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## POLICY PAPER

# The Role of Elasticities in Forecasting Irish Income Tax Revenue

**Niall Conroy***
*Irish Fiscal Advisory Council*

*Abstract:* This paper examines the role of tax elasticities in forecasting tax revenue. Tax elasticities give the expected change in revenue for a change in the tax base. We examine how important the choice of elasticity is for forecasting income tax up to four years ahead. We find that using elasticities which were estimated using data adjusted for tax policy changes produces improved forecasts, particularly at longer forecast horizons. This improvement is statistically significant. These results are found using Irish data. However, this paper demonstrates a methodology with potential for widespread application in many other countries. Better forecasts of government revenue could aid better fiscal planning and medium-term budgeting.

## I INTRODUCTION

Forecasting tax revenue is key to good budgeting and setting appropriate fiscal policy. Tax elasticities measure the response of revenue to a one per cent change in the tax base (also referred to as the macroeconomic driver) if tax policy (for example tax rates and credits) is held fixed. If the elasticity of income tax, for example, is above 1, then you would expect a one per cent increase in the tax base to yield an increase in income tax receipts of more than one per cent. Changes in tax revenue are determined by two key factors, changes in the tax base and changes

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* niall.conroy@fiscalcouncil.ie

in policy. Tax elasticities are key to determining the impact changes in the tax base have on government revenue. As a result, tax elasticities are key to forecasting tax revenue.

The tax base is influenced by macroeconomic developments and the tax policy set by government. For example, the amount of income earned in the economy will influence the amount of income tax paid. Policy decisions around what levels of income are eligible for taxation will also impact on the tax base. Meanwhile policymakers' choices on tax rates, bands and credits will all influence the effective tax rate. There is also feedback between government revenue collected and the macroeconomy, as a rise in tax rates would act as a drag on economic activity and vice versa.

Conroy (2020) showed how more accurate empirical estimates of tax elasticities for Ireland can be found by using a tax revenue series which has been adjusted for tax policy changes. Estimates of tax elasticities which do not account for the impact of tax policy changes may be biased. This would be most acute if policy changes were correlated with the economic cycle.

This paper examines if varying the elasticity used has a significant impact on forecast accuracy for tax revenue. More specifically, would using these recently estimated policy-adjusted elasticities significantly improve forecast accuracy? To the author's knowledge, this is the first paper which examines how varying the elasticity used impacts on the accuracy of forecasts of tax revenue. As a result, no other paper has tested if using policy-adjusted elasticities yields superior forecasting performance, relative to unadjusted elasticities.

This analysis is performed on Irish data, as policy-adjusted elasticities have been empirically estimated in a previous paper (Conroy, 2020). The analysis here focuses on Irish income tax, but the findings could be generalised to other countries and other tax headings.

Historical data are used to see which elasticities would have worked best in forecasting future income tax. In all cases, forecasts take account of the impact of tax policy changes. Using tax outturns from the previous year (denoted year $T-1$), we compile forecasts for the current year (denoted year $T$) and out as far as four years ahead (denoted year $T+4$). Much of the previous literature has focused only on shorter forecast horizons (years $T$ and $T+1$ typically).

We find that the elasticity used is important for forecast accuracy. More specifically, we find that elasticities estimated using policy-adjusted revenue yield superior forecasting performance. These improvements are statistically significant, with reduced bias and smaller absolute errors on average. These improvements are larger at longer forecast horizons, as errors cumulate. The divergence in forecasting performance reflects how policy-adjusted and unadjusted elasticities differ substantially. These elasticities differ because of large and regular income tax policy changes which occurred in Ireland during the sample period examined.

This paper shows that the use of policy-adjusted elasticities could significantly improve forecast accuracy in Ireland. The implications could be wider still, as policy-adjusted elasticities could be estimated and then used for fiscal forecasting in many other countries. Improved government revenue forecasts can facilitate multi-year budgeting and running the appropriate fiscal policy.

Much of the previous literature has focused on in-year and one-year-ahead forecasts. As a result, this paper also gives a sense of how forecast errors vary depending on the length of the forecast horizon. We find that typically the longer the forecast horizon, the larger forecast errors are on average. In many cases, four-year-ahead forecast errors are twice as large as those for in-year forecasts.

## II RELEVANT LITERATURE

There has been some recent work on estimating revenue elasticities using policy-adjusted revenue data, which this paper builds on. Individual country datasets on tax policy changes have allowed single country studies estimating tax elasticities using policy-adjusted revenue data.[1,2]

More specifically, this paper follows recent work on empirically estimating Irish government revenue elasticities. Conroy (2020) compiled a new dataset of the impact of tax policy changes on various government revenue headings.[3] This dataset is based on Budget Day estimates of the impact of these tax policy changes. As a result, policy-adjusted revenue could then be used when estimating elasticities. Factoring out tax policy changes allows empirical estimates to more accurately capture the elasticity between changes in the tax base and tax revenue.

Previous estimates of revenue elasticities did not account for the impact of policy changes. This may have biased estimates as, for some revenue headings, policy changes have followed the economic cycle. Princen *et al*. (2013) show that many EU countries made pro-cyclical discretionary tax cuts prior to the financial crisis.

Conroy (2020) found that using a policy-adjusted revenue series had a significant impact on the elasticity estimated for income tax. A much larger elasticity (1.4, significantly above 1) was found using policy-adjusted revenue. This contrasts with estimates using unadjusted revenue (0.8, significantly below 1).

[1] See Wolswijk (2009) and Bettendorf and van Limbergen (2013) for the Netherlands; Havranek *et al.* (2016) for the Czechia; Koester and Priesmeier (2012) for Germany; and Conroy (2020) for Ireland.

[2] Boschi and d'Adonna (2019) attempt a cross-country study (15 European countries), using a qualitative approach, assigning a dummy if a discretionary tax change occurred.

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

Income tax policy changes were large, regular and pro-cyclical in Ireland over the period examined (Figure 1). As a result, there is a significant difference in the elasticity estimated using policy-adjusted or unadjusted data.[4]

An elasticity of 1.4 implies that a one per cent increase in income would yield a 1.4 per cent increase in income tax receipts, with an unchanged tax system. This reflects the progressive nature of the Irish income tax system, as marginal tax rates exceed the average rate.

The major contribution of the present paper is examining how sensitive forecasts of tax revenue are to the elasticity applied. More specifically, we examine if elasticities based on policy-adjusted data produce superior forecasts. We use formal tests (Diebold and Mariano, 2002) of whether differences in forecasting performance are statistically significant.

To the author's knowledge, this is the first paper which examines how varying the elasticity used impacts on the accuracy of forecasts of tax revenue. As a result, no other paper has tested if using policy-adjusted elasticities yields superior forecasting performance, relative to unadjusted elasticities.

We find that the choice of elasticity used is an important factor in forecasting government revenue. More specifically, we find that using a policy-adjusted elasticity does indeed lead to improved forecasting performance. These improvements are also found to be statistically significant. While the results of this paper relate to Ireland, the findings may be applicable to fiscal forecasting in a wider range of countries.

Also relevant in the literature are more general studies of forecasting performance of government revenue. Buettner and Kauder (2010) review the practice and performance of forecasting government revenue in OECD countries. They find that uncertainty in forecasting macroeconomic drivers and the timing of forecasts are key factors for forecast accuracy. They also find that independence of forecasting from government has a strong positive effect on the accuracy of forecasts.[5]

Frankel and Schreger (2013) find some evidence of optimism bias in fiscal forecasts of euro area countries. Merola and Pérez (2013) find that European Commission and OECD fiscal forecast errors are correlated with the electoral cycle of the EU countries examined.[6]

[4] Two other Irish revenue headings were examined in Conroy (2020), namely Pay Related Social Insurance (PRSI) and Value Added Tax (VAT). In both cases, policy changes in Ireland had been relatively limited over the sample period considered, hence elasticities estimated using policy-adjusted revenue were not significantly different from those estimated using unadjusted revenue data. As a result, this paper focuses on income tax.

[5] ElBerry and Goeminne (2021) show that increased fiscal transparency is correlated with smaller fiscal forecast errors in developing countries.

[6] Fioramanti *et al*. (2016), Frankel and Schreger (2013) and Merola and Pérez (2013) all focus on the General Government Balance, rather than forecasts of revenue and expenditure separately.

Another contribution this paper makes to the literature is to extend the horizon of forecasts analysed out to four years ahead. This allows us to analyse how the size of average errors changes as the forecast horizon expands. Much of the previous international literature focuses on shorter forecast horizons.[7]

## III DATA AND METHODOLOGY

This section details the data and methodology used to assess the forecasting performance of several tax elasticities.

### 3.1 Data

For this empirical work, we assess Irish income tax. Historical income tax data are obtained from the Irish Department of Finance databank and are on an Exchequer basis.

This paper focuses on how changing the elasticity used impacts on forecasting performance. Using historical data, we can see what forecasts would have been produced when applying different elasticities and evaluate how close they would have been to the eventual outturn.[8] Specifically, we focus on the impact of using different elasticities to forecast income tax.

The methodology adopted in this paper to forecast government revenue employs a new dataset (Conroy, 2020) of the impact of tax policy changes. This dataset is made up of official Budget Day estimates drawing on information from Irish Revenue Commissioners and the Department of Finance as to what the cost/yield of tax policy changes would likely be. These ex-ante estimates of the impact of tax policy changes will contain errors, as they are not adjusted ex-post. Few, if any, assessments of the actual impact of policy changes on revenues are completed ex-post. This means that there is a significant information gap in relation to the impacts of policy changes on tax revenues.

In the absence of more comprehensive assessments of individual policy changes, these ex-ante estimates provide the best route to correcting income tax revenue for policy changes made. Initial year, full year and one-off impacts of tax policy changes are recorded.

Estimates of the impact of tax policy changes have been included in Irish Budget Day documentation since 1987, so that is when the analysis starts.[9]

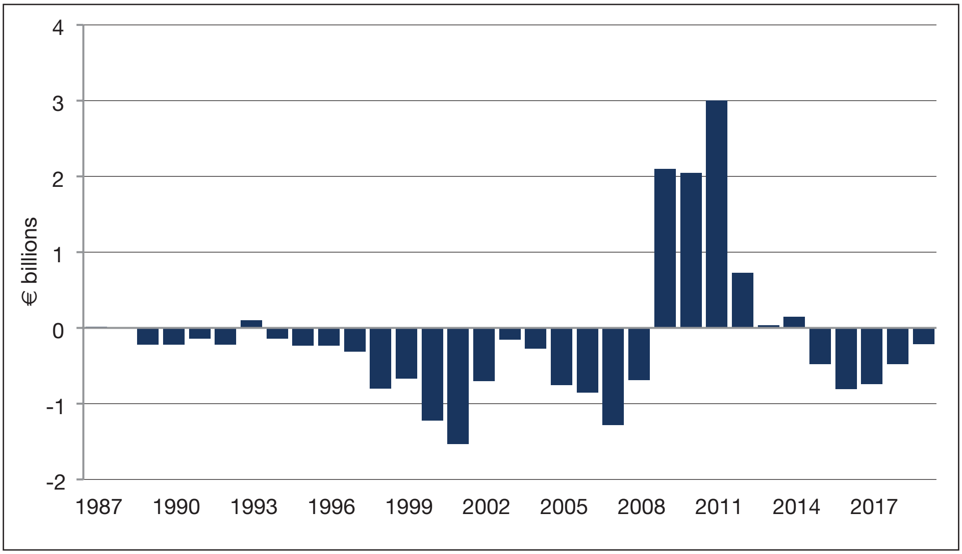
[7] For example, Fioramanti et al. (2016) examine the fiscal forecast errors of the European Commission. They examine errors in forecasting the General Government Balance for the current year and one-year-ahead.

[8] As explained later, this is different to fitting the data, as we only use the revenue outturn for year $T-1$ and then use this as a base for forecast revenue for the years $T$ to $T+4$.

[9] 2019 is the final year considered for forecasts.

Figure 1 shows how significant income tax policy changes have been over the past 30 years.[10]

**Figure 1: Estimated Impacts of Policy Changes on Income Tax Revenues**




*Sources:* Irish Department of Finance and author's own calculations.
*Note:* Units are € billions. The sample period is 1987-2019. Positive values indicate that policy changes were expected to raise revenue overall, or an effective tax rise. This is measured against a no-policy change baseline, which does not include indexation of tax bands or credits for inflation or wage growth. As a result, widening income tax bands and increasing tax credits in line with indexation are recorded as a revenue-reducing measure here.

In the period of strong economic and income growth preceding the financial crisis, there were significant policy changes which reduced the amount of income tax paid. Had these policy changes not been made, income tax revenue would have grown even more rapidly during this period of employment and income growth.[11] From 2009 to 2012, significant income tax policy changes were made to raise additional revenue and to reduce a structural government deficit. These changes mitigated the fall in income tax collected in 2009/2010 somewhat and aided the increase in receipts in 2011/2012. Given how pro-cyclical income tax policy changes were in Ireland over this period, it is no surprise that estimates of the elasticity of income tax differ greatly if a policy-adjusted income tax series is used.

[10] Section 3.2 describes how tax policy changes are calculated, using estimates of the initial year and full year impacts.
[11] The Irish experience is not uncommon, Princen *et al*. (2013) shows that many EU states made pro-cyclical discretionary tax cuts prior to the financial crisis.

The ex-ante estimates of the impact that policy changes have on revenues that we use (taken from annual Budget documentation) are based on an assumed "no policy change" baseline. The no policy change baseline used by the Irish Department of Finance assumes no automatic indexation of tax bands or credits. This means that any widening of tax bands or increase in 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.

As the government 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 forecast exercises. The non-agricultural income variable combines non-agricultural wages and salaries with non-agricultural self-employed earnings.

Distortions caused by the activities of multinationals mean GDP and GNP are no longer reliable indicators of economic activity in Ireland. Alternative metrics which strip out the impact of foreign-owned multinational enterprises on the economy are more suitable for Ireland. With this in mind, Domestic GVA and modified GNI (GNI*) are used as robustness checks (which are shown in Appendix A).[12]

Figure 2 shows the log of domestic GVA, GNI* and non-agricultural income over the period 1985 to 2019.[13] The three metrics all show a similar profile. However, we find that using non-agricultural income yields significantly better forecasts for income tax, compared to using domestic GVA or GNI* as the macroeconomic driver (see Appendix A).[14]

### 3.2 Methodology

The contribution of this paper is to see how forecasting performance varies depending on the elasticity used. With this in mind, we keep the forecasting methodology constant, only varying the elasticity used in each case.

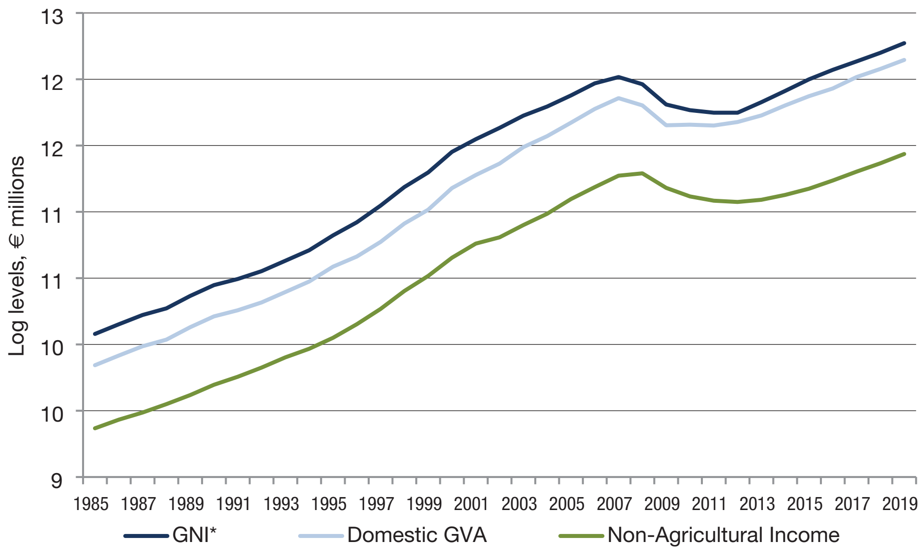
The methodology used here is standard in the literature. To forecast income tax for the current year, the outturn from the previous year (excluding any one-off factors) is used. This is combined with expected growth of the macroeconomic driver this year (multiplied by the elasticity), and the assumed impact of tax policy changes.

[12] Domestic GVA is a measure that captures the gross value added of sectors that are not dominated by foreign-owned multinational enterprises. The non-domestic sector is defined as the sum of sectors where the turnover of foreign-owned multinational enterprises exceeds 85 per cent of the sector total on average. 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.

[13] The growth rate (given by the difference in logs) of the macroeconomic drivers is used to forecast income tax, further details in Section III.2.

[14] In practical terms, the accuracy of revenue forecasts would also depend on the accuracy of forecasts of the macroeconomic driver.

**Figure 2: Measures of Income and Output in Ireland**




*Sources:* Central Statistics Office and author's own calculations.
*Notes:* Units are log levels, € millions. The sample period is 1985-2019.

One-off factors are also incorporated into the forecasts. In practice, official agencies will often apply judgement to forecasts. In the forecasting exercise conducted in this paper there is no judgement applied, hence it is excluded from Equation (1).[15]

$$Income\ tax_{t,\ forecast} = Income\ tax_{t-1} - one\text{-}off_{t-1}) * (1 + MDgrowth_t * elasticity) + Policy_t + one\ off_t \quad (1)$$

$$Policy_t = Policy\ initial_t + (Policy\ full\ year_{t-1} - Policy\ initial_{t-1}) \quad (2)$$

where $MDgrowth_t$ represents growth of the macroeconomic driver in year $T$ (given by the logged difference). $Policy\ initial_t$ describes the impact income tax policy changes are expected to have in euro terms in the year they are introduced. $Policy\ full\ year_{t-1}$ describes the full year impact policy changes introduced in year $T-1$ are expected to have (which may differ from the impact they had in the year they were introduced). $One\ off_t$ describes any one-off factors which impact on income tax receipts in year $T$.

Income tax policy changes can have an impact on receipts, both through the impact of the changes in the initial year, but also through the carryover effect from changes in the previous year (as shown in Equation 2).

[15] In practice, when judgement is applied to official forecasts, it is typically focused on in-year and one-year-ahead forecasts.

We use the latest estimates of the impact of tax policy changes, even if these may not have been predicted years in advance. This is because the focus of the paper is on the impact of different elasticities on forecasting performance.[16]

Given the volatile nature of Irish macroeconomic data (Conroy, 2015), large forecast errors for Irish macroeconomic variables are likely. Macroeconomic forecast errors are also likely to be larger over longer forecast horizons, as errors cumulate. Given we are assuming perfect foresight of the macroeconomic drivers, the forecast errors for income tax in this paper are lower than would be the case if real time forecasts of the macroeconomic drivers were used. This would be more pronounced over longer forecast horizons.

Longer-term fiscal forecasts are key to support a medium-term orientation of fiscal policy. With that in mind, this paper examines forecasting performance over the horizon of the current year ($T$) out to four years ahead ($T + 4$).

For this exercise, the outturns for the previous year ($T - 1$) are the basis for the forecasts over all time horizons ($T$ to $T + 4$). For example, forecasts for the current year ($T$) are then used as a base for forecasting one-year ahead ($T + 1$). The forecasts for the year $T + 1$ can then be used as a base to forecast $T + 2$ and so on.[17] More generally, when forecasting n years ahead (to year $T + n$), the forecast for the previous year is used as the base to grow from (as in, year $T + n - 1$). A generic formula for forecasting n years ahead is given in Equation (3) (where n ranges from zero to four).

$$Income\ tax_{t+n,\ forecast} = (Income\ tax_{t+n-1,\ forecast} - one\ off_{t+n-1}) * (1 + MDgrowth_{t+n} * elasticity) + Policy_{t+n} + one\ off_{t+n} \quad (3)$$

By using the outturn for the previous year ($T + n - 1$) to forecast income tax for the year ($T + n$), there is a danger of assuming that the level of income tax in year $T + n - 1$ is sustainable and not being heavily impacted by temporary factors. By subtracting any one-off or temporary factors impacting year $T + n - 1$ which are known, this risk is mitigated.

We are compiling forecasts for the years 1988-2019. So, there are 32 forecasts (and hence errors) for each methodology for in-year forecasts (year $T$). For the four-year-ahead forecasts ($T + 4$), we have 28 such forecasts and errors.

We use a variety of elasticities to see what works best for forecasting total income tax receipts. Table 1 explains where each of the elasticities originates from. The Irish Department of Finance forecasts the two main elements of Irish income tax separately. These are Pay as You Earn (PAYE) income tax and Universal Social

[16] Diebold-Mariano tests are used to examine if differences in forecast accuracy are statistically significant.
[17] While tax policy changes for future years would not be known when actually making forecasts, we assume they are known in this exercise so that we are isolating the effect of changing the elasticity and/or the tax base used.

**Table 1: Elasticities used to forecast income tax in Ireland**

| *Elasticity* | *Origin/rationale* |
|---|---|
| 1.4 | Long-Run elasticity estimated using policy-adjusted tax revenue in Conroy (2020)[18] |
| 0.8 | Long-Run elasticity estimated using unadjusted tax revenue in Conroy (2020) |
| 1.89 | Weighted average of the elasticities used by the Irish Department of Finance to forecast Pay As You Earn (PAYE) income tax receipts (2.1) and Universal Social Charge (USC) receipts (1.2) |

*Sources:* Various.
*Notes:* Income tax here refers to all income tax (PAYE, USC and other).

Charge (USC) receipts.[19] As a result, the Department of Finance uses separate elasticities for PAYE income tax (2.1) and USC (1.2).[20] Taking a weighted average of these two elasticities results in an elasticity of 1.89, shown in Table 1 above.[21]

The estimates of the impact of income tax policy changes used in this paper are the same as those which were used in Conroy (2020) to estimate policy-adjusted elasticities. As a result, one might expect those elasticities to perform well in this forecasting exercise.

## IV RESULTS

In this section, we present the results from attempts to forecast income tax receipts. Three different elasticities are tested for their suitability in forecasting income tax receipts. In each case we are using the outturn of the macroeconomic driver (non-agricultural income) and Budget Day estimates of the impact of income tax policy changes. One might expect larger forecast errors if we were using forecasts of the macroeconomic drivers, rather than the outturns. This exercise is seeking to find the most appropriate elasticity to apply. As a result, we focus solely on the impact of changing the elasticity used. As outlined in Section III, these forecasts take account of the impact of income tax policy changes.

[18] Both long-run and short-run elasticities were estimated in Conroy (2020). As the focus of this paper is on the longer forecast horizon, only the long-run elasticities are used here.
[19] In both cases non-agricultural income is used as the macroeconomic driver.
[20] The difference in elasticities found for USC and PAYE Income Tax using an analytical approach is mainly driven by tax credits, which occur in income tax but not the USC. Tax credits result in less tax being paid by those at the bottom of the income distribution, and also result in a higher marginal tax rate at the income level at which they are exhausted.
[21] Weights are determined by the relative sizes of PAYE income tax receipts and USC receipts over the period 2011-2019.

Multiple macroeconomic drivers were experimented with, particularly new measures of activity for Ireland such as Domestic GVA and modified GNI (GNI*). Table A.2 (in Appendix A) shows that forecasts using non-agricultural income are significantly more accurate than those using Domestic GVA or GNI*. As a result, non-agricultural income is used throughout this section.

As a robustness check, the analysis is repeated excluding the financial crisis years (2009-2012). The results are shown in Appendix C and they mirror the results found using the full sample which are shown below.

To test if the errors from each of these elasticities are centred on zero, we examine the time series of the errors produced by each elasticity at each time horizon. So for each elasticity, there are five time series to be examined (one for each year of the forecast horizon, year $T$, $T + 1$, $T + 2$, $T + 3$ and $T + 4$).

If the error series is not normally distributed, then simple $T$-tests can be used to determine if forecasts are centred on outturns. If we reject the null hypothesis (that errors are zero on average), then there is evidence that forecasts using that elasticity at that forecast horizon are biased, and not centred on the outturns.

If the forecast error series is not normally distributed, then a non-parametric test (the Wilcoxon signed-rank test) of whether the median is zero is used (detailed results are shown in Appendix B).[22]

We use Diebold-Mariano (2002) tests to see if the differences in forecasting performance of the different elasticities are statistically significant. Diebold-Mariano tests examine whether two competing forecasts have equal predictive accuracy.[23] These tests are performed at each forecast horizon, and for the pooled sample of forecasts at all horizons (which provides a larger sample size).

The elasticity of 1.4 comes from empirical work by Conroy (2020), estimated using policy-adjusted revenue. When this elasticity is used, both T-tests and Wilcoxon signed-rank tests suggest that there is no significant evidence of bias in these forecasts at any point in the forecast horizon (Figure 3 and Appendix B).

By contrast, using an elasticity which was estimated with unadjusted income tax data (0.8) produces forecasts which are biased at all forecast horizons. T-tests and Wilcoxon signed-rank tests both show that forecasts are not centred on outturns (see Table B.1 in Appendix B for full results).[24] A higher elasticity would result in forecasts closer to the outturns on average.

Next, we examine the elasticities which are used by the Irish Department of Finance. An elasticity of 1.89 is a weighted average of the elasticities used by the Department to forecast PAYE income tax and USC receipts.

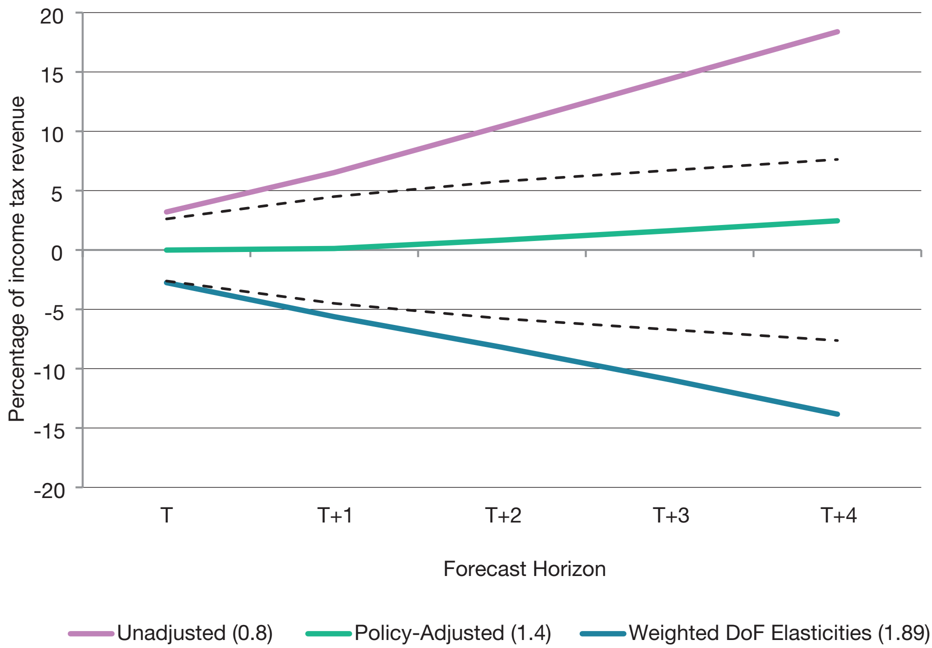
Both T-tests and Wilcoxon signed-rank tests indicate that forecasts using an elasticity of 1.89 are not centred on outturns. This suggests that a lower elasticity would result in forecasts closer to the outturns on average.

[22] See Wilcoxon (1945) for details.

[23] The test can be summarised as an asymptotic z-test of the hypothesis that the mean of the forecasting loss differential is zero.

[24] Forecasts underestimate outturns on average.

**Figure 3: Average Income Tax Forecast Errors**




*Sources:* Author's own calculations.
*Notes:* The average forecast error is shown (as a percentage of income tax revenue). Values below zero indicate forecasts exceed the outturns on average and vice versa. Errors are calculated using the full sample of forecasts (1988-2019). For illustrative purposes, the dashed lines show plus/minus two standard errors, centred on zero. To construct these bands, the largest standard errors of the three forecasting methods are used here (these come from the unadjusted elasticity of 0.8). This is purely for illustrative purposes. When formally assessing if average errors are significantly different from zero, T-tests or Wilcoxon signed-rank tests are used.

Table 2 shows the results of Diebold-Mariano tests. This tests if one forecast series is significantly more accurate than another forecast series. The results suggest that the policy-adjusted elasticity (1.4) produces significantly better forecasts than the unadjusted elasticity (0.8) at all forecast horizons. Similarly, the weighted Department of Finance (DoF) elasticity (1.89) significantly outperforms the unadjusted elasticity (0.8) at all forecast horizons.

Comparing the policy-adjusted elasticity to the weighted DoF elasticity, we can see some evidence for the policy-adjusted elasticity performing better. These improvements are statistically significant when pooling forecast errors over all horizons or when looking at four-year-ahead forecasts.

**Table 2: Diebold-Marino tests (1987–2017)**

| *Elasticity* | *T* | *T+1* | *T+2* | *T+3* | *T+4* | *Pooled* |
|---|---|---|---|---|---|---|
| Policy-Adjusted (1.4) vs Unadjusted (0.8) | 0.65** | 0.58** | 0.53** | 0.48** | 0.43** | 0.49** |
| Policy-Adjusted (1.4) vs Weighted DoF elasticities (1.89) | 1.03 | 1.01 | 0.92 | 0.82 | 0.74* | 0.86* |
| Weighted DoF elasticities (1.89) vs Unadjusted (0.8) | 0.62* | 0.58** | 0.58** | 0.58** | 0.58** | 0.57** |

*Source:* Author's own calculations.
*Notes:* +/– indicates values in the table are relative Root Mean Squared Errors (RMSE). Values below 1 suggest that the forecast named first is superior. Values with ** or * indicate forecasts are significantly different at a 1 per cent or 10 per cent significance level. Pooled results use forecasts over all horizons (N = 150).

Figure 4 shows the forecasting performance of the three elasticities, using the average absolute percentage error to gauge the size of typical forecast errors. As one would expect, the average size of errors increases as the forecast horizon expands. For each of the three elasticities used, the average absolute errors for four-year-ahead ($T + 4$) forecasts are more than double those for in-year forecasts (T). This is an interesting and novel finding, as much of the previous literature on tax forecasting has focused on shorter forecast horizons (up to one-year-ahead typically).

The elasticity estimated using policy-adjusted data (1.4) performs best here, yielding the smallest average absolute errors.[25] This is most noticeable over longer forecast horizons, as errors cumulate. However, it should be kept in mind that these average absolute forecast errors are still quite large, ranging from 4 per cent (in-year forecasts) to 9 per cent (four-year-ahead forecasts).

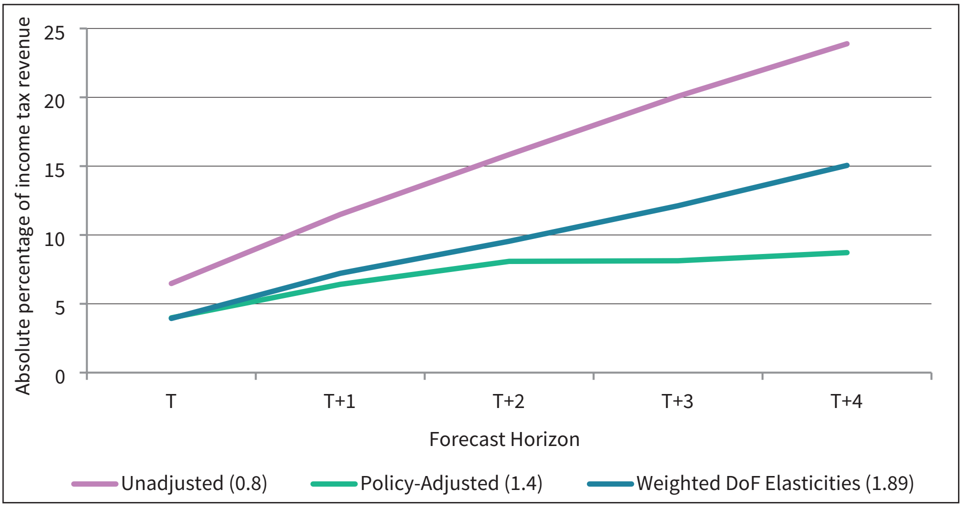
Another noticeable feature is that for the policy-adjusted elasticity, forecast errors do not increase in size as the forecast horizon expands beyond $T + 2$.[26] By contrast, the other two elasticities see the forecast error size increase as the forecast horizon expands.

The weighted average of elasticities used by the Department of Finance (1.89) works well for in-year forecasts. Over longer time horizons, the size of these forecast errors grows more rapidly than for the policy-adjusted elasticity

[25] The weighted average of elasticities used by the Department of Finance (1.89) does produce slightly lower average absolute errors for in-year forecasts.

[26] As a robustness check, the analysis is performed excluding the period around the financial crisis (2009-2012). The results are shown in Appendix C. The same pattern is apparent with the restricted sample (Figure C.2)

**Figure 4: Size of Forecast Errors (%)**




*Sources:* Author's own calculations.
*Notes:* The average absolute forecast error is shown (as a percentage of income tax revenue). Errors are calculated using the full sample of forecasts (1988-2019).

(Figure 4). This is consistent with Table 2, which suggested there was little difference in forecasting performance over shorter forecast horizons.

Forecasting with the elasticity estimated using unadjusted data (0.8) gives the largest average absolute errors at all forecast horizons. This again highlights the benefits and importance of forecasting using elasticities which were estimated using policy-adjusted data.

To assess the uncertainty around projections from these models, Table 3 shows the average absolute errors for each of these different elasticities over different forecast horizons in cash terms (scaled by 2019 receipts). As nominal income tax revenue has been trending upwards over time, if one just took the average absolute error in millions of euros, this would give greater weight to more recent observations.

To mitigate this, we take the average absolute error in percentage terms for the whole sample, and then multiply this by the 2019 outturn for income tax. This gives a sense of the typical size of absolute errors in 2019 cash terms. For example, using an elasticity of 1.4 results in an average absolute error of 4.0 per cent when forecasting the current year (*T*). Multiplying a 4.0 per cent error by the 2019 outturn (€22.9 billion) gives an average absolute error of €913 million.

We can see that the size of errors varies significantly across the elasticities (Table 3). These differences are quite substantial in cash terms and could have significant implications for budgetary planning in Ireland. For each of the

**Table 3: Average Absolute Error (€ millions)**

| *Elasticity* | *T* | *T+1* | *T+2* | *T+3* | *T+4* |
|---|---|---|---|---|---|
| Policy-Adjusted (1.4) | 913 | 1,471 | 1,854 | 1,864 | 1,999 |
| Weighted DoF elasticities (1.89) | 903 | 1,655 | 2,189 | 2,780 | 3,452 |
| Unadjusted (0.8) | 1,485 | 2,635 | 3,633 | 4,605 | 5,479 |

*Source:* Conroy, 2020 and Department of Finance.
*Notes*: Units are € millions. Values correspond to the average absolute percentage error for that elasticity at that forecast horizon multiplied by the 2019 outturn of income tax receipts (€22.9 billion). Errors are calculated using the full sample of forecasts (1988-2019).

elasticities, the average error size increases as the forecast horizon extends. In line with this, the difference between the performance of the various elasticities also increases as the forecast horizon expands. This illustrates how the choice of elasticity is more important the longer the forecast horizon is, as errors cumulate.

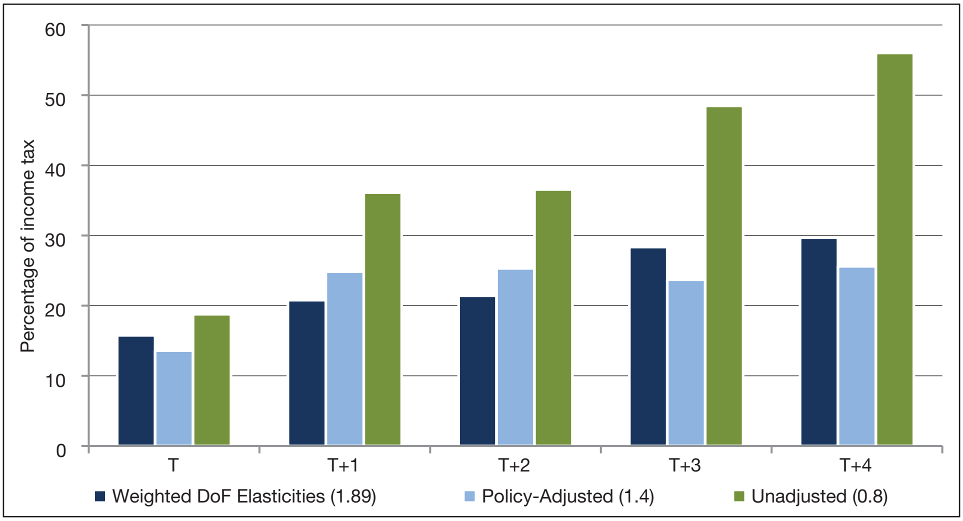
The difference in average error size using the policy-adjusted elasticity (1.4) compared to unadjusted elasticity (0.8) is quite stark here. For a four-year-ahead forecast, the difference in average error size is more than €3 billion. This would be a substantial amount of income tax revenue and would have significant implications for fiscal planning in Ireland. This shows how these improvements in forecasting are economically significant as well as statistically significant.

A final aspect of forecasting performance considered is the maximum absolute error (as a percentage of income tax) recorded for any year in the period considered (1987-2019). The cost of forecast errors may be highly non-linear to the forecaster, with large errors possibly being much more costly from a planning/budgeting point of view. As a result, one may prefer forecasting methods that avoid very large errors. Figure 5 shows the largest absolute percentage forecast error made using the various elasticities at each point of the forecast horizons.[27] On this metric, we can see that the policy-adjusted elasticity (1.4) performs best at three of the five forecast horizons examined. For one- and two-year-ahead forecasts, the weighted average elasticity (1.89) performs best. At each forecast horizon, the elasticity estimated using unadjusted data (0.8) performs the worst.

In summary, the choice of elasticity used has a significant impact on the income tax forecasts produced. Overall, the policy-adjusted elasticity performs best in forecasting income tax receipts. It produces forecasts which are unbiased, with the smallest errors on average. This is a substantial improvement on using the unadjusted elasticity, highlighting the importance of adjusting for policy changes. These improvements are largest when forecasting several years ahead, as errors cumulate. The improvements are also found to be statistically significant.

[27] Examining these instances in detail, a variety of different years give the largest errors for the different elasticities used. In addition, the largest errors come from both underestimation and overestimation.

**Figure 5: Maximum Absolute Error for Income Tax**




*Sources*: Author's own calculations.
*Note:* The largest absolute percentage error over the entire sample period (1988-2019) is shown.

Improving forecasts of government revenue can aid medium-term budgeting and running appropriate fiscal policy. As a result, using policy-adjusted elasticities could yield better fiscal forecasts and better fiscal policy itself.

This paper shows that the use of policy-adjusted elasticities could significantly improve income tax forecasts in Ireland. However, the implications could be wider still, as policy-adjusted elasticities could be estimated and then used for fiscal forecasting in many other countries. Policy-adjusted elasticities have been estimated in other countries. However, to the author's knowledge, there has been no previous study of the improvements in forecast accuracy from using policy-adjusted elasticities.

## V CONCLUSIONS

Forecasting government revenue is key to good budgeting and setting appropriate fiscal policy. We make several contributions to the literature on forecasting government revenue. First, we show how forecasting performance depends on the elasticity applied. Second, we show that elasticities estimated using policy-adjusted data produce superior forecasts. Third, we use formal tests to show that these improvements in forecast performance are statistically significant. Finally, we assess forecasting performance over a longer horizon than has been examined previously, out to four years ahead. While the specific results here are found using

Irish income tax data, the findings could be applicable to several other countries and tax headings.

Improving forecasts of government revenue can aid medium-term budgeting and running appropriate fiscal policy. As a result, these findings could lead to improvements not just in fiscal forecasting, but in fiscal policy itself.

We find that the quality of income tax forecasts varies greatly depending on the elasticity used. More specifically, using policy-adjusted elasticities yields big improvements in forecast accuracy. This reflects significant income tax policy changes which occurred over the sample period. These gains in forecast quality are most evident over longer forecast horizons where errors cumulate. We use Diebold-Mariano tests to formally test that these improvements in forecasting performance are statistically significant. We find that these forecasting improvements are statistically significant.

We use historical data to see which elasticities would have worked best in forecasting revenue. A new dataset is also used to take account of income tax policy changes when making these forecasts. Using income tax outturns for the previous year ($T - 1$), we compile forecasts for the current year ($T$) and out as far as four years-ahead ($T + 4$). Much of the previous literature on forecasting the public finances has focused on in-year ($T$) and one-year-ahead forecasts ($T + 1$). So, this paper makes a key contribution in extending the forecast horizon examined.

This paper shows that the use of policy-adjusted elasticities could improve forecast accuracy in Ireland. However, the implications could be wider still, as policy-adjusted elasticities could be estimated and then used for fiscal forecasting in many other countries.

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## APPENDIX A: RESULTS USING ALTERNATIVE MACROECONOMIC DRIVERS

This appendix shows the results of forecasting income tax using a variety of macroeconomic drivers. From Table A.1 we can see that non-agricultural income performs best in forecasting income tax receipts.

**Table A.1: Income Tax Forecast Errors using Different Macroeconomic Drivers**

| *Macro Driver* | *Elasticity*[1] | *Average Absolute Error*[2] |
|---|---|---|
| Non-Agri income | 1.5 | 6.6 |
| Domestic GVA | 1.3 | 8.8 |
| GNI* | 1.3 | 8.7 |

*Source:* Author's own calculations.
*Notes:* Average absolute forecast errors shown are a percentage of income tax.
[1] This is the elasticity which is calibrated to minimise the average absolute error over the whole forecast horizon for that macroeconomic driver.
[2] Equal weight is given to the average absolute errors (as a percentage of income tax revenue) for each of the five points on the forecast horizon (years $T$ to $T + 4$).

Using non-agricultural income produces smaller forecast errors at all points of the forecast horizon, from in-year forecasts ($T$) to four-year-ahead forecasts ($T + 4$). Using Diebold-Mariano tests, we can see that these differences in forecasting performance are statistically significant. (Table A.2) There is no significant difference between using Domestic GVA or GNI* for forecasting.

**Table A.2: Diebold-Mariano Tests of Macroeconomic Drivers**

| *Macroeconomic Driver* | *Relative RMSE* |
|---|---|
| Non-Agri income (1.5) vs GNI* (1.3) | 0.69** |
| Non-Agri income (1.5) vs Domestic GVA (1.3) | 0.67** |
| Domestic GVA (1.3) vs GNI* (1.3) | 0.98 |

*Source:* Author's own calculations.
*Notes:* Values are relative Root Mean Squared Errors (RMSE). Values below 1 suggest that the first forecast is superior. Values with ** or * indicate forecasts are significantly different at a 1 per cent or 10 per cent significance level.

## APPENDIX B: ASSESSING BIAS IN FORECASTS

This appendix shows the results of various attempts to examine average forecast errors. We want to establish if average errors are significantly different from zero. If the errors are normally distributed, a simple *T*-test that the average error equals zero will tell us if the forecasts are biased. Due to our small sample sizes, the tests conducted have relatively low power. Thus, a failure to reject a null hypothesis cannot be considered conclusive evidence that the null is true. Instead, this is an indication that within our sample, we cannot find enough evidence to support rejecting the null hypothesis.

We test for normality using the Cramér-von Mises criteria (Cramér, 1928). If we find evidence to reject the null (that errors are distributed normally), then we employ a non-parametric test (the Wilcoxon signed-rank test) of whether the median is zero. The null hypothesis for this test is that errors are centred on zero.

**Table B.1: Assessing Average Income Tax Forecast Errors**

| *Elasticity* | *Forecast Horizon* | *T-test* | *Normality test* | *Wilcoxon signed-rank test* |
|---|---|---|---|---|
| 1.4 | *T* | 0.99 | 0.00** | 0.33 |
| 1.4 | *T* + 1 | 0.94 | 0.06 | 0.56 |
| 1.4 | *T* + 2 | 0.65 | 0.37 | 0.41 |
| 1.4 | *T* + 3 | 0.41 | 0.85 | 0.50 |
| 1.4 | *T* + 4 | 0.24 | 0.62 | 0.31 |
| 1.89 | *T* | 0.00** | 0.03* | 0.00** |
| 1.89 | *T* + 1 | 0.00** | 0.25 | 0.00** |
| 1.89 | *T* + 2 | 0.00** | 0.53 | 0.00** |
| 1.89 | *T* + 3 | 0.00** | 0.69 | 0.00** |
| 1.89 | *T* + 4 | 0.00** | 0.41 | 0.00** |
| 0.8 | *T* | 0.02* | 0.00** | 0.00** |
| 0.8 | *T* + 1 | 0.01* | 0.00** | 0.00** |
| 0.8 | *T* + 2 | 0.00** | 0.00** | 0.00** |
| 0.8 | *T* + 3 | 0.00** | 0.01* | 0.00** |
| 0.8 | *T* + 4 | 0.00** | 0.04* | 0.00** |

*Source:* Author's own calculations.
*Notes*: *P*-values are shown. * and ** indicate statistical significance at a 5 per cent and 1 per cent level respectively. Rejecting the null in the normality test suggest that the forecast errors are not normally distributed and hence the Wilcoxon signed-rank test may be a better way to assess if errors are centred on zero. For both the *T*-test and the Wilcoxon signed-rank test, the null is that errors are centred on zero.

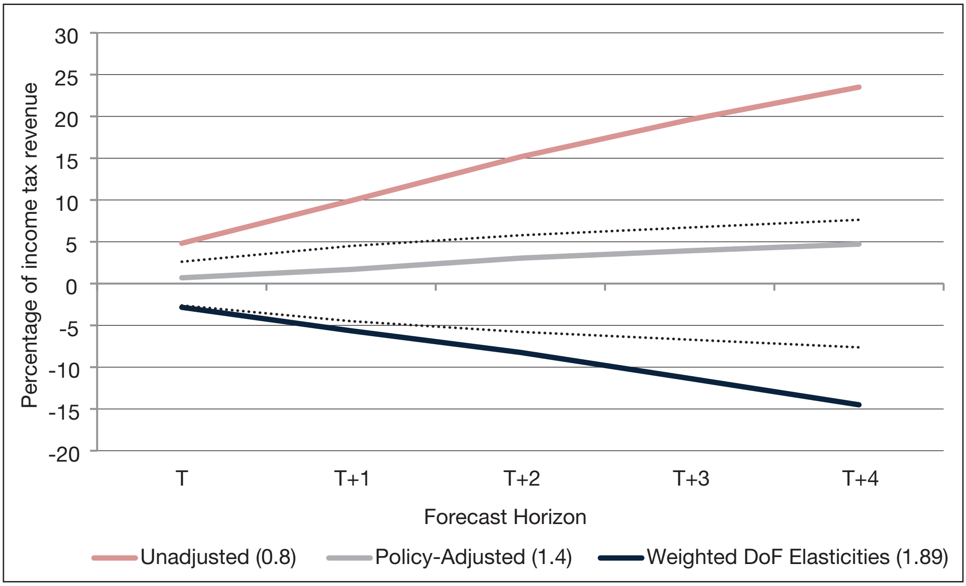
We find that forecast errors from elasticities of 1.4 and 1.89 are broadly normal, hence T-tests may be appropriate. In any event, the *T*-tests and Wilcoxon signed-rank test give similar results. Forecast errors using the policy-adjusted elasticity (1.4) are centred on zero. This is the case at all forecast horizons. For the weighted elasticity (1.89), we find that errors are not centred on zero at all forecast horizons.

For the unadjusted elasticity (0.8), it appears that the forecast errors are not normally distributed. As a result, it is best to focus on the Wilcoxon signed-rank test. Looking at this, the median forecast errors are significantly different to zero at all forecast horizons.

## APPENDIX C: RESULTS EXCLUDING THE FINANCIAL CRISIS (2009-2012)

This appendix shows the main tables and charts shown in the main text if the Great Financial Crisis period is excluded from the analysis. The years 2009-2012 are excluded from the results presented below.

**Figure C.1: Average Income Tax Forecast Errors**




*Sources:* Author's own calculations.
*Notes:* The average forecast error is shown (as a percentage of income tax revenue). Values below zero indicate forecasts exceed the outturns on average and vice versa. Errors are calculated using the full sample of forecasts, except for 2009-2012 (1988-2008 and 2013-2019). For illustrative purposes, the dashed lines show plus/minus two standard errors, centred on zero. To construct these bands, the largest standard errors of the three forecasting methods are used here (these come from the unadjusted elasticity of 0.8).

As was the case when using the full sample (Figure 3), the elasticity estimated using policy-adjusted data (1.4) performs best. At all forecast horizons, those forecasts are centred on outturns. By contrast, the two other elasticities produce forecasts which are on average statistically different from the outturn, particularly at longer forecast horizons.

Table C.1 shows the Diebold-Marino tests using the restricted sample. The policy-adjusted elasticity produces significantly better forecasts than the unadjusted elasticity at all forecast horizons.

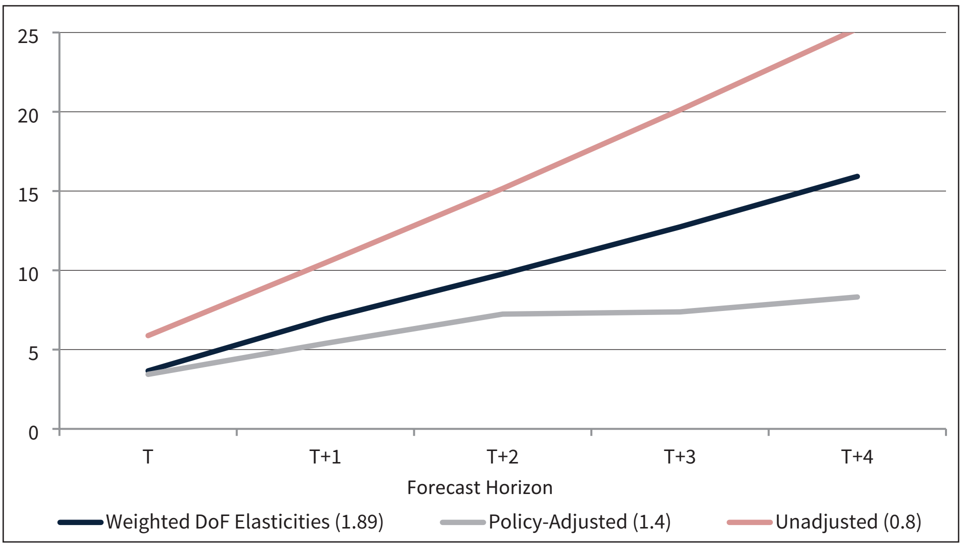
The policy-adjusted elasticity outperforms the weighted DoF elasticity, but only at longer forecast horizons. As was found previously, the weighted DoF elasticity significantly outperforms the unadjusted elasticity. In summary, the results using this restricted sample mirror those produced using the full sample.

**Table C.1: Diebold-Marino Tests (1987-2008 and 2013-2017)**

| *Elasticity* | *T* | *T+1* | *T+2* | *T+3* | *T+4* | *Pooled* |
|---|---|---|---|---|---|---|
| Policy-Adjusted (1.4) vs Unadjusted (0.8) | 0.58** | 0.51** | 0.47** | 0.43** | 0.40** | 0.44** |
| Policy-Adjusted (1.4) vs Weighted DoF elasticities (1.89) | 0.86 | 0.82 | 0.76 | 0.71* | 0.70* | 0.73** |
| Weighted DoF elasticities (1.89) vs Unadjusted (0.8) | 0.68* | 0.62* | 0.62* | 0.60** | 0.57** | 0.59** |

*Source:* Author's own calculations.
*Notes*: +/- indicates values in the table are relative Root Mean Squared Errors (RMSE). Values below 1 suggest that the forecast named first is superior. Values with ** or * indicate forecasts are significantly different at a 1 per cent or 10 per cent significance level. Pooled results use forecasts over all horizons, excluding 2009-2012 (N=130).

**Figure C.2: Size of Forecast Errors (%)**




*Sources* Author's own calculations.
*Notes:* The average absolute forecast error is shown (as a percentage of income tax revenue). Errors are calculated excluding the financial crisis period (2009-2012).

Figure C.3 shows the average absolute forecast errors of the three elasticities when the financial crisis period is excluded. As was the case for the full sample, the size of errors increases as the forecast horizon expands. The policy-adjusted elasticity has the smallest sized errors. This is most pronounced at longer forecast horizons as errors cumulate. As was the case for the full sample, average error size does not increase substantially beyond $T + 2$, unlike the other two elasticities.

Table C.2 shows the average absolute errors in cash terms, excluding the 2009-2012 period. We can see that the size of errors increases as the forecast horizon expands. In addition, the gains from using the policy-adjusted elasticity compared to the unadjusted elasticity are large in cash terms (almost €4 billion when forecasting $T + 4$). These results mirror those produced when using the full sample of data.

**Table C.2: Average Absolute Error (€ millions)**

| *Elasticity* | *T* | *T+1* | *T+2* | *T+3* | *T+4* |
|---|---|---|---|---|---|
| Policy-Adjusted (1.4) | 789 | 1,237 | 1,660 | 1,692 | 1,908 |
| Weighted DoF elasticities (1.89) | 839 | 1,591 | 2,240 | 2,922 | 3,652 |
| Unadjusted (0.8) | 1,349 | 2,402 | 3,477 | 4,613 | 5,789 |

*Source:* Author's own calculations.
*Notes*: Units are € millions. Values correspond to the average absolute percentage error for that elasticity at that forecast horizon multiplied by the 2019 outturn of income tax receipts (€22.9 billion). Errors are calculated excluding the financial crisis period (2009-2012).