adjust revenue for tax policy changes. With this in mind, if one is performing an analysis like this without correcting for policy changes, then it is revenue buoyancy, rather than revenue elasticities, that are being estimated.

The novel aspect of the data used in this paper is the new dataset we compile on the impact of tax policy changes on different categories of government revenue.[3] This dataset is created by examining historical budget day documentation. These documents describe the impact tax policy changes from each budget were expected to have on government revenue. Estimates of the impact of policy changes were included in budget day documentation since 1987, so that is when our analysis starts.[4]

The policy changes given in the annual budget documentation are based on an assumed no policy change baseline. The "no policy change" baseline used by the Department assumes no automatic indexation of tax bands or credits. As a result, any increase in tax bands or credits would be recorded as a revenue-reducing measure. In a growing economy, keeping tax bands and credits fixed will result in more tax being paid at higher rates, resulting in higher revenue.

The estimates of the impact of tax policy changes do incorporate some assumed behavioural responses to these changes.[5] This is helpful as it means these estimates are more likely to reflect the total impact these policy changes would make. However, ex-ante estimates of the impact of policy changes will inevitably include errors as they are not adjusted ex-post. Despite these errors, this data source provides the best route to correcting government revenue for policy changes made. Estimates of the initial year, full year and one-off impacts are all recorded.

To construct a policy-adjusted revenue variable, we utilise each of these three pieces of information. The proportional adjustment method put forward by Prest (1962) is utilised here, as is common in the literature. The policy-adjusted revenue series represents what revenue would have been in previous years if today's tax system had applied. So, in the final year of analysis (2018), policy-adjusted revenue

[3] The full dataset is available at https://www.fiscalcouncil.ie/estimating-irelands-tax-elasticities-a-policy-adjusted-approach/

[4] One exception is the reduced (9 per cent) rate of VAT (mainly applicable to tourism related activities) introduced midway through 2011, which was not listed in Budget 2011 documentation. The estimate of the cost of this reduction (€120 million in 2011, €350 million in a full year) is taken from the jobs initiative documentation (Department of Finance, 2011).

[5] An example of this is the tax on sugar sweetened beverages introduced in 2018, which assumed reformulation from producers in response to the tax.

(*PAR*) is equal to actual revenue collected ($PAR_{2018} = R_{2018}$). Policy-adjusted revenue figures for the years prior to 2018 must be calculated so that they are comparable to the tax system applying in 2018. With this in mind, the policy-adjusted series can be described mathematically in Equations (1) and (2).

$$Policy\ change_t = (Policy\ initial_t) + (Policy\ full\ year_{t-1} - Policy\ initial_{t-1}) + One\ off_t \quad (1)$$

$$PAR_t = \mathrm{R_t} * \Pi_{k=t+1}^{j} \left(\frac{R_k}{R_k - Policy\ change_k} \right) \text{ for all } t < j \quad (2)$$

PAR_t represents policy-adjusted revenue in year t. R_t represents revenue collected in year t. $One\text{-}off_t$ represents one-off factors impacting on a revenue heading in year t. $Policy\ change_t$ represents the impact of tax policy changes on revenues collected in year t. This is calculated using initial year and full year impacts of policy changes as well as one-off impacts, as described in Equation (1).

The intuition behind this method is to back-cast the series (for all the years prior to 2018) by adding/subtracting all the policy changes made in subsequent years. The result is a series that is adjusted for the cumulative effects of tax policy changes made over the period assessed. In effect, this converts the series to be representative of what revenue would have been collected had today's (2018 in this case) tax system applied for the entire period.

Table 1: Summary Statistics (1987-2017)

Macro Drivers (Growth Rates)	*Mean*	*Min*	*Max*
Income	6.4	–10.4	14.7
Consumption	6.0	–10.6	16.0
B&C	8.8	–41.5	29.0
Revenue Headings (Growth Rates)	*Mean*	*Min*	*Max*
Income Tax	6.3	–10.2	22.4
VAT	6.8	–20.6	20.6
PRSI	7.1	–10.2	17.3
Policy changes	*Mean Absolute Policy Change (% of Revenue)*	*Min Policy Change (% of Revenue)*	*Max Policy Change (% of Revenue)*
Income Tax	6.3	–17.1	21.7
VAT	1.1	–3.4	3.2
PRSI	1.0	–5.3	4.5

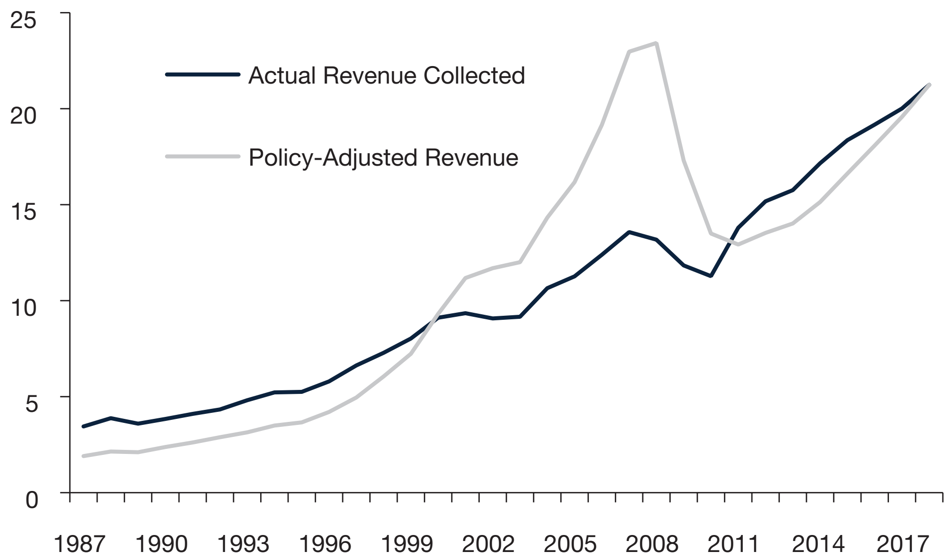
Sources: CSO, Department of Finance, Budget Documentation and author's calculations.
Notes: Minimum policy changes refer to the largest revenue reducing tax changes (tax cuts). Maximum policy changes refer to the largest revenue increasing tax changes (tax rises).

Looking at income tax, there are frequent adjustments from year to year, mainly in changing of tax bands, credits and rates. Table 1 shows that in absolute terms, the cost or yield of policy changes is equivalent to more than 6 per cent of income tax in an average year.

Figure 1 shows actual and policy-adjusted income tax revenue. It is quite striking how low policy-adjusted revenue is compared to revenue collected in the early years of the sample. However, given how the policy-adjusted series is constructed, this is less surprising. The policy-adjusted revenue series describes what level of revenue would have been collected in 1987 had today's tax system applied. If today's level of tax bands had applied in 1987, substantially fewer people would have qualified to pay tax at the higher rate of 40 per cent for example, due to the much higher entry point at which that rate applies today.

A single person with no children could earn up to €34,550 before entering the higher rate of tax in 2018. This would have been a substantial annual income in 1987. By way of comparison, the average industrial wage in 1987 was approximately €13,100 (CSO, 2017).

Figure 1: Actual and Policy-Adjusted Income Tax Revenue (€ billions, 1987-2018)



Sources: Department of Finance, Budget documentation and author's calculations.
Note: Policy-adjusted revenue takes account of tax policy changes which impact on receipts, as outlined in the text.

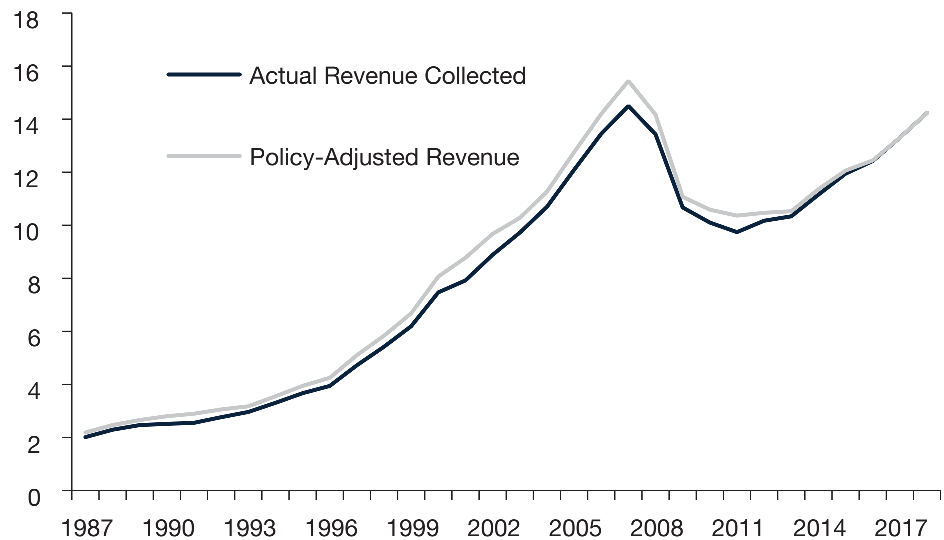
In the period of strong economic and income growth preceding the crisis, income tax receipts grew robustly. However, during this period there were significant policy changes which reduced the amount of tax paid. Had these policy changes not been made, revenue would have grown even more rapidly.[6] This can be seen with the divergence of the policy-adjusted and actual revenue series in the early to mid-2000s.

From 2009 to 2012, significant income tax policy changes were made to raise additional revenue and get the government deficit under control. These changes somewhat mitigated the fall in income tax collected in 2009/2010, and aided the increase in receipts in 2011/2012. The policy-adjusted series gives a sense of the changes in revenue that would have occurred had policy remained fixed. There would have been a more dramatic rise prior to the crisis, and a more dramatic fall in the years 2008-2011.

Income tax policy changes meant that revenue did not respond as strongly to changes in the macroeconomic environment as would otherwise have been the case. As a result, if one used unadjusted revenue to estimate elasticities, these estimates would be biased downwards.

Comparing the policy-adjusted and actual revenue series also gives a sense of how procyclical income tax policy was pre- and post-crisis. The tax cuts in the pre-crisis phase helped fuel unsustainable economic growth, while tax rises post-crisis exacerbated the downturn.

Figure 2: Actual and Policy-Adjusted VAT (€ billions, 1987-2018)

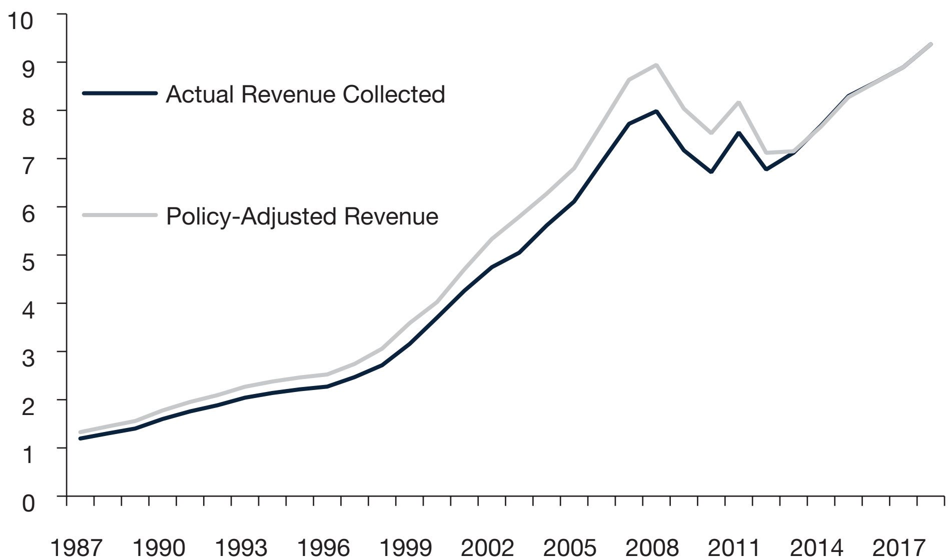


Sources: Department of Finance, Budget documentation and author's calculations.
Note: Policy-adjusted revenue takes account of policy changes which impact on receipts, as outlined in the text.

[6] This presumes that any behavioural responses to these tax cuts did not outweigh the revenue foregone by reducing rates and widening bands etc.

Value-Added Tax (VAT) and Pay Related Social Insurance (PRSI) have much smaller deviations between the actual and policy-adjusted series compared to income tax (Figures 2 and 3). This is evident in Table 1, with the average absolute size of policy changes for PRSI and VAT much smaller than for income tax. With this in mind, we should expect that using policy-adjusted revenue will have less of an impact on the estimated elasticities for these two revenue headings.

Figure 3: Actual and Policy-Adjusted PRSI (€ billions, 1987-2018)



Sources: Department of Finance, Budget documentation and author's calculations.
Note: Policy-adjusted revenue takes account of policy changes which impact on receipts, as outlined in the text.

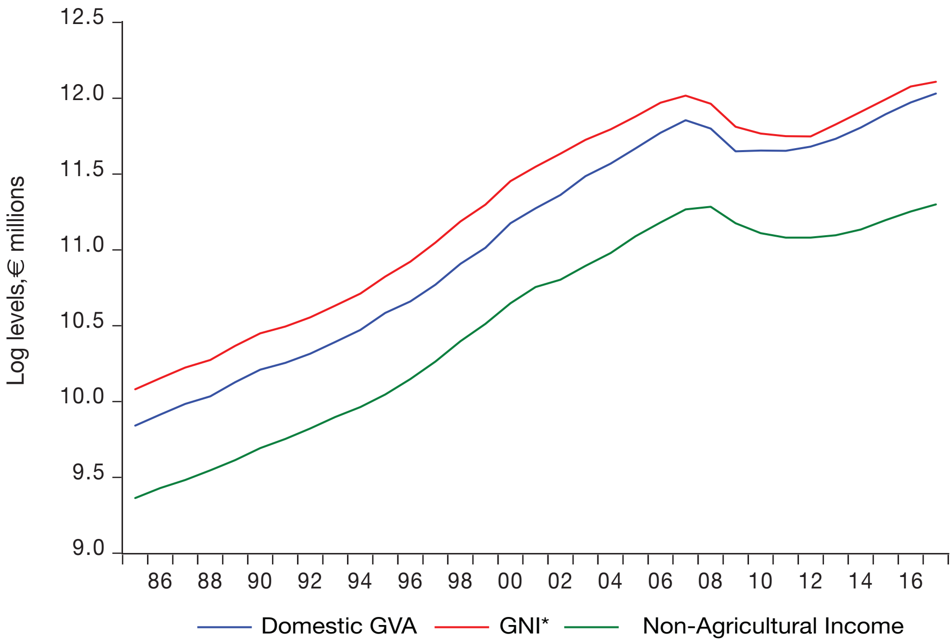
Turning next to macroeconomic drivers, the distortions caused by the activities of multinationals mean GDP and GNP are no longer reliable indicators of economic activity in Ireland. Alternative indicators which strip out the impact of foreign-owned multinational enterprises on the economy provide a better measure of economic activity in Ireland. As a result, domestic GVA and modified GNI (GNI*) may be more suitable macroeconomic drivers of income tax and PRSI. Domestic GVA describes gross value added by sectors not dominated by multinational enterprises.[7] GNI* describes Gross National Income excluding; factor income of redomiciled companies, depreciation on R&D service imports and trade in intellectual property, and depreciation on aircraft leasing.

[7] This is an official measure of economic activity that is produced by the Central Statistics Office. The non-domestic sector is defined as sectors where foreign-owned multinational enterprise turnover on average exceeds 85 per cent of the sector total.

As the revenue figures are in nominal terms, the macroeconomic drivers are also taken in nominal form. Non-agricultural income is used in the baseline income tax and PRSI regressions, with domestic GVA and GNI* (both in nominal terms) used as robustness checks (results shown in Appendix B).

For VAT, nominal personal consumption and nominal investment in the building and construction sector are used as macroeconomic drivers. Building and construction investment is included as the housing sector yields considerable VAT receipts (Addison-Smyth and McQuinn, 2016).[8] Each of these macroeconomic drivers is taken from the quarterly and annual National Accounts published by the Central Statistics Office. The non-agricultural income variable comes from Table 1 from the annual National Income and Expenditure accounts, combining non-agricultural wages and salaries with non-agricultural self-employed earnings.

Figure 4: Measures of Income and Output in Ireland (1985-2017)



Sources: CSO and author’s calculations.

Figure 4 shows the log of domestic GVA, GNI* and non-agricultural income over the period 1985 to 2017. The three metrics all show a similar profile and hence it is not surprising that our results for income tax and PRSI are robust to the choice of any of the three macroeconomic indicators shown.

[8] In addition, when only personal consumption is used (results in Appendix B), the residuals in the long-run equations were found to be non-stationary. By contrast when both consumption and investment in the building and construction sector are used, the residuals are found to be stationary (see Appendix A).

3.2 Methodology

While conceptually straightforward, a variety of approaches have been used in the literature to estimate elasticities. The approach in this paper mirrors those taken in Mourre and Princen (2015) and Wolswijk (2007).

For the estimation of the long-run elasticity, the standard approach is to estimate Ordinary Least Squares (OLS), with data transformed to logs. We test each of our revenue variables and macroeconomic drivers for unit roots using the Augmented Dickey-Fuller (ADF) test. In each case, stationarity was achieved after first differencing (Appendix A).

As suggested by Stock and Watson (1993), we add a lag and the contemporaneous change of the independent variable, giving dynamic OLS estimates, to correct the coefficient bias.[9] This is shown in Equation (1). For the standard errors, the Newey-West correction (Newey and West, 1987) is applied.

The base two-step specification is as follows:

$$\begin{aligned}\text{Log}\,(PAR_t) = \alpha_1 + \alpha_2 * \text{Log}\,(MD_t) + \alpha_3 * \text{Dlog}\,(MD_{t-1}) \\ + \alpha_4 * \text{Dlog}\,(MD_t) + \varepsilon_t\end{aligned} \tag{3}$$

$$\begin{aligned}\text{Dlog}\,(PAR_t) = \beta_0 + \beta_1 * \text{Dlog}\,(MD_t) + \beta_2 * (\text{Log}\,(PAR_{t-1}) \\ - (\alpha_1 + \alpha_2 * \text{Log}\,(MD_{t-1}) + \alpha_3 * \text{Dlog}\,(MD_{t-2}) \\ + \alpha_4 * \text{Dlog}(MD_{t-1}))) + \mu_t\end{aligned} \tag{4}$$

Where PAR_t represents policy-adjusted revenue (income tax, PRSI or VAT), and MD_t represents the macroeconomic driver of that revenue heading (non-agricultural income, GNI*, domestic GVA, personal consumption or investment in the building and construction sector).

The long-run elasticity α_2 is estimated first in Equation (3). Using those coefficients, Equation (4) is then estimated, with β_1 representing the short-run elasticity and β_2 representing the speed of error correction. So changes in the short-run can be due to changes in the macroeconomic driver or through returning to the long-run relationship between revenue and the appropriate macroeconomic driver.

After estimating equations such as those given in (3) above, we test if these non-stationary variables are integrated. We do this by performing a stationarity test on the residuals of these long-run equations. For each of the three revenue headings we find that these errors are indeed stationary and hence a co-integrating relationship exists between revenue and the respective macroeconomic driver (Table A.2).

[9] As we have only 30 observations, we limit ourselves to one lag and the contemporaneous change in the independent variable.

An equivalent one-step specification is also estimated:

$$\begin{aligned}\text{Dlog}\,(PAR_t) = \beta_0 + \beta_1 * \text{Dlog}\,(MD_t) + \beta_2 * (\text{Log}\,(PAR_{t-1}) \\ - \beta_3 * (\text{Log}\,(MD_{t-1}) - \beta_4 * \text{Dlog}\,(MD_{t-2}) \\ - \beta_5 * \text{Dlog}\,(MD_{t-1})) + \mu_t\end{aligned} \tag{5}$$

Several variations of the models described were also estimated. Firstly, we investigated if the speed of error correction was symmetric. This was done by estimating separate error correction coefficients when the revenue level is above/below its long-run level. We found no significant evidence of an asymmetric speed of error correction.

On a similar theme, we tried interacting the speed of error correction with a dummy for instances of a positive output gap.[10] No significant difference was detected. We also tried interacting this output gap dummy with the long-run impact of the macroeconomic driver. In some instances, we found a statistically significant coefficient, but even when these impacts were statistically significant, they were not economically significant.[11]

As a final variation, we inserted the unemployment rate in levels into the long-run equation. This made a slight difference to some of the income tax results and had no impact on the PRSI or VAT results. These results are reported in Appendix C.

After these various specifications were estimated, we decided to use the simplest and most parsimonious models, particularly given that we have only 30 observations. These are given in Equations (3) to (5) above.

Any revenue elasticity can be thought of as the ratio of the marginal tax rate to the average tax rate. For income tax or PRSI, the elasticity gives an insight into the progressivity of the tax structure for a given level of income (Creedy and Gemmell, 2011). An elasticity above one indicates a progressive tax structure. A one per cent increase in income leads to a greater than one per cent increase in revenue, as the marginal tax rate is greater than the average tax rate. Conversely, an elasticity below one would indicate a regressive tax structure.

IV RESULTS

In this section, we first present the results of the elasticities estimated for the three revenue headings examined.

[10] Using output gap estimates from Casey (2018) based on domestic GVA.

[11] For example, for income tax we estimated that the long-run elasticity was 1.39 with a negative output gap and 1.41 with a positive output gap.

4.1 Income Tax

Four versions of the results are presented in Table 2. To see the impact of adjusting revenue for policy changes, we estimate models using policy-adjusted revenue and unadjusted revenue. The preferred estimates are those which use policy-adjusted revenue, given in columns (1) and (2). The estimates in columns (3) and (4) correspond to revenue buoyancy. We estimate the one-step and two-step models, as outlined by Equations (3), (4) and (5) in Section III. The models in Table 2 use non-agricultural income as the macroeconomic driver. As a robustness check, models were also estimated with domestic GVA or GNI* as the macroeconomic driver and the results are presented in Appendix B. The results are very similar to those shown in Table 2.

Table 2: Income Tax Results (1987-2017)

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Income(-1))	1.40+**	1.34+**	0.83–**	0.81–**
	(0.08)	(0.02)	(0.06)	(0.04)
Short-Run Elasticity				
Dlog (Income)	1.51**	1.54**	0.98**	0.80**
	(0.33)	(0.13)	(0.18)	(0.11)
ECM	–0.27	–0.27	–0.19**	–0.18
	(0.19)	(0.21)	(0.09)	(0.12)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: +/- indicates that the long-run elasticity estimated is significantly greater/less than one. ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

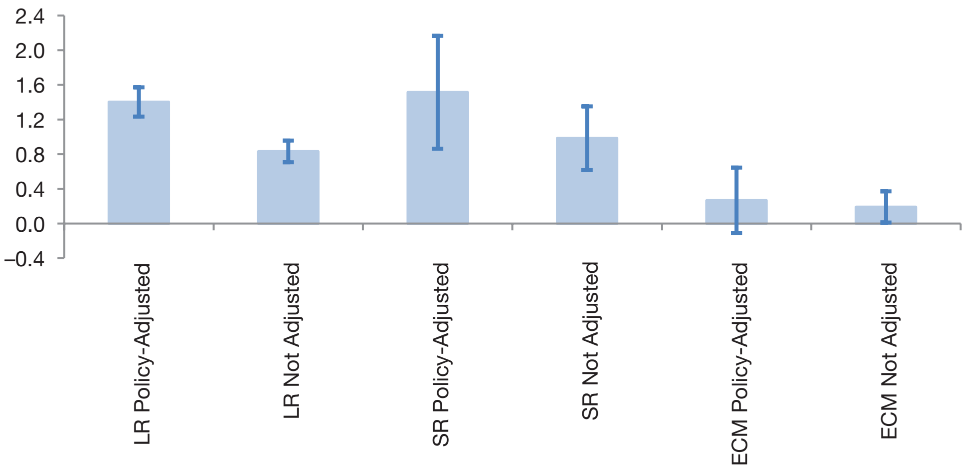
Looking across the four columns, the results are heavily influenced by whether the revenue data are adjusted for policy changes. Looking at the long-run elasticity, we can see that when adjustments for policy changes are made, estimates significantly higher than one are found. This would point towards the progressivity of the Irish income tax system (i.e., the marginal tax rate is higher than the average tax rate). Conversely, if no adjustment is made for policy changes (as previous studies have done), much lower estimates of the long-run elasticity are found (significantly below one in this case).

The key driver of this result is that income tax policy changes over this period have been procyclical. That is, when income had been growing strongly, tax cuts were introduced, meaning income tax revenue grew more slowly than otherwise would have been the case. Conversely, when downturns have occurred, policy changes to raise revenue were introduced, meaning revenue did not fall as rapidly as may have been expected (Figure 1). In both cases, policy changes have reduced the apparent responsiveness of income tax receipts to changes in the economy. Therefore, when estimated without adjusting for policy changes, the elasticity is underestimated.

In Appendix C, these equations are estimated with the unemployment rate in levels included as a control. For the equations using policy-adjusted revenue, including the unemployment rate makes little difference to the results. For the equations using unadjusted revenue, including the unemployment rate leads to a larger long-run elasticity (just below one).[12] As the unemployment rate captures the economic cycle (albeit imperfectly), it may be capturing some of the impact that policy changes have made in recent years. This is because policy changes in recent years have been correlated with the economic cycle.

Figure 5 shows the different coefficients estimated using policy-adjusted revenue or unadjusted revenue. The "whiskers" in this chart represent plus or minus two standard errors of the coefficients estimated. We can see that the long-run estimates are significantly different depending on whether or not policy-adjusted revenue is used. This highlights the importance of using policy-adjusted revenue when estimating elasticities.

Figure 5: Coefficients Estimated using Policy-Adjusted and Unadjusted Income Tax Revenue.



Sources: CSO, Department of Finance and author's calculations.
Notes: Absolute values of the ECM coefficients are shown. +/– two standard errors are shown. LR refers to the long-run elasticity, SR refers to the short-run elasticity and ECM refers to the error correction coefficient estimated (in absolute terms). Estimates in each case are using the one-step estimator, corresponding to columns (1) and (3) in Table 2.

[12] This is still significantly below the elasticity found when using policy-adjusted revenue.

Looking next at the short-run elasticities, adjusting for policy changes can also increase the elasticity estimated. Formally testing the short-run estimates in column (1) against (3) does not yield significant differences. However, testing column (2) against (4) does indicate that there is a significant difference between them.

Comparing the short-run and long-run elasticities, in each of the four sets of estimates the difference between them is not statistically significant. Comparing the results from the one-step and two-step models, we can see that these are very similar and in no case are the coefficients significantly different (comparing column (1) vs (2) and (3) vs (4)).

Examining the error correction coefficient, this appears to be stronger when policy-adjusted revenue is used. This makes some intuitive sense. Consider the case where large policy changes are made: unadjusted revenue would deviate from what macroeconomic drivers would suggest. It would be unlikely that revenue would quickly correct back to the level suggested by the macroeconomic driver alone. While not statistically significant, the range of estimates (between 18 and 27 per cent correction per annum) are in line with those found elsewhere in the literature (for example Wolswijk, 2007, and Köster and Priesmeier, 2017).

As a robustness check, the equations are also estimated over different time periods. For income tax, we find that the results are robust to the sample period used. Appendix D examines if there is a structural break around the introduction of income tax credits (2000). We do not find strong evidence of a structural break. Estimates of these equations pre- and post-2000 are not significantly different.

4.2 PRSI

Four versions of the results are presented in Table 3. As was the case with income tax, models were also estimated with domestic GVA or GNI* as the macroeconomic driver as opposed to non-agricultural income. These results are shown in Appendix B and are very similar to those presented below.

There is far less variation across the results for PRSI compared to income tax. This is mainly because policy changes have been much less substantial for PRSI, particularly compared to income tax (Table 1). Given the limited policy changes, it is not surprising that the estimates in columns (1) and (2) are similar to (3) and (4).

Looking at the long-run elasticity, estimates of one or just above one are found consistently across specifications. In each case, the estimates are not significantly different to one. This would indicate that PRSI is neither a progressive nor regressive revenue heading.

Estimates of the short-run elasticity vary somewhat depending on what estimation strategy is used. Using the two-step estimation strategy, a short-run elasticity of close to one is found. When using the one-step estimator, a much lower elasticity is found (0.48-0.59). The speed of error correction estimated varies somewhat depending on whether revenue is adjusted for policy measures. As was the case for income tax, the speed of error correction is faster when policy-adjusted PRSI is used.

Table 3: PRSI Results (1987-2017)

	(1)	(2)	(3)	(4)
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Income (–1))	1.00**	1.01**	1.03**	1.03**
	(0.03)	(0.02)	(0.04)	(0.03)
Short-Run Elasticity				
Dlog (Income)	0.48	0.97**	0.59**	0.98**
	(0.25)	(0.10)	(0.24)	(0.10)
ECM	–0.48**	–0.42**	–0.34**	–0.32*
	(0.23)	(0.16)	(0.15)	(0.12)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

Appendix B shows the results of estimating these equations with the unemployment rate in levels included (Table B.2). The results are very similar to when the unemployment rate is not included.

For PRSI, we find that the results are reasonably robust to the sample period used. In particular, estimates of the long-run elasticity seem very stable over time. The speed of error correction and the short-run elasticity show some evidence of increasing when later years are included in the sample (with either an expanding or moving sample window).

4.3 VAT

Four versions of the results are presented in Table 4. Personal consumption and investment in the building and construction sector are used as the macroeconomic drivers in this case. Table B.5 shows estimates when only personal consumption is used as the macroeconomic driver.

Like PRSI, policy changes impacting on VAT receipts have been relatively limited in the years examined (particularly when compared with income tax). Despite the relatively small differences between adjusted and unadjusted revenue, there are some differences in the elasticities estimated using the different series.

Adjusting for policy changes yields slightly higher coefficient estimates for building and construction investment, and lower coefficient estimates for consumption. In all four sets of estimations we find that the sum of the two long-run elasticities are not significantly different to one. The speed of error correction is very fast and consistent across all four of the specifications.

The estimated short-run elasticities vary somewhat also. The short-run consumption elasticities exceed the long-run relationship and imply significant

Table 4: VAT Results (1987-2017)

	(1)	(2)	(3)	(4)
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Consumption (–1))	0.80**	0.82**	0.88**	0.90**
	(0.04)	(0.03)	(0.06)	(0.03)
Log (B&C (–1))	0.21**	0.20**	0.18**	0.17**
	(0.03)	(0.02)	(0.04)	(0.02)
Short-Run Elasticity				
Dlog (Consumption)	1.42**	0.95**	1.32**	0.94**
	(0.12)	(0.10)	(0.24)	(0.11)
Dlog (B&C)	0.13**	0.15**	0.17**	0.17**
	(0.04)	(0.04)	(0.06)	(0.04)
ECM	–0.73**	–0.75**	–0.68**	–0.62**
	(0.19)	(0.23)	(0.19)	(0.22)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis. B&C represents investment in the building and construction sector as defined in the National Accounts.

overshooting in the VAT response to a change in consumption. The short-run VAT responses to building and construction investment are much closer to the estimated long-run building and construction elasticity.

For VAT, we find that the results are robust to the sample period used. All the coefficients of interest appear to be unaffected by changing the sample period (either with an expanding or moving sample window).

Appendix B shows the results of estimating these equations with the unemployment rate in levels included (Table B.3). As was the case with PRSI, the results are very similar to when the unemployment rate is not included.

As a robustness check, the same equations were estimated using only personal consumption in the long-run and short-run. With this specification, we find a consistent long-run elasticity with respect to consumption, just above one. We also find some evidence of an overshoot short-run response to changes in consumption. These results are shown in Table B.5.

4.4 Summary of Results

Table 5 provides a summary of various estimates of the Irish long-run elasticity of income tax. Looking at previous empirical studies of Irish data, estimates just above/below one have been found. Interestingly, analytical work from

Acheson *et al*. (2017) and Price *et al*. (2014) suggested an elasticity well above one. In explaining the difference between their empirical and analytical results, Acheson *et al*. (2017) notes that not correcting for policy changes may be biasing their empirical estimates downwards.

This paper provides some supportive evidence for this hypothesis, as our empirical estimates when adjusting for policy changes (1.40) are indeed much higher than when not adjusting for policy changes (0.83). The estimates we find when not adjusting for policy changes is in the range of estimates from other papers which used unadjusted revenue.

Wolswijk (2007) performed a similar exercise to this paper, using policy-adjusted revenue to estimate long-run and short-run elasticities for several tax heads for a single country (the Netherlands). Interestingly, Wolswijk (2007) finds a long-run income tax elasticity of a similar magnitude to this paper.

Table 5: Estimates of Income Tax Elasticities in Ireland

	Method	*Macro Driver*	*Policy-Adjusted Revenue*	*Estimate*
Deli *et al*. (2017)	Empirical	GNP	No	1.17
Acheson *et al*. (2017)	Empirical	Income	No	0.83
Acheson *et al*. (2017)	Analytical	Income	No	2.0[1]
Acheson *et al*. (2017)	Analytical	Income	No	1.2[2]
Price *et al*. (2014)	Analytical	Income	No	2.11
Köster and Priesmeier (2017)	Empirical	GDP	No	0.88[3]
Wolswijk (2007)	Empirical	Income	Yes	1.57[4]
Conroy (2020)	Empirical	Income	No	0.83
Conroy (2020)	Empirical	Income	Yes	1.40

Sources: OECD, CSO and author's calculations.
Notes: 1 Refers to estimate based on income tax only, not including USC. 2 Estimate based on USC only. 3 Total current government revenue, rather than income tax is the dependent variable. 4 Wolswijk (2007) is an analysis on the Netherlands. As it uses a very similar approach to this paper, adjusting for policy measures and estimating short- and long-run elasticities, the results are shown.

Table 6 provides a summary of estimates of the long-run elasticity of PRSI in Ireland. There have not been many previous studies examining the elasticity of PRSI receipts in Ireland. Analytical work suggests an elasticity well above one, while previous empirical work found an elasticity close to one when examining social security contributions in the EU as a whole. Estimates from this paper suggest an elasticity of one in Ireland, implying that PRSI is neither progressive nor regressive.

Table 6: Estimates of PRSI Elasticities in Ireland

	Method	*Macro Driver*	*Policy-Adjusted Revenue*	*Estimate*
Mourre and Princen (2015)	Empirical	Income	Yes	0.98[1]
Price *et al*. (2014)	Analytical	Income	No	1.51
Conroy (2020)	Empirical	Income	Yes	1.00

Sources: Various.
Note: 1 Panel analysis of the EU, no individual country elasticities are estimated.

Table 7 provides a summary of estimates of the long-run elasticity of VAT receipts. Mourre and Princen (2015) find a long-run elasticity of consumption taxes for the EU to be just above one. In some respects our estimates from Table 4 are not comparable to other estimates, as building and construction investment is also included in the regressions. Using only consumption as an explanatory variable (as shown in Table B.5) gives a long-run elasticity of 1.08, in line with previous empirical estimates. Wolswijk (2007) performs a similar exercise to this paper, examining Value-Added Tax in the Netherlands using policy-adjusted revenue. A long-run elasticity of just below one is found for the Netherlands.

Table 7: Estimates of VAT Elasticities in Ireland

	Method	*Macro Driver*	*Policy-Adjusted Revenue*	*Estimate*
Acheson *et al*. (2018)	Empirical	Taxable Income	No	0.6
Acheson *et al*. (2018)	Empirical	Consumption	No	0.7
Price *et al*. (2014)	Analytical	Consumption	No	1.18
Mourre and Princen (2015)	Analytical	Consumption	Yes	1.08[1]
Wolswijk (2007)	Analytical	Consumption	Yes	0.90[2]
Conroy (2020)	Empirical	Consumption	Yes	1.09[3]
Conroy (2020)	Empirical	Consumption	Yes	0.80[4]

Sources: OECD, CSO and author's calculations.
Notes: 1 Panel analysis of the EU, no individual country elasticities are estimated. 2 Wolswijk (2007) is an analysis on the Netherlands. As it uses a very similar approach to this paper, adjusting for policy measures and estimating short- and long-run elasticities, the results are shown. 3 This refers to estimates where only consumption is used as an explanatory variable (Table B.5). 4 This refers to estimates where consumption and investment in the building and construction sector are used as explanatory variables (Table 4).

Lyons *et al*. (2009) estimate price and income elasticities for several categories of consumption in Ireland. They find that most categories of expenditure have income elasticities above one (the exceptions being food, beverages and tobacco and miscellaneous goods and services). In formulating VAT forecasts, the Department of Finance assumes an elasticity of one with respect to nominal consumption (TFMRG, 2019). The results in this paper would suggest that building and construction investment may also play a significant role. When only consumption is used as a predictor, an elasticity just above one would appear appropriate.

Using an analytical approach, Acheson *et al*. (2018) derived an elasticity well below one. Similarly, Price *et al*. (2014) found an elasticity significantly above one. Both studies used consumption as the macroeconomic driver.

V CONCLUSIONS

This paper contributes to the literature of empirical studies on Irish tax elasticities. We make three major contributions. First, we compile a new dataset on the impact of tax policy changes on different headings of government revenue. This allows us to use policy-adjusted revenue when estimating elasticities. We find that using policy-adjusted revenue has a significant impact on the elasticities estimated. Second, we estimate elasticities for PRSI and VAT, which have largely been ignored in the Irish empirical literature. Third, we estimate both long-run and short-run elasticities in a dynamic setting.

When using policy-adjusted revenue, we find a long-run income tax elasticity significantly above one. Estimates using unadjusted revenue are significantly lower and below one. This highlights the importance of accounting for the role played by tax policy on revenue collected when trying to assess the link between changes in the tax base and revenue raised. Finding an elasticity significantly above one suggests the income tax system is progressive.

Adjusting for policy changes is important in the case of income tax for two reasons. Firstly, income tax policy changes have been frequent and sizeable in Ireland. Secondly, income tax policy changes have been negatively correlated with the economic cycle. Because policy changes have been negatively correlated with the economic cycle, using unadjusted revenue would lead to a downward bias of estimates of the elasticity.

For VAT and PRSI, we find that adjusting for policy changes has a less significant impact due to the typically smaller and less frequent policy changes in these areas. For PRSI we find a long-run elasticity of one, suggesting a structure which is neither progressive nor regressive. For VAT, we find that a significant role is played both by personal consumption and investment in the building and construction sector. For all three of the revenue sources examined, our results are robust to varying the estimation strategy and/or the macroeconomic driver used.

In distinguishing between long-run and short-run elasticities, some interesting results emerge. For income tax, we find that the short-run elasticity is similar to the long-run elasticity. For PRSI, we find some evidence that the short-run elasticity is smaller than the long-run estimate, implying undershooting in response to a change in income. Conversely, for VAT we find an unusually strong short-run elasticity, implying overshooting in response to a change in consumption.

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APPENDIX A
UNIT ROOT AND COINTEGRATION TESTS

Table A.1 shows the results using the Augmented Dickey-Fuller (ADF) test on unit roots. As policy-adjusted revenue is used in the regression analysis, we use policy-adjusted revenue for these stationarity tests.[13] We find that each of the three revenue sources is stationary after first differencing. For the macroeconomic drivers, we find similar results, with all the variables showing evidence of stationarity after taking first differences. Modified GNI (GNI*) is the only variable which shows any evidence of stationarity before differencing.

Table A.1: Augmented Dickey-Fuller Test

	(1) *Level*	*(2)* *Level with Trend*	*(3)* *First Difference*
Income Tax	–0.43	–2.87	–4.58**
VAT	–1.25	–2.40	–2.67*
PRSI	–0.45	–1.92	–3.88**
Income	–0.55	–3.14	–2.93*
Consumption	–0.56	–2.31	–2.96*
B&C Investment	–1.55	–1.86	–3.65**
GNI*	–0.62	–3.35*	–3.06**
Domestic GVA	–0.11	–3.07	–2.63*

Sources: CSO, Department of Finance and author's calculations.
Notes: T statistics are shown, ** and * indicate significance at 5 per cent and 10 per cent levels respectively.

The residuals from the long-run equations are also tested for stationarity using the ADF test (these equations are described in column 2 of Tables 2, 3 and 4). This yields satisfactory results of stationary residuals in each case (Table A.2).

Table A.2: Augmented Dickey Fuller Tests on Residuals from Long-Run Dynamic OLS Equations

	(1) *Level*
Income Tax	–3.05**
VAT	–3.58**
Domestic GVA	–6.05**

Sources: Author's calculations.
Notes: ** and * indicate significance at 5 per cent and 10 per cent levels respectively.

[13] Similar results are found if unadjusted revenue is used.

Table A.3 shows the results of cointegration tests of the three revenue sources examined and their respective macroeconomic drivers. The tests are performed using both the policy-adjusted revenue series and the unadjusted series. For income tax and VAT, we find significant evidence of a long-run relationship between policy-adjusted revenue and the macroeconomic driver. For PRSI, we find the trace statistic is slightly below a statistically significant level. However, one must keep in mind the relatively small sample for these tests.

It is also interesting to examine the differences here in using the unadjusted revenue series and the policy-adjusted revenue series. Using the unadjusted series, we do not find evidence of a stable long-run relationship between revenue and the macroeconomic driver in any of the three cases.

Table A.3: Johansen System Cointegration Test (rank test)

	Null: None	*Null: at most one*
Income Tax (policy-adjusted)	25.7**	0.6
Income tax	3.7	0.2
PRSI (policy- adjusted)	12.7	1.0
PRSI	5.6	0.05
VAT (policy-adjusted)	13.7*	0.07
VAT	11.1	0.02

Sources: CSO, Department of Finance and author's calculations.
Notes: In each case tests are performed with one lag. The macroeconomic drivers for Income tax, PRSI and VAT are non-agricultural income, non-agricultural income and personal consumption respectively. 29 observations are used (1989-2017). ** and * indicate significance at 5 per cent and 10 per cent levels respectively.

Table A.4: Granger-Causality Tests

	Null: Macro driver does not cause revenue	*Null: Revenue does not cause macro driver*
Income Tax (policy-adjusted)	18.3**	12.3**
Income tax	0.1	2.3
PRSI (policy-adjusted)	12.7**	0.3
PRSI	6.2**	0.1
VAT (policy-adjusted)	6.0**	12.1**
VAT	6.2**	15.6**

Sources: CSO, Department of Finance and author's calculations.
Notes: In each case tests are performed with two lags. The macroeconomic drivers for Income tax, PRSI and VAT are non-agricultural income, non-agricultural income and private consumption respectively. 29 observations are used (1989-2017). ** and * indicate significance at 5 per cent and 10 per cent levels respectively.

Looking at the Granger-causality tests, for income tax and VAT we find evidence for causality running in both directions. For PRSI there is a more conclusive result, with income Granger-causing PRSI and PRSI not Granger-causing income.

When using the unadjusted revenue series for income tax, we find no evidence of Granger-causality in either direction.

APPENDIX B: RESULTS USING ALTERNATIVE MACROECONOMIC DRIVERS

Table B.1: Income Tax Results using GNI*

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (GNI* (–1))	1.34+**	1.29+**	0.80–**	0.80–**
	(0.13)	(0.03)	(0.06)	(0.04)
Short-Run Elasticity				
Dlog (GNI*)	0.53*	1.37**	0.40**	0.72**
	(0.27)	(0.15)	(0.19)	(0.11)
ECM	–0.19	0.02	–0.21**	–0.23
	(0.23)	(0.21)	(0.08)	(0.12)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: +/- indicates that the long-run elasticity estimated is significantly greater/less than one. ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

Table B.2: Income Tax Results using Domestic GVA

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Domestic GVA (–1))	1.22+**	1.22+**	0.75–**	0.75-**
	(0.09)	(0.05)	(0.04)	(0.02)
Short-Run Elasticity				
Dlog (Domestic GVA)	0.67**	1.30**	0.49**	0.72**
	(0.20)	(0.16)	(0.17)	(0.10)
ECM	–0.15	–0.09	–0.29**	–0.34**
	(0.12)	(0.14)	(0.10)	(0.15)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: +/- indicates that the long-run elasticity estimated is significantly greater/less than one. ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

Table B.3: PRSI Results using GNI*

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (GNI* (–1))	0.97**	0.98**	1.00**	1.01**
	(0.03)	(0.02)	(0.04)	(0.03)
Short-Run Elasticity				
Dlog (GNI*)	0.06	0.85**	0.25**	0.87**
	(0.10)	(0.10)	(0.11)	(0.10)
ECM	–0.55**	–0.41**	–0.35**	–0.31**
	(0.19)	(0.17)	(0.11)	(0.12)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

Table B.4: PRSI Results using Domestic GVA

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Domestic GVA (–1))	0.90-**	0.93**	0.95–**	0.97**
	(0.04)	(0.02)	(0.02)	(0.02)
Short-Run Elasticity				
Dlog (Domestic GVA)	0.18*	0.84**	0.24**	0.86**
	(0.10)	(0.11)	(0.08)	(0.10)
ECM	–0.37*	–0.22*	–0.51**	–0.42*
	(0.21)	(0.21)	(0.18)	(0.19)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis. - indicates that the long-run elasticity estimated is significantly less than one.

Table B.5: VAT Results using only Personal Consumption

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Consumption (–1))	1.09+**	1.10+**	1.14+**	1.14+**
	(0.03)	(0.03)	(0.03)	(0.02)
Short-Run Elasticity				
Dlog (Consumption)	1.82**	1.27**	1.81**	1.27**
	(0.12)	(0.09)	(0.12)	(0.09)
ECM	–0.27**	–0.25**	–0.36**	–0.30**
	(0.11)	(0.13)	(0.14)	(0.15)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis. + indicates that the long-run elasticity estimated is significantly above one.

APPENDIX C: RESULTS USING THE UNEMPLOYMENT RATE AS A CONTROL VARIABLE

This appendix shows the results if the unemployment rate in log levels is added to each of our equations. This is an attempt to capture the impact of the economic cycle. While using estimates of the output gap did not prove significant, using the unemployment rate may have more of an impact. Given it is more consistently measured across countries and subject to less measurement error, it may prove a more useful measure of the economic cycle.

Table C.1: Income Tax Results using Income and the Unemployment Rate (1987-2017)

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Income (–1))	1.33+**	1.27+**	0.97**	0.96**
	(0.07)	(0.02)	(0.03)	(0.04)
Log (UR (–1))	–0.10*	–0.13**	0.28**	0.26**
	(0.05)	(0.03)	(0.04)	(0.05)
Short-Run Elasticity				
Dlog (Income)	1.42**	1.53**	1.03**	0.80**
	(0.38)	(0.13)	(0.13)	(0.10)
ECM	–0.39	–0.36	–0.52**	–0.50**
	(0.27)	(0.25)	(0.13)	(0.17)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: +/- indicates that the long-run elasticity estimated is significantly greater/less than one. ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

We can compare the results here to those presented in the main text (Table 2). For the first two columns (where policy-adjusted revenue is used), the results do not change due to the inclusion of the unemployment rate. In both instances, a long-run elasticity of income tax to income in excess of one is found. In both cases we find that the short-run elasticity exceeds the long-run elasticity.

For the coefficient on the unemployment rate itself, we find a negative and significant coefficient when using policy-adjusted revenue. Ordinarily, one might expect a negative coefficient as this implies a lower unemployment rate being associated with more income tax being paid. As income is also included, multi-collinearity could arise.

When unadjusted revenue is used (columns (3) and (4)), including the unemployment rate has more of an impact. In Table 2 estimates of the long-run income tax elasticity were significantly below one (when using unadjusted revenue). By contrast when the unemployment rate is controlled for, an elasticity of one is found. This may be because the unemployment rate is capturing the economic cycle, which is also linked to policy changes.

When unadjusted revenue is used, we find a positive significant coefficient on the unemployment rate. Ordinarily, one would be surprised to see the unemployment rate positively correlated with income tax revenue. However, the unemployment rate here could be capturing policy changes which are not being adjusted for here. As the unemployment rate fell in the late 1990s/early 2000s, tax policy changes reduced the amount of revenue which would otherwise have been collected. Conversely as the unemployment rate rose in the late 2000s, income tax policy changes were introduced to increase the amount of revenue collected.

Including the unemployment rate in levels may somewhat mitigate for not adjusting revenue for policy changes. This is due to recent income tax policy changes being procyclical. This may be why the elasticities estimated here are larger than when the unemployment rate is not included, and closer to the policy-adjusted estimates.

Table C.2: PRSI Results using Income and the Unemployment Rate (1987-2017)

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Income (–1))	0.94**	1.02**	0.98**	1.11+**
	(0.06)	(0.03)	(0.10)	(0.05)
Log (UR (–1))	–0.10	0.01	–0.07	0.13**
	(0.08)	(0.04)	(0.16)	(0.06)
Short-Run Elasticity				
Dlog (Income)	0.50*	0.97**	0.60**	0.98**
	(0.25)	(0.10)	(0.23)	(0.10)
ECM	–0.46**	–0.40**	–0.30*	–0.28*
	(0.22)	(0.16)	(0.17)	(0.14)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: +/- indicates that the long-run elasticity estimated is significantly greater/less than one. ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

The results presented here are very similar to those shown in the main text (Table 3). In each of the four columns, the long-run elasticity is found to be close to one. For the short-run elasticity, similar patterns are found, with an elasticity close to one when a two-step estimator is used. When a one-step estimator is used, a short-run elasticity below one is found.

The error correction speeds found are also similar to those estimated when the unemployment rate is not included. As for the coefficient on the unemployment rate itself, in three of the four cases it is not found to be statistically significant.

Table C.3: VAT Results using Consumption, Building and Construction and the Unemployment Rate (1987-2017)

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Consumption (–1))	0.83**	0.83**	0.88**	0.89**
	(0.04)	(0.04)	(0.06)	(0.04)
Log (B&C (–1))	0.17**	0.18**	0.19**	0.17**
	(0.04)	(0.04)	(0.06)	(0.04)
Log (UR (–1))	–0.05	–0.03	0.00	0.01
	(0.03)	(0.04)	(0.04)	(0.04)
Short-Run Elasticity				
Dlog (Consumption)	1.46**	0.96**	1.31**	0.94**
	(0.12)	(0.10)	(0.26)	(0.11)
Dlog (B&C)	0.11**	0.15**	0.17*	0.16**
	(0.04)	(0.04)	(0.07)	(0.04)
ECM	–0.78**	–0.78**	–0.68**	–0.62**
	(0.21)	(0.23)	(0.20)	(0.22)
N	30	30	30	30

Sources: CSO, Department of Finance and author's calculations.
Notes: ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis. B&C represents investment in the building and construction sector as defined in the National Accounts.

For VAT, it appears that including the unemployment rate makes little difference to the results. The long-run elasticities for income and building and construction are very similar to those in Table 4. The short-run elasticities are also very similar to when the unemployment rate is not included. Looking at the coefficient on the unemployment rate, it is statistically insignificant in each case.

APPENDIX D:
RESULTS PRE- AND POST- INTRODUCTION OF TAX CREDITS

This appendix investigates if there may be a structural break during the sample period (1987-2017). Acheson *et al*. (2017) identify the tax credit system as playing a key role in the progressivity of the Irish income tax system. Given income tax credits were introduced in 2000, one might expect to see an increase in the elasticity and hence progressivity in the income tax system thereafter.

With this in mind, we conduct Chow tests on the results presented in the main text (Table 2). We do not find significant evidence of a structural break in the years 1999 or 2000.

To compare results pre- and post the introduction of income tax credits, we run the same analysis as in the main text on the sample periods 1987-1999 and 2000-2017. These are shown in Table D.1. Given the reduced number of observations due to splitting the sample, we focus on just the two-step estimator here. Even in doing this, we find the error correction term estimated is often unstable.

Table D.1: Income Tax Results Pre- and Post-Tax Credits

	(1)	*(2)*	*(3)*	*(4)*
Estimation Method:	*One-step*	*Two-step*	*One-step*	*Two-step*
Policy-Adjusted:	*Adjusted*	*Adjusted*	*Unadjusted*	*Unadjusted*
Long-Run Elasticity				
Log (Income (–1))	1.23+**	1.32+**	0.81–**	0.98**
	(0.06)	(0.11)	(0.08)	(0.19)
Short-Run Elasticity				
Dlog (Income)	1.30**	1.75**	0.84**	0.80**
	(0.10)	(0.27)	(0.10)	(0.10)
ECM	–1.05**	–0.13	–0.92**	–0.12
	(0.27)	(0.15)	(0.25)	(0.12)
Sample Period	1987-1999	2000-2017	1987-1999	2000-2017
N	13	18	13	18

Sources: CSO, Department of Finance and author's calculations.
Notes: +/- indicates that the long-run elasticity estimated is significantly greater/less than one. ** and * indicate significance at 5 per cent and 10 per cent levels respectively, standard errors are in parenthesis.

We formally test if the long-run coefficient in column (1) is different to column (2) and if the coefficient in (3) differs from that in (4). We might expect that the tax system would become more progressive and hence have a higher income tax elasticity after the introduction of tax credits. In both the adjusted and unadjusted case, we find that the long-run elasticity is indeed higher in the later period. However, in both cases we find that this difference is not significantly different.

For the short-run coefficients, we do find a significant difference for the policy-adjusted estimates. The later sample appears to yield higher estimates of the short-run coefficient (as one might expect). There is no significant difference in the short-run elasticity when unadjusted revenue is used (comparing Columns 3 and 4).

In conclusion, the long-run elasticity does appear to increase somewhat if estimated only after the tax credit system was introduced. However, this increase is not found to be statistically significant.

APPENDIX E:
EXAMPLES OF LARGE POLICY CHANGES

This appendix shows a selection of the largest policy changes which impacted on the three revenue headings examined.

Table E.1: Examples of the Largest Policy Changes in the Sample Period (1987-2017)

Year Income Tax	*Initial year yield (+)/cost (–)*	*Full year yield (+)/cost (–)*	*Policy Change*
2009	+€2,105m	+€4,151m	Introduction of Income levy. The rates were later doubled in a supplementary budget.
2007	–€1,331m	–€1,359m	Increases in income tax credits and widening of bands
VAT	*Initial year yield (+)/cost (–)*	*Full year yield (+)/cost (–)*	*Policy Change*
2012	+€560m	+€670m	Increase in standard rate from 21% to 23%.
2011	–€120m	–€350m	Introduction of special reduced rate (tourism/hospitality sector)
PRSI	*Initial year yield (+)/cost (–)*	*Full year yield (+)/cost (–)*	*Policy Change*
2013	+€265m	+€289m	Removal of weekly PRSI allowance from full rate and modified rate PRSI contributors.
2002	–€237m	–€347m	The top rate of employers PRSI was reduced from 12% to 10.75%

Source: Budget documentation.